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GEOLOGICAL SOCIETY
OF MALAYSIA

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ISSUED BIMONTHLY

PERSATUAN GEOLOGI MALAYSIA

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About the Society

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

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

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Point Load Strength of a medium grained marble from the Kuala Lumpur Limestone

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Department of Geology
University of Malaya

Abstract : A log-log plot of the loads at failure (P) versus the squares of the equivalent core diameters (De^2) of variously sized blocks of a medium grained marble from the Kuala Lumpur Limestone yields a gradient of 0.727 ($\tan 36^\circ$). From this plot, a point load strength index [$Is_{(50)}$] of 3.68 MPa has been determined for the medium grained marble. This value of the point load strength index is related to the uniaxial compressive strength by a multiplication factor of 30.8.

INTRODUCTION

The Point Load Strength, as described by Broch and Franklin (1972), has gained widespread acceptance as an index test for the strength classification of rock material and as a means of estimating other strength parameters such as the uniaxial compressive strength (ISRM, 1985; Brook, 1985). Little or no specimen preparation is needed for this test which involves the splitting of rock specimens by application of a concentrated load through a pair of spherically truncated, conical platens; the specimens being in the form of cores (the diametral and axial tests), cut blocks (the block test), or irregular lumps (the irregular lump test). The most widely known version of the test involves the diametral splitting of rock cores and determination of the point load strength index which is related to a reference core diameter of 50 mm. Where cores with other diameters are tested, a size correction factor needs to be introduced (ISRM, 1985).

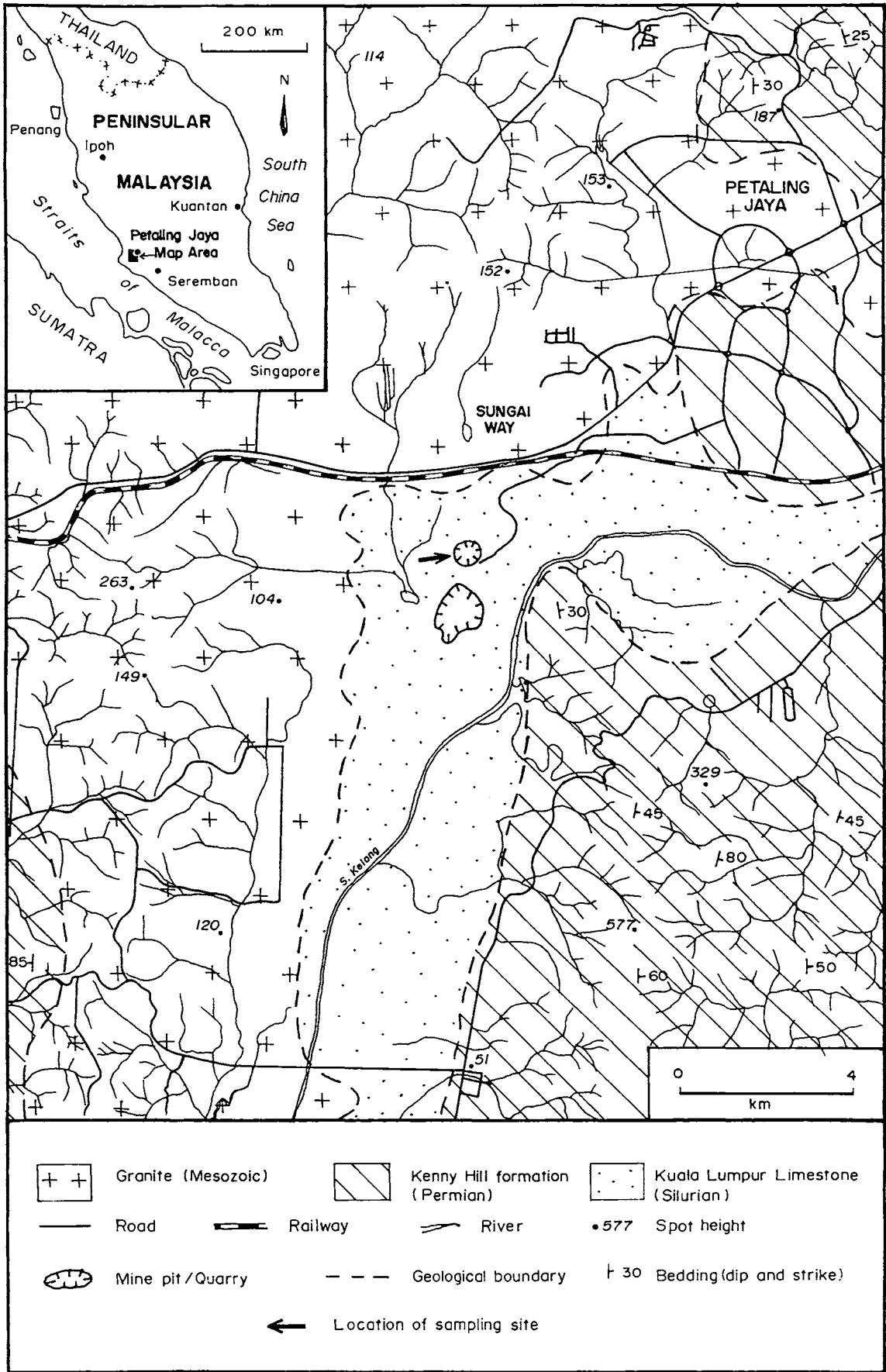
Where specimens with shapes other than cores are tested, however, both shape and size correction factors need to be introduced. The shape correction factor is based on the minimum cross-sectional area of the tested specimen and involves calculation of an 'equivalent core

diameter' (Brook, 1985). The size correction factor is best determined from the log-log plots of the loads at failure (P) versus the squares of the equivalent core diameters (De^2) of a range of specimen sizes, for this allows interpolation (or extrapolation) of the load corresponding to an equivalent core diameter of 50 mm (ISRM, 1985).

In this paper are presented the results of point load tests that have been carried out on blocks of a medium grained marble from the Kuala Lumpur Limestone. Correlation of the point load strength index [$Is_{(50)}$] with the uniaxial compressive strength is also discussed.

KUALA LUMPUR LIMESTONE

In the Sungai Way area of Selangor State in Peninsular Malaysia (Fig. 1) are found marbles (recrystallized limestones) that have been mapped as a part of the Kuala Lumpur Limestone (Yin, 1976). This Formation consists almost entirely of carbonates with relatively little impurity, though regional metamorphism, and a superimposed contact metamorphism close to Mesozoic granite intrusions, has caused marmorization and largely obliterated the original sedimentary features (Gobbett, 1964). The Formation is of a Middle to Upper Silurian



age, and over most of its mapped area, is a crystalline calcitic limestone, frequently containing a small percentage of magnesium, while dolomitic limestone and dolomite are locally dominant. Surface outcrops are limited to a few localities and the Formation is mostly only found in mine pits and subsurface quarries beneath a cover of alluvial sediments of variable thickness.

SAMPLING SITE

In the Sungai Way area, the marble bedrock forms an irregular, pinnacle and trough topography beneath gravelly to sandy and clayey alluvial sediments of some 5 to 35 m in thickness. The pinnacles, which are of various shapes and sizes, are often pock-marked with cavities and are separated by troughs of sinuous and elongate shape. The tops of the pinnacles furthermore, show an approximately accordant surface that dips eastward at about 5°.

The bedrock is variously coloured from white to light and dark grey and is fine to coarse grained. These colours and textures are patchily distributed in the area, though a thin inter-banding of light and dark grey layers is often seen. Secondary calcite veins are also found within the bedrock which is cut by several joints and faults of variable strikes and dips. Along these structural discontinuity planes, which show very irregular to smooth faces, secondary iron oxide and hydroxide stains are sometimes found.

In thin-sections, the bedrock shows effects of both recrystallisation and deformation, though these effects are variably distributed in the area. The thin-sections also show that the bedrock consists exclusively of recrystallized calcite, though secondary iron oxide grains are sometimes seen.

METHOD OF STUDY

In connection with a study of the geotechnical properties of the marble bedrock, point load tests were carried out as the point load strength index [$IS_{(50)}$] has been considered to be a simple and rapid means of obtaining a strength classification. A large, fresh marble

block of some 0.1 m³ was collected at an old mine pit/quarry and then sawn into smaller tetrahedral shaped blocks of various sizes. These tetrahedral shaped blocks were air dried for a week before being tested in an ELE Point Load Test Apparatus.

Thin-sections, prepared from the large block, show it to have a heterogranular-granoblastic texture with approximately equal amounts of coarse (mostly 0.4 to 0.8 mm in size), and fine (mostly 0.02 to 0.1 mm in size), grained calcite crystals.

RESULTS AND DISCUSSION

Results of the point load tests are shown in Table 1 with values of the uncorrected point load strengths appearing to be rather variable. When loads at failure (P) of the different sized blocks are plotted in a log-log graph versus the squares of their equivalent core diameters (De^2), however, a distinct linear relationship is seen (Fig. 2) with the best-fit line (drawn visually) yielding a gradient of 0.727 (i.e. $\tan 36^\circ$).

From this log-log plot, the load at failure corresponding to an equivalent core diameter of 50 mm is seen to be 9.2 MPa. The point load strength index [$IS_{(50)}$] of the medium grained marble is therefore 3.68 MPa. In terms of a point load strength classification, as suggested by Brook (1975; 1985), the medium grained marble would be classified as being of medium strength.

Compression tests carried out on borehole samples of the medium grained marble yield a mean uniaxial compressive strength of 113.44 MPa (Raj, in prep.). The point load strength index would thus need to be multiplied by a factor of 30.8 to be equivalent to the uniaxial compressive strength. It is to be noted that this multiplication factor of 30.8 is somewhat different from the factors of between 18 and 24 reported by Broch and Franklin (1972) and Brook (1975; 1985). It must be pointed out, however, that correlations between the point load strength index and the uniaxial compressive strength are only approximate with the correlation factor varying with the lithology and anisotropy of tested specimens (ISRM, 1985).

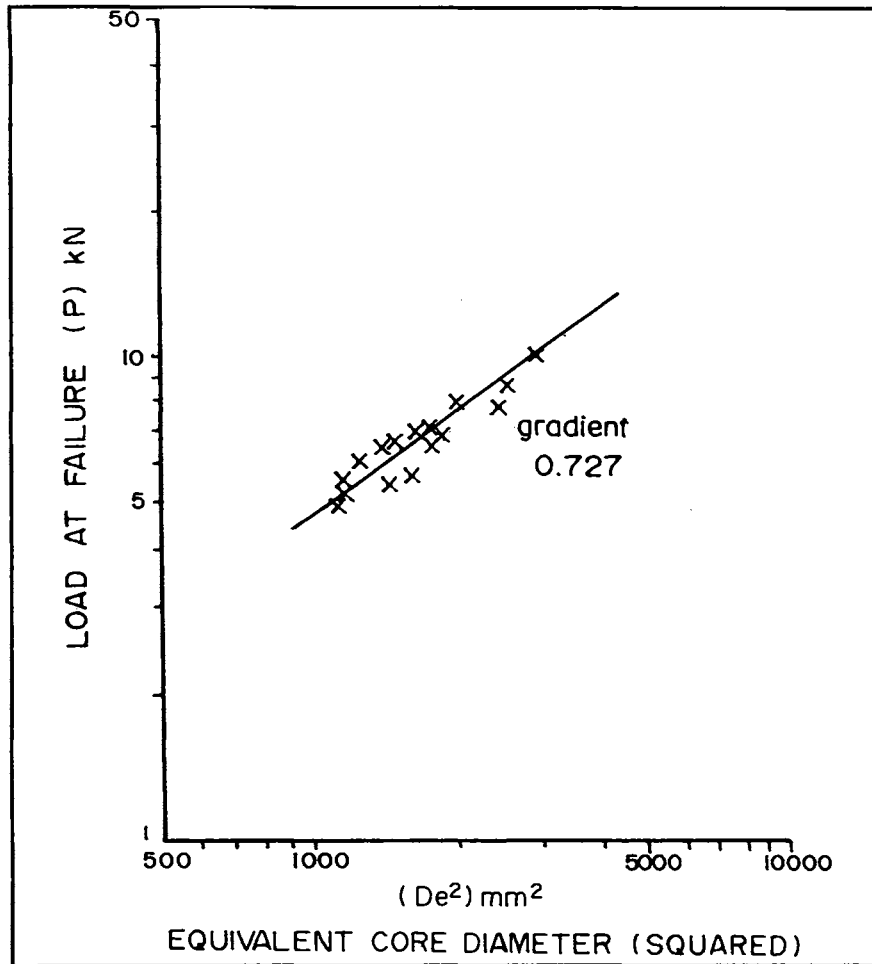


Figure 2: Log-log plot of loads at failure (P) in kN versus squares of equivalent core diameters (De^2) in mm^2 .

Table 1: Results of point load tests

SAMPLE NUMBER	LENGTH mm	HEIGHT mm	WIDTH mm	EQUIVALENT CORE DIAMETER (SQUARED) mm^2	LOAD AT FAILURE lbf	LOAD AT FAILURE kN	UNCORRECTED POINT LOAD STRENGTH MPa
40a	31.95	40.00	32.64	1661.6	1,600	7.00	4.21
40b	60.96	35.74	35.15	1598.9	1,250	5.70	3.56
40c	42.72	28.14	32.11	1150.0	1,250	5.50	4.78
40d	34.70	54.38	27.86	1928.2	1,800	8.00	4.15
40e	55.88	28.19	34.67	1244.1	1,400	6.00	4.82
40f	35.92	66.34	29.92	2526.2	1,950	8.70	3.44
40g	63.50	36.17	29.84	1373.9	1,700	6.50	4.73
40h	61.32	37.26	23.65	1121.4	1,050	4.80	4.28
40j	50.62	40.18	35.94	1838.1	1,550	6.80	3.70
40k	82.75	34.14	33.81	1468.8	1,550	6.70	4.56
40m	53.95	52.22	25.78	1713.5	1,600	7.00	4.09
40n	47.55	29.72	39.27	1485.2	1,250	5.50	3.70
40o	46.94	38.91	29.51	1461.7	1,500	6.50	4.45
40p	29.16	44.70	42.37	2410.5	1,800	8.00	3.32
40q	29.13	52.25	44.63	2967.9	2,250	10.20	3.44
40r	64.41	37.26	24.08	1141.9	1,050	5.00	4.38

CONCLUSIONS

Arising from the above discussion, it is concluded that medium grained marble from the Kuala Lumpur Limestone shows a point load strength index [$I_{s(50)}$] of 3.68 MPa; this value being related to the uniaxial compressive strength by a multiplication factor of 30.8.

ACKNOWLEDGEMENTS

This study forms part of an on-going reserach project supported by IRPA Grant 04-07-04-172 from the Malaysian Government. Equipment used for the tests was purchased with a grant provided by Projek Lebuhraya Utara-Selatan Sdn. Bhd. (PLUS). En. Roshdy drafted the figures.

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Manuscript received 26 January 1993

PERTEMUAN PERSATUAN
Meetings of the Society

**Symposium on Tectonic Framework and Energy Resources of
the Western Margin of the Pacific Basin – Report (Laporan)**

In lieu of the usual Annual Petroleum Geology Seminar, the Society co-hosted with the Circum-Pacific Council for Energy and Mineral Resources (CPCEMR) an International Symposium on Framework on Energy Resources of the Western Margin of the Pacific Basin on the 29th November to 2nd December 1992 at Hotel Shangri-La, Kuala Lumpur.

The Symposium was attended by well over 500 participants including those from China, USA, England, Australia, Philippines and Indonesia. For the technical sessions, there were 6 Keynotes Addresses and 60 Papers. In addition there were 16 Poster Displays where current research projects and findings were displayed; 22 Exhibition Booths for participants to get personalised attention from the various exhibitors and hands-on demonstrations of new services, techniques and products; a series of video shows on geoscience and other fascinating topics and a hospitality suite hosted by Western Atlas International.

A getting-to-know-you gathering for all Symposium participants in the form of an 'ice-breaker' cocktail reception was held on the evening of 29th November 1992 with the compliments of Schlumberger (M) Sdn. Bhd. For the Opening Ceremony on Monday 30th November 1992, we were fortunate to have the Deputy Minister of Primary Industries, YB Dato' Tengku Mahmud Mansor to formally declare open the Symposium.

This is the first time the Society has co-hosted an International Symposium. In fact the offer to stage this Symposium together with the internationally established Circum-Pacific Council for Energy and Mineral Resources was as far back as April 1991. Under the able and far-sighted Chairmanship of Ahmad Said, the President of the Geological Society of Malaysia, the Organising Committee managed to put together a very successful Symposium and to quote Mr. Michel Halbouty, Chairman Circum Pacific Council for Energy and Mineral Resources "the most well organised and Symposium that I have attended so far".

The two Post-Symposium Fieldtrips to Sabah and Sarawak met with overwhelming support and were ably led by C.S. Hutchison (Sabah) and Azhar Hj. Hussin (Sarawak).

The Symposium turned out to be an overwhelming success. For that we have to thank the many authors of papers, the authors of posters, the exhibitors, the many helpers and last but not least, the many participants who turned up make this Symposium possible and memorable.

G.H. Teh

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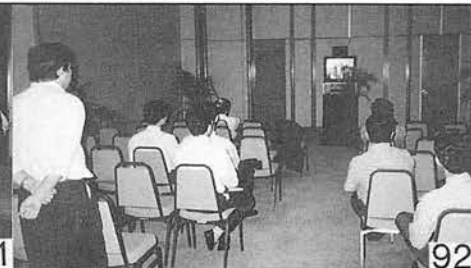
SYMPOSIUM ON TECTONIC FRAMEWORK AND ENERGY RESOURCES OF THE WESTERN MARGIN OF THE PACIFIC BASIN



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SYMPOSIUM ON TECTONIC FRAMEWORK AND ENERGY RESOURCES OF THE WESTERN MARGIN OF THE PACIFIC BASIN



SYMPOSIUM ON TECTONIC FRAMEWORK AND ENERGY RESOURCES OF THE WESTERN MARGIN OF THE PACIFIC BASIN

CAPTIONS TO PHOTOS

- 1-3. At the registration desk.
4-6. The popular Icebreaker Cocktail Reception.

Opening Ceremony

7. GSM President, Ahmad Said with the Welcoming Address.
8. CPCEMR Chairmen, Michel T. Halborty with his Address.
9. YB Deputy Minister of Primary Industries with the Opening Address.
10. A token of appreciation for the Deputy Minister.
11-19. The large turnout at the Opening Ceremony.

Technical Sessions

20. David G. Howell with his Keynote Address.
21. K. Magara on giant oil accumulation.
22. Hanif with a question.
23. A.W.R. Wight on the Tarakan Basin.
24. K. Robinson with his paper.
25. A.C. Cook emphasizes a point.
26. S. Harder with his presentation.
27. R. McCabe on paleomagnetic evidences.
28. Xue Aimin on paleogeothermal evolution.
29. Charles D. Master on World Petroleum Resources.
30. G.W. Moore on the SW Pacific Basin.
31. A.G. Lodge on S. China Sea petroleum basins.
32. M.F.J. Flower with his presentation.
33. Michel T. Halborty poses a question.
34. Qiu Yan on the evolution of the China Sea.
35. J.S. Watkins presenting a joint paper.
36. J.A. Genereux on the Greater Sarawak Basin.
37. Thang Qi Rui on the Qaidam Basin.
38. C.S. Bristow on the Khorat Group Sediments.
39. C.A. Foss with his paper.
40. Charles S. Hutchison with his Keynote Address.
41. M. Boedihardi on Indonesia's geothermal prospects.
42. Mohd. Tahir on the Malay Basin.
43. S. Subono with his presentation.
44. R. Hall on the Sorong Fault Zone.
45. B.M. Clennell on Mélange in Sabah.
46. D. Sukarna on the Bayah area.
47. H.G.D. Mackay with his joint paper.
48. S.A. Kusuama on the evolution of S. Sumatra.
49. C.S. Lee with his paper.
50. O. Matsubayashi on heat flow distribution.
51. S. Hada on the Non-Chantha Buri Suture Zone.
52. David A. Falvey with his Keynote Address.
53. P.R. King on the Taranaki, New Zealand.
54. H.P. Hazebroek on NW Sabah.
55. Sunny Lim on the Kinabalu Main Field.
56. T.R. Walker the S. Sandakan Basin.
57. R.H.F. Wong with his presentation.
58. S. Creaney on oil quality.

59. P.M. Black on basin development, New Caledonia.
60. Hadiyanto on the West Aceh Basin.
61. P.B. Woodroof on hydrocarbon geochemistry.
62. J.A. Rodd with his presentation.
63. M.G. Johnson with his Keynote Address.
64. R.E. Besems on microplankton biostratigraphy.
65. Idris Mohamed on Balingian and Luconia Provinces.
66. Felix Tongkul on Neogene basins in Sabah.
67. E.F. Durkee on SW Philippines.
68. T.O. Simandjuntak on East Sulawesi.
69. S. Tokuhashi on the Niigata oil basin.
70. A Richardson on the Banda Arc.
71. J. Sopaheluwakan with his paper.
72-74. Lunch
75. Cathy Elliot on gravity lineament.
76. Richard Sinding-Larsen with his Keynote Address.
77. J. Paran with his presentation.
78. A question from the floor.
79. J. Reinemann presenting E.R. Landis' paper.
80. Chen Shick Pei on coal in Malaysia.
81. It's teatime.
82. Xia Kang-yuan on the South China Sea.
83. B. Situmorang with his paper.
84. K.R. Chakraborty on geothermal energy.
85. R. Murphy with a comment.
86. H.J. Olson on geothermal assessment.

Poster Displays

87. Thrust tectonics along continental margin N.W. Sabah by Petronas.
88. Southern Sandakan Basin by WMC.
89. Central Luconia Gas Province by Shell.
90-91. Lunchtime.
92. Participants relaxing at the video room.
93. The ever popular Hospitality Suite.

Exhibition

- 94-107. The Deputy Minister at the exhibition.
95-107. The many exhibitors at the Symposium.

CPCEMR Dinner

- 108-111. A drink and conversation before dinner.
112. Members of CPCEMR admiring Society's batik shirt.
113. CPCEMR Chairman, Michel T. Halborty, with a Welcoming Speech.
114. GSM President thanking the CPCEMR.
115. Amomento to Michel T. Halborty from the Society.
116-119. And it's on with the dinner.

GSM dinner for CPCEMR

- 120-123. The tables at the dinner.
124-125. Michel T. Halborty leads the way at MPC's Karaoke Lounge.

**Welcoming Address by Ahmad Said, President,
Geological Society of Malaysia**

YB Dato' Tengku Mahmud Mansor,
Deputy Minister of Primary Industries,
Mr. Michel Halbouty,
Chairman Circum-Pacific Council for Energy and Mineral Resources,
Y. Bhg. Dato'-Dato',
Distinguished Guests,
Ladies and Gentlemen,

On behalf of the Geological Society of Malaysia, I take great pleasure in welcoming YB Dato' Tengku Mahmud Mansor, Deputy Minister of Primary Industries and all our distinguished guests and participants to the opening of this Symposium on the Tectonic Framework and Energy Resources of the Western Margin of the Pacific Basin. We are indeed very honored to have YB Dato' Tengku Mahmud here today to grace this occasion, which is a significant event for us.

This Symposium, as you are all aware, is jointly organized by the Geological Society of Malaysia and the Circum-Pacific Council of Energy and Mineral Resources, which is represented here today by no less than its Chairman, Mr. Michel Halbouty and several of its directors.

Every year, it has been a tradition of the Society to host at least two annual conferences, namely The Annual Geological Conference normally held in mid-year and The Annual Petroleum Seminar normally held at this time of the year. About two years ago, Mr. Carlos Del Solar, a director of the Circum-Pacific Council, who was fortunate enough then to be based in Kuala Lumpur, suggested a joint symposium in lieu of the petroleum seminar. Everybody thought it was a good idea and the meeting started getting organized. As it has always happened to Mr. Del Solar, he got himself transferred back to the U.S. halfway through all the organizing. However, the interest generated was really tremendous and today we see gathered here a truly distinguished international group of geoscientists, be they from industry or academic institutions, to share new knowledge on the tectonics and energy resources of the Western Pacific region.

We have a total of 67 technical papers in the programme, selected from well over 100 submissions, covering a variety of subjects relating to the theme of this Conference. I would like to thank all the authors and speakers for the time and effort they have put into their preparations for this Conference.

Also in conjunction with the Conference, we have organized two fieldtrips to Sabah/Sarawak which are now overbooked. We really apologize to those of you who could not make the trips, more so because the Society is actually subsidising part of the costs of the fieldtrips!

Ladies and Gentlemen,

The Geological Society of Malaysia is indeed proud to have successfully organized a significant number of conferences, seminars, workshops, fieldtrips and technical talks over

the past years. Apart from the usual meetings, the Society is currently looking forward to co-hosting the 1994 AAPG International Convention which will be held in Kuala Lumpur in August 1994, by which time both we and the AAPG hope, the oil price will have picked up significantly!

The Society has continued its record of publications with 32 technical bulletins, the latest of which can be picked up at the Society booth outside the hall. The Society membership is steadily growing and we currently have 600 members.

This Symposium has also had a good response from oil and service companies having the exhibition booths outside the hall. We have 22 booths and I wish to thank all the companies for their excellent support for the Symposium. There are also 20 interesting poster displays and I thank all the authors for their tremendous efforts.

I would also like to thank the companies who have made generous contributions for the organization of the Symposium, especially Schlumberger for last night's cocktail, Halliburton for today's lunch and Western Atlas for their hospitality suite.

I would also like to thank the members of the Organizing Committee especially Prof. Charles Hutchison who organized the technical programme together with Encik Nik Ramli and Ho Wang Kin, Barney Mahendran, Michael Leong, Dr. Teh Guan Hoe, Lee Chai Peng, Anna and Ng Tham Fatt who really put in a lot of the work for this Conference, the fieldtrips organizers Dr. Azhar Hussein, Justin Jok Jau, Tungah Surat and Boniface Bait and all the other individuals in the Society and the Circum-Pacific Council who have helped in one way or another.

On a concluding note, I would like to thank all our distinguished guests, especially YB Dato' Tengku Mahmud Mansor, and all participants for all their support and kind attendance this morning and I hope all of you have an enjoyable Conference.

Thank you.

**Address by Michel T. Halbouty, Chairman,
Circum-Pacific Council for Energy and Mineral Resources**

The Officers and Directors of the Circum-Pacific Council are very pleased that the Council shares this meeting with the Geological Society of Malaysia. This is the 20th year of the Circum-Pacific Council's existence and it is indeed noteworthy and most propitious to conclude the year with this prestigious meeting in Kuala Lumpur.

Before proceeding with my remarks I would like to take two minutes to briefly cite the unique and auspicious beginning of the Council. A group of international geoscientists got together 20 years ago to discuss the apparent lack of interest in geoscientific activities in the Pacific Basin. In fact, the group was appalled that so little research, exploration and development were being conducted in such a vast area that covers over 1/3 of the earth and over one-half of its population.

After much deliberation and soul-searching, the group then-and-there decided to do something to rectify such a flagrant omission and the Circum-Pacific Council for Energy and Mineral Resources was formed with the objective to do whatever necessary to enhance knowledge, research and activities in the search for energy and minerals in the entire Pacific Basin. And, I think we have accomplished our purpose by the many symposiums, conferences, workshops, lectures, publication of maps and the volumes of the Council's Earth Science Series. The Council's Map Project is acclaimed as an outstanding and singular achievement in scientific endeavors. We adopted the theme that "the future is in the Pacific" — and that analysis is just as true today as it was to us 20 years ago. This Symposium is another milestone in the Council's basic objective and sharing it with the Geological Society of Malaysia makes it even more meaningful.

Now, I would like to comment briefly on critical issues that the Asia-Pacific region faces today. It is interesting to note that the Asia-Pacific region last year surpasses Europe to become the second largest oil consuming region in the world and will continue to demand large supplies of oil. Of course, the U.S. is the number one consumer.

Fereidun Fesharaki, Director of Resources program at the East-West Center in Hawaii, used the Asia-Pacific import scenario to underscore his belief that the region is continually growing beyond previous estimates which, in turn, means more oil is needed to supply the growth. Asia-Pacific oil demand, which increased by 7 percent in 1991, is expected to rise an average of 4 percent annually to 18.6 million barrels per day by the end of the decade. Last year, the region's crude oil production reached 6.5 million barrels per day. And, although total production is expected to increase to about 7 million barrels per day between now and through 1994, it is believed that these supplies will do little to satisfy the region's growing appetite for crude oil.

In fact, the region, which includes East Asia, Southeast Asia, South Asia and Australia, is expected to increase its oil imports to 65 percent of total consumption by the year 2000, up from 48 percent last year. It is probable that Mideast oil will represent more than 90 percent of total imports by the end of this decade which is an unusually heavy dependence from one region. The Asia-Pacific's widening supply/demand imbalance will not be easy to close. So, the bottom line is that the Asia-Pacific region will need a lot of oil to feed its growing economy. There are two ways in which this can be accomplished :

- 1) Continue to increase imports and just forget about the problems; or
- 2) The other and more logical way is to obtain as much self-sufficient as possible by exploring for more reserves. I believe that there is from 80 to 100 billion barrels of potential undiscovered reserves in the region and there is no reason why this potential should not be pursued.

There are many sedimentary basins and structures in the region yet to be explored and there are many which are inadequately explored. Exploration will not only find more reserves but the activity associated with it will enhance the region's economy. In addition to exploration for discoveries in new areas, the exploration thrust should also include the mature – already developed and producing basins. It is doubtful that any mature petroleum production basin or province in the world can be classified as thoroughly evaluated. All mature basins should be carefully re-appraised for their full potential. To accelerate the finding of the full potential which exists in the Asia-Pacific region, a high level of exploratory drilling and searching are required in the mature areas. A large portion of the world's estimated undiscovered commercial oil and gas will come from mature areas which are the exploratory "hot spots" of the past. In all, I expect that 30 to 40% of the future commercial potential will be found in basins that are productive today.

Accelerating discoveries in these areas depends principally on increased geophysical activity, exploratory drilling and, above all, the development of new exploratory concepts. And we should not forget the subtle traps – those which are seldom explored on purpose but are generally found by accident. All basins contain facies changes, unconformities with truncated beds, buried erosional or constructive surfaces such as reefs, hills, barrier sand bars, channels, and other related geologic and sedimentary phenomena which form the basic requirements for the creation of subtle traps. Today's geophysical techniques can materially assist in locating subtle traps and offer valuable data on the ultimate controls of lithologic characteristics and sources of the deposits and the environment of deposition. It should be very clear – in view of the numerous possibilities for depositional and postdepositional changes within strata – that the conditions essential to the creation of stratigraphic traps must occur, and probably abound, in all basins. It is difficult to imagine a basin – particularly, an ancient one – that does not contain, at least in one area or within at least one stratigraphic interval, numerous and varied features which, directly or indirectly, may serve as a trap for petroleum. These are referred to as paleogeomorphic traps which are formed where ancient subaqueous or land surfaces existed and the relief features on them are buried by younger strata of a different lithology. Buried reefs, channels, barrier sand bars and hills on erosional surfaces are examples of such features.

It still amazes me that exploration supervisors and managers demand either a strong geophysical subsurface and/or geological closure before an interest is manifested. In other words, unless a prospect has very positive geophysical structural indications there is no relative interest in the submitted prospect. This approach is very short-sighted, non-innovative, and unproductive.

It is my opinion that in the Asia Pacific region the basins abound with subtle traps and could contain billions of barrels of reserves which must be purposefully sought after, purposefully searched and purposefully drilled. The majority of the current reserve figures that are given for this region are those that are estimated to be obtained from structural features and billions of more barrels equivalent could be added through production from subtle traps. Throughout my 63 years as a practicing geoscientist and explorer, I have observed that the geological and geophysical professions, worldwide, have been able to continuously add to the knowledge of geologic processes involved in the accumulation of oil and gas and how to search

for the assorted traps which catch the oil and gas. As a result, geologists and geophysicists are now less inclined to condemn areas or decline new concepts than we did 20 years ago. Exploration ideas are changing constantly with the application of new technology, research and drilling of wells which provide new geologic data of the basins or of the producing area – even down to the field itself.

So – there is a vast potential in the Asia-Pacific area – in both onshore and offshore – all that is required to develop it is a comprehensive exploration and drilling program associated with boldness in thinking and creativity. All of the countries in the region should concentrate on finding new reserves within their own borders; and it may be appropriate and imperative that the countries open up more of their areas to foreign exploration and on more favorable terms. Such an attitude would generate more discoveries and production. After all, it is better to use the region's own oil than that of foreign sources – foreign imports drain the economy of the region and are most uncontrollable – a confrontation in the volatile Middle East could cut off supplies at anytime – very suddenly – without notice. The Asia Pacific region has a bountiful petroleum potential – the only requirement is to explore, find, and produce more oil and reduce imports by establishing not a total, but a reasonable assuring self-sufficiency. Besides petroleum, there are other energy and mineral resources not only in the Asia-Pacific area, but in the vast Pacific basin and its neighboring land areas. These resources play a vital role in meeting the ever growing needs of society worldwide. For this reason it is necessary for the Asia Pacific region to better understand the world's energy and mineral resource problems so that cooperative solutions might be found to avoid any sudden shortages of energy and mineral commodities.

The joint participation of scientists and technologists in studies of geologic phenomena is indispensable as in this meeting. The advancement and application of scientific concepts and techniques as applied to economic and policy issues are important for this region, as well as the world. Cooperative scientific programs with entities from countries outside of the Asia Pacific region can contribute information to the important formulation and implementation of Asia-Pacific policy, including international trade and investment. This would also include cooperative efforts in the development of energy and mineral raw materials, water resources, isolation of hazardous wastes, seabed resources, international boundary disputes and technical assistance programs. What I am saying is that full international cooperation is needed which would offer economic, diplomatic and other policy benefits going beyond the immediate needs and interests of science. After all, policy and/or political decisions often affect scientific thinking and progress. And, let us not forget environmental principles which should be followed in all kinds of petroleum and/or mineral development and operation. The Asia-Pacific countries should encourage companies to operate in an environmentally responsible manner and they should also encourage environmental excellence as a goal.

I thank the Symposium Organizing Committee of the Geological Society of Malaysia for the opportunity to spend these few moments with you and I know that the program that has been organized will afford those of us who are here to become more knowledgeable by listening to the many excellent papers that will be presented.

Thank you.

**Opening Address by YB Dato' Tengku Mahmud Mansor,
Timbalan Menteri Perusahaan Utama Malaysia**

Mr. Chairman,
Y. Bhg. Dato'-Dato',
Distinguished participants,
Ladies and Gentlemen,

I am honoured to be invited to officiate the opening of this Symposium on Tectonics and Energy Resources of the Western Pacific. I would like to thank the co-hosts for this Symposium, the Geological Society of Malaysia and the Circum-Pacific Council of Energy and Mineral Resources.

The Asia Pacific Region is experiencing a period of dynamic growth and is headed to be the world's largest market. With this economic growth there will be a corresponding increase in energy. Therefore, it is important that a thorough study be made in relation to the future of energy needs in this region in order to sustain future economic growth.

Ladies and Gentlemen,

Oil and coal are the main source of primary energy in this region. Our petroleum resource base is very small compared to the global context. Oil reserves in the Asia Pacific Region has only 45 billion barrels or 4.4% of the world's total. Gas reserves are 300 trillion cubic feet or 8.4% of the world's total. Whereas coal with its vast reserve made up of 29% of world's total. The region produced 6.6 million barrels of oil per day in 1991 which was 10.3% of world production while consumption was 14.1 million barrels per day or 21.4% of world consumption. Today this region imports more than 50% of its oil requirement.

While energy demand has been rising, there is also a growing awareness of the environment and standards are being set everyday. Nuclear power coal and in some cases hydroelectric plants are being opposed. Natural gas, once considered an unwanted by product of oil production now provides one-fifth of the world's energy needs. A substantial growth in natural gas demand is expected and liquefied natural gas will play a growing role in the fuel diversification strategies of many Asia Pacific countries.

Ladies and Gentlemen,

Coal provides one-quarter of the world energy needs, but nearly half of the needs of the Asia Pacific Region. Coal prices will remain low but cost meeting environmental measures will increase. However commercialization of advanced clean coal technology will lead to a better growth in the next century. We are faced with a number of challengers but our 2 important goals are to achieve environmental aims and sustained economic growth. To meet these goals fossil fuels has important implications. The low cost of fossil fuels will help economic growth but with greater reliance on them, there is an even greater need to find ways of using them in an environmentally accepted manner.

In the 1980's oil production increased rapidly in the region with Australia, India and Malaysia joining China and Indonesia as important producers of crude oil. Now, in the 1990's new oil production areas are being developed especially in Papua New Guinea and Vietnam. The region has tremendous potential for petroleum resources and exploration must continue. Even with most of the major oil companies in the world facing major exploration budget cutbacks and exploration and production capital possibly diverted to the CIS and Eastern Europe which are opening up their areas, the outlook for oil exploration in the region is still very good.

Ladies and Gentlemen,

Many areas of this region are underexplored. Frontier areas like interior basins, deep jungle areas and deepwater areas are virtually unexplored. Many areas of the Western Pacific are tectonically active today and this has led to complex geology in many areas. Therefore it is important that further efforts are made to fully understand the geology of the areas so as to assist in the search not only for petroleum and coal resources but also geothermal resources. Although a lot of data has been gathered in the past by various companies and organisations, there are still many areas not covered by today's modern high technology subsurface data especially seismic data. It is important further efforts be made to fully understand the geology of the areas of the Western Pacific.

This conference is a noteworthy contribution to these efforts. Today we see a gathering of geoscientist from all over the world, who are actively involved in these efforts. I personally extend a warm welcome to Mr. Michel Halbouty, Chairman of the Circum-Pacific Council. Mr. Halbouty has been active for the last 60 years in the science of petroleum geology and needs no introduction. His presence at this conference shows his commitment to the advancement of geoscience. We wish him many more years of distinguished service.

I would like to congratulate the Geological Society of Malaysia for its continuous efforts in promoting the advancement sciences. I am very impressed with the technical programme finalized for 3 days of deliberations and I wish you all the best in your deliberations.

Thank you.

SYMPOSIUM ON TECTONIC FRAMEWORK AND ENERGY RESOURCES OF THE WESTERN MARGIN OF THE PACIFIC BASIN

PROGRAMME

MONDAY, NOVEMBER 30, 1992

Lecture Hall A

OPENING CEREMONY

- 08:40 : Welcoming Address by Ahmad Said, President, Geological Society of Malaysia
 08:50 : Address by Michel T. Halbouty, Chairman, Circum-Pacific Council for Energy and Mineral Resources.
 09:00 : Opening Address by YB Dato' Tengku Mahmud Mansor, Deputy Minister of Primary Industries Malaysia
 09:15-09:45 : *Coffee & Tea*
 09:45:10:30 : **Keynote 1:** Plate Tectonics and Petroleum Habitats
David G. Howell (U.S. Geological Survey, Menlo Park)

Lecture Hall A

- 10:30-11:00 : **Paper 1**
 Giant oil accumulations and their areal concentration efficiency
K. Magara (United Arab Emirates Univ.)
- 11:00-11:30 : **Paper 2**
 Estimates of offshore hydrocarbon resource potential in Tertiary sedimentary basins and areas along the western rim of the Pacific Basin
K. Robinson (U.S. Geological Survey, Denver)
- 11:30-12:00 : **Paper 3**
 Tarakan Basin, NE Kalimantan, Indonesia: a century of exploration and future hydrocarbon potential
A.W.R. Wight, L.H. Hare & J.R. Reynolds (Sceptre Resources, Jakarta)
- 12:00-12:30 : **Paper 4**
 Tertiary coal measures as source sequences for oil
A.C. Cook & M.M. Faiz (Keiraville Konsultants, Australia)

Lecture Hall B

- 10:30-11:00 : **Paper 10 (not presented)**
 The sedimentary basins of SE Asia and their petroleum potential
V. Vysotsky, R. Rodnikova & A. Titkov (Institute of Foreign Geology, Moscow)
- 11:00-11:30 : **Paper 11**
 A single mechanism for Cenozoic extension in and around Indochina
S. Harder & R. McCabe (Texas A & M Univ.) and M. Flower (Univ. Illinois)
- 11:30-12:00 : **Paper 12**
 Paleomagnetic evidence to define a stable East Asia and Sundaland
R. McCabe, et al. (Texas A & M, et al.)
- 12:00-12:30 : **Paper 13**
 The nonlinear inversion of paleogeothermalevolution: example from the north part of the South China Sea
Xue Aimin (Chinese Academy of Sciences, Beijing)

12:30-14:00 : **Lunch Break**

Lecture Hall A

14:00–14:45 : **Keynote 2:** World Petroleum Resources – where, why and how much?
Charles D. Masters (U.S. Geological Survey, Reston)

Lecture Hall A

14:45–15:15 : **Paper 5**
Paleogeographic development of the Southwestern Pacific Basin
G.W. Moore (Oregon State University)

15:15–15:45 : **Paper 6**
The Tertiary megasequence stratigraphy of the South China Sea petroleum basins
A.G. Lodge (BHP Petroleum, Australia)

15:45–16:15 : *Coffee & Tea*

16:15–16:45 : **Paper 7 (not presented)**
Geology of Spratly Islands and vicinity
Pow-foong Fan (Univ. of Hawaii)

16:45–17:15 : **Paper 8**
Tectonic implications of Cenozoic magmatism in Southeastern and Eastern Asia
M.F.J. Flower (Univ. Illinois) and S.H. Harder & R.J. McCabe (Texas A & M Univ.)

17:15–17:45 : **Paper 9**
Tectonic features and evolution of the China Sea and adjacent regions
Qiu Yan & Li Tanggen (MGMR, Guangzhou)

Lecture Hall B

14:45–15:15 : **Paper 14**
Cenozoic structure and stratigraphy of the eastern continental shelf and upper slope of Vietnam
S. Wirasantosa & J.S. Watkins (Texas A & M Univ.) and G. White (Halliburton)

15:15–15:45 : **Paper 15 (not presented)**
Preliminary research into the plate collision, rotation and divergence pattern of China and its periphery since Mesozoic
Fei Qi (China Univ. of Geosciences)

16:15–16:45 : **Paper 16**
The tectonic significance of transform faults within a portion of the Greater Sarawak Basin
G.A. Posehn & J.A. Genereux (Intera, Canada) and A.M. Mantaring (Idemitsu Oil Expl.)

16:45–17:15 : **Paper 17**
Statistical analysis of the structural evolution of western Qaidam Basin
Zhang Qi Rui, et al. (Academia Sinica, Beijing)

17:15–17:45 : **Paper 18**
Fission track analysis of Khorat Group sediments, Khorat Plateau, Thailand
C.S. Bristow (Birkbeck College, London)

PROGRAMME

TUESDAY, DECEMBER 1, 1992

Lecture Hall A

08:30–09:15 : **Keynote 3:** Tectonic Framework of the Southeast Asian Tertiary Basins
Charles S. Hutchison (University of Malaya)

Lecture Hall A

09:15–09:45 : **Paper 19**
The Bouguer gravity variation over Southeast Asia as derived from satellite altimeter data
C.A. Foss & J. Savage (ARK Geophysics)

09:45–10:15 : **Paper 62**
Geology, energy potential and development of Indonesia's geothermal prospects
M. Boedihardi, A. Mulyono (Pertamina), A. Ginting & M.D. Mosby (Unocal), and V.T. Radja (PLN, Indonesia)

10:15–10:45 : *Coffee & Tea*

10:45–11:15 : **Paper 21**
Structural trap styles of the Malay Basin
Mohd. Tahir Ismail & K.W. Rudolph (Esso Production Malaysia Inc.)

11:15–11:45 : **Paper 22**
Thermal studies in oil basinal areas of Indonesia
S. Subono & Siswoyo (Lemigas, Jakarta)

11:45–12:15 : **Paper 23**
Development of the Sorong Fault Zone region, eastern Indonesia
R. Hall (Univ. College London), J. Ali (Southampton Univ.) and C. Anderson (UC Santa Barbara)

Lecture Hall B

09:15–09:45 : **Paper 30**
Geology of the Bayah area: implications for Tertiary evolution of West Java, Indonesia
D. Sukarna, Kusnama & S.A. Mangga (GRDC, Bandung)

09:45–10:15 : **Paper 31**
Hydrocarbon habitat in offshore Southeast Asia: comparison between the Mekong, South Con Son, Natuna and Malay Basins
P. Cullen, D.J. Lucas, H.G.D. Mackay, J.J. McGuckin & I.R. Wilson (Enterprise Oil Expl. Ltd.)

10:45–11:15 : **Paper 64**
Heat flow distribution in the western margin of the Pacific
O. Matsubayashi (Geol. Surv. Japan), T. Nagao (Kanazawa Univ.), and S. Uyeda (Texas A & M Univ.)

11:15–11:45 : **Paper 33**
Terrane analysis and tectonics of the Nan-Chantha Buri Suture Zone
S. Hada (Kochi Univ.) and S. Bunopas (DMR, Thailand)

11:45–12:15 : **Paper 34**
Australia-Philippines cooperative marine seismic and sniffer survey in four Philippine offshore sedimentary basins
C.S. Lee, D. Ramsay & M. Galloway (Bureau of Mineral Res., Aust.) and F. Rellira & D. Baladad (OEA, Philippines)

Lecture Hall A

12:15–12:45 : Paper 24

The timing and tectonic significance of mélangé formation in eastern Sabah, Malaysia
B. M. Clennell (Univ. of London)

Lecture Hall B

12:15:12:45 : Paper 35

The Tertiary tectonic evolution of southern Sumatra, Indonesia
Kusnama, S.A. Mangga & D. Sukarna (GRDC, Bandung)

12:45–14:00 : **Lunch Break**

Lecture Hall A

14:00–14:45 : **Keynote 4: Evolution of the island arc and marginal basins of the Western Pacific**

David A. Falvey (Australian Geological Survey)

Lecture Hall A

14:45–15:15 : Paper 25

Basin reactivation associated with the mid-Cenozoic initiation of subduction, Taranaki, New Zealand
P.R. King, et al. (IGNS, Lower Hutt)

Lecture Hall B

14:45–15:15 : Paper 36

Oil quality variations in the Malay Basin – geochemical insights
S. Creaney & Abdul Hanif Hussein (Esso Production Malaysia)

15:15–15:45 : Paper 26

Tertiary tectonic evolution of the NW Sabah continental margin
H.P. Hazebroek, D.N.K. Tan & J.M. Lamy (Sabah Shell)

15:15–15:45 : Paper 37

Tectonism, magmatism and sedimentary basin development in the Mesozoic–Early Tertiary period, New Caledonia
P.M. Black (Auckland Univ., New Zealand)

15:45–16:15 : **Coffee & Tea**

16:15–16:45 : Paper 27

The role of advanced seismic interpretation in development planning for the Kinabalu Main Field, offshore NW Borneo
C.F.W. Hocker (Sabah Shell)

16:15–16:45 : Paper 38

Petroleum generation in the West Aceh Basin, Sumatra
Hadiyanto (Univ. of Wollongong, NSW, Aust.)

16:45–17:15 : Paper 28

Structural framework and hydrocarbon potential of the Southern Sandakan Basin, Eastern Sabah, Malaysia
T.R. Walker, et al. (WMC Petroleum, et al.)

16:45–17:15 : Paper 39

Source rock and hydrocarbon geochemistry, offshore NW Sabah, Malaysia
P. B. Woodroof & A. D. Carr (British Gas)

17:15–17:45 : Paper 29

Sequence stratigraphy of the Middle Miocene–Pliocene, southern offshore Sandakan Basin, Eastern Sabah, Malaysia
R.H.F. Wong (PETRONAS)

17:15–17:45 : Paper 40

New targets for oil and gas exploration in Fiji, Solomon Islands and Vanuatu
J.A. Rodd (SOPAC, Fiji)

PROGRAMME

WEDNESDAY, DECEMBER 2, 1992

Lecture Hall A

08:30–09:15 : **Keynote 5:** 3-D Seismic Benefits from Exploration through Development: An Exxon Perspective
M.G. Johnson (Exxon Exploration Co., Houston)

Lecture Hall A

09:15–09:45 : **Paper 41**
Microplankton biostratigraphy in tropical Tertiary deposits of offshore NW Borneo
R.E. Besems (Sarawak Shell)

09:45–10:15 : **Paper 42**
Sequence stratigraphy of Tertiary sediments offshore Sarawak (Balingian and Luconia Provinces)
Idris Mohamed & Ooi Chit Meng (Sarawak Shell Bhd.)

10:15–10:45 : **Coffee & Tea**

10:45–11:15 : **Paper 43**
Tectonic control on the development of the Neogene basins in Sabah, East Malaysia
F. Tongkul (Universiti Kebangsaan Malaysia, Sabah)

11:15–11:45 : **Paper 44**
Geothermal evolution modelling with apatite fission tract data – the geothermal history analysis of Hefei Basin, Eastern China
Xue Aimin (Chinese Academy of Sciences, Beijing)

11:45–12:15 : **Paper 45**
Oil, geology and changing concepts in the Southwest Philippines (Palawan and the Sulu Sea)
E.F. Durkee (E.F. Durkee & Associates Inc.)

12:15–12:45 : **Paper 46**
Sedimentology of the Miocene Semirara Formation, Philippines
C.S. Bristow (Birkbeck College, London) and P.R. Bird (Kirkland Resources)

Lecture Hall B

09:15–09:45 : **Paper 63**
The geophysical characteristics and evolution of northern and southern margins of South China Sea
Xia Kang-yuan and Zhou Di (A. Sinica)

09:45–10:15 : **Paper 53**
Neogene tectonics and orogeny of Indonesia
T. O. Simandjuntak (GRDC, Bandung)

10:45–11:15 : **Paper 54**
Sedimentological and mineralogical analysis of the turbidite sandstone beds at the eastern margin of the Niigata Neogene backarc oil basin, Northwest Japan; with special reference to the coexistence of shallow marine and deep-marine turbidite sandstone beds
S. Tokuhashi (Geol. Surv. of Japan)

11:15–11:45 : **Paper 55**
Lithosphere structure and dynamics of the Banda Arc Collision Zone, eastern Indonesia
A. Richardson (Univ. of London)

11:45–12:15 : **Paper 56**
Tectonic evolution of the Banda Arc, E. Indonesia: Southern Tethyan crust obduction, metamorphism and fragmentation of eastern Gondwanaland
J. Sopaheluwakan (Indonesian Inst. of Sciences, Bandung)

12:15–12:45 : **Paper 57**
A new investigation of some continental scale gravity lineaments in Australia
Cathy Elliot (Univ. of Melbourne)

Post-Symposium fieldtrip # 1 Geology of Sarawak – Report (Laporan)

The end of the CPCEMR-GSM Symposium on the Tectonic Framework and Energy Resources of the Western Margin of the Pacific Basin on the evening of the 2nd December 1992 paved the way for the start of the post-Symposium field trip on the Geology of Sarawak. Thirty two participants from Europe, United States of America, China, Japan, Philippines, New Zealand and Australia, together with trip organisers Azhar Haji Hussin, Boniface Bait and Justin Jok Jau departed from the Shangrila Hotel, Kuala Lumpur for the Subang International Airport. The party flew on the Malaysia Airline carrier MH2532 for Kuching Airport, arriving shortly before midnight. They were transferred to the Aurora Hotel, the place of accommodation the next 2 nights.

On Thursday morning of 3rd December 1992, the party started off on the geological field visits in the Kuching-Bau area after breakfast. The first few outcrops exposed the Pedawan Formation along the new roadcuts between the Sungai Sarawak Kiri and the town of Siniawan. A short refreshment break in the historic town of Siniawan, a frontier town for the Bau region in the 18th and 19th century, was most welcome. For most participants, the stroll through the town, visits to the wooden shops, and watching the locals cross the Sungai Sarawak Kanan in their long boats and dug-out canoes was like walking back in time. We then proceeded to the Bau-Krokong area to examine several exposures of the Bau Limestone as well as its relationships with the Pedawan Formation. Discussions were mainly centered on the paleoenvironments and paleogeography of these Jurassic-Cretaceous formations and their economic significance.

Bukit Young Gold Mine was the host to the lunch held at Dewan Suarah Bau. Before lunch, participants visited the Museum at this Dewan Suarah where many exhibits of the Bidayuh people were magnificently displayed. After thanking the management of the Bukit Young Gold Mine for the sumptuous lunch, the party then proceeded to north Kuching.

En route, we made a stop at one of the pottery factories on the Kuching-Serian Road. We were guided through the factory where we were shown the various stages of the manufacturing process of pottery. Before departure, we were led into the show room for souvenir-shopping.

Our planned visit to the Bako Peninsula was cancelled because the low river level at Sungai Bako did not permit the transport of our large bus on the ferry. As a small compensation, we stopped at Kampong Buntal, a fishing village which overlooks Buntal Bay. From there, we had a panoramic view of the geology of the Bako Peninsula.

Our last geological stop for the day was the Kayan Sandstone exposure at Bukit Puteri, at the southern part of the Santubong Peninsula. This exposure stirred up many discussions; two broad groups of argument were suggested for the deformational/truncation features of these rocks. One group favour the sedimentary origin while another group preferred a tectonic origin.

On our return to Kuching, many participants stopped at the Fort Margherita to visit the Police Museum and the new Riverside Park. Many chose to take the "bot penambang" to cross the Sungai Sarawak and walked back to the hotel.

PROGRAMME

WEDNESDAY, DECEMBER 2, 1992

Lecture Hall A

08:30–09:15 : **Keynote 5:** 3-D Seismic Benefits from Exploration through Development: An Exxon Perspective
M.G. Johnson (Exxon Exploration Co., Houston)

Lecture Hall A

09:15–09:45 : **Paper 41**
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C.S. Bristow (Birkbeck College, London) and P.R. Bird (Kirkland Resources)

Lecture Hall B

09:15–09:45 : **Paper 63**
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12:15–12:45 : **Paper 57**
A new investigation of some continental scale gravity lineaments in Australia
Cathy Elliot (Univ. of Melbourne)

12:45–14:00 : *Lunch Break*

Lecture Hall A

14:00–14:45 : **Keynote 6:** Regional Data Processing and analysis as a basis for co-operative resource assessment
Richard Sinding-Larsen (Inst. Technology, Univ. Trondheim)

Lecture Hall A

14:45–15:15 : **Paper 47**
Hydrocarbon occurrences in the Cooper and Eromanga Basins in Central Australia
J. Paran (Sagasco Resources, Adelaide)

15:15–15:45 : **Paper 48 (not presented)**
Indonesia geothermal energy resources development programme—past, present and future projects
Vincent T. Radja (PLN, Indonesia)

15:45–16:15 : *Coffee & Tea*

16:15–16:45 : **Paper 49**
Coal in the western Pacific Basin, an overview
E. R. Landis (US Geological Survey, Colorado.)

16:45–17:15 : **Paper 50**
Coal as an energy resource in Malaysia
Chen Shick Pei (Geol. Survey Malaysia, Kuching)

Lecture Hall B

14:45–15:15 : **Paper 58**
Strike slip duplexes: their role in basin formation and evolution, with reference to the North Sumatra Back Arc, Ombilin Intermontane and West Sumatra Fore Arc Basins
B. Situmorang & B. Yulihanto (Lemingas, Jakarta) and R.S. Himawan (Maxus)

15:15–15:45 : **Paper 59**
Geothermal energy and uranium mineralization potential of the Main Range granite province, Peninsular Malaysia
K.R. Chakraborty (Univ. of Malaya)

16:15–16:45 : **Paper 60**
Deep, slim hole, diamond core drilling program proves effective for geothermal assessment in Hawaii
H.J. Olson (Univ. of Hawaii) and J.E. Deymonaz (Consultant, Oregon)

16:45–17:15 : **Paper 61 (not presented)**
Geothermal systems within a 'pulled-apart' segment of the Philippine Fault (Central Leyte): their characteristics and relation to volcanism and strike-slip tectonics
H.J. Tebar (PNOC, Philippines)

POSTER DISPLAYS

- | | |
|---|--|
| <p>P1 : Southern Sandakan sub-basin – 7th oil province for Borneo.
<i>A.F. Williams et al. (WMC Pet. (M) Sdn. Bhd.)</i></p> <p>P2 : West Batangas Basin – untested depocenter in Philippines South China Sea.
<i>R.A. Reyes (TransAsia Oil)</i></p> <p>P3 : Thrust tectonics along the north-western continental margin of Sabah.
<i>(PETRONAS)</i></p> <p>P4 : A new geological map of Borneo island.
<i>R. B. Tate (Univ. Malaya)</i></p> <p>P5 : Scientific exploration of the western margins of the Pacific Basin by the Ocean Drilling Program.
<i>T. Janecek, et al. (ODP, Texas A & M)</i></p> <p>P6 : Detailed sedimentological core logging – an essential step towards understanding reservoir architecture and performance.
<i>D. Barr and S. Soo (Core Lab., Malaysia)</i></p> <p>P7 : The Philippine Sea geotraverse.
<i>A.G. Rodnikov (Geophysical Committee, Moscow)</i></p> <p>P8 : Geology and mineralogy of the late Jurassic–Quaternary sedimentary cover in the oceans and on the continents.
<i>I.S. Gramberg, et al. (Vpiizarubezh-geologia)</i></p> | <p>P9 : Geological architecture of the Miocene carbonate buildups from the Central Luconia Gas Province, offshore Sarawak, Malaysia.
<i>Updesh Singh, et al. (Sarawak Shell Bhd.)</i></p> <p>P10 : University of London Group for Geological Research in Southeast Asia.
<i>R. Hall (Univ. London)</i></p> <p>P11 : A satellite derived Bouguer Gravity map of Southeast Asia.
<i>T. Savage & C.A. Foss (ARK Geophysics)</i></p> <p>P12 : Structural control on facies distribution and economic deposits in the Ombilin Basin, West Sumatra, Indonesia.
<i>Chris Howells (Univ. London)</i></p> <p>P13 : Resources and climate-related study of the epicontinental seas of Australia and Southeast Asia.
<i>(USGS)</i></p> <p>P14 : GIS for coastal management
<i>(Hunting Technical Services)</i></p> <p>P15 : Sedimentological aspects toward precise formation evaluation and testing.
<i>Mohamed Taha (Schlumberger)</i></p> <p>P16 : Fluvio-lacustrine deposits in a Tertiary intermontane basin, Thailand.
<i>D.M. Strogon (Univ. London)</i></p> |
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EXHIBITORS

- | | |
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| <p>B1 : GEOPHYSICAL CONSULTANTS</p> <p>B2 : TEKNOSIF SDN. BHD.</p> <p>B3 : HALLIBURTON ENERGY SERVICES GROUP</p> <p>B4 : HALLIBURTON ENERGY SERVICES GROUP</p> <p>B5 : COGNISEIS DEVELOPMENT</p> <p>B6 : PETRONAS</p> <p>B7 : SCHLUMBERGER (M) SDN. BHD.</p> <p>B8 : GECO SEISMIC SDN. BHD.</p> <p>B9 : EXLOG/EASTMAN-TELECO</p> <p>B10 : PALTECH PTY. LTD.</p> <p>B11 : GEOLOGICAL SURVEY OF MALAYSIA</p> | <p>B12 : GEOCHEM GROUP LTD.</p> <p>B13 : CPCEMR</p> <p>B14 : CCOP</p> <p>B15 : DIGICON (M) SDN. BHD.</p> <p>B16 : TERRA CONTROL/INTERA TECHNOLOGIES</p> <p>B17 : WESTERN ATLAS INTERNATIONAL</p> <p>B18 : WESTERN ATLAS INTERNATIONAL</p> <p>B19 : SIMON PETROLEUM TECHNOLOGY</p> <p>B20 : CROCKER DATA PROCESSING PTY. LTD.</p> <p>B21 : SOPAC</p> <p>B22 : GEOLOGICAL SOCIETY OF MALAYSIA</p> |
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Post-Symposium fieldtrip # 1 Geology of Sarawak – Report (Laporan)

The end of the CPCEMR-GSM Symposium on the Tectonic Framework and Energy Resources of the Western Margin of the Pacific Basin on the evening of the 2nd December 1992 paved the way for the start of the post-Symposium field trip on the Geology of Sarawak. Thirty two participants from Europe, United States of America, China, Japan, Philippines, New Zealand and Australia, together with trip organisers Azhar Haji Hussin, Boniface Bait and Justin Jok Jau departed from the Shangrila Hotel, Kuala Lumpur for the Subang International Airport. The party flew on the Malaysia Airline carrier MH2532 for Kuching Airport, arriving shortly before midnight. They were transferred to the Aurora Hotel, the place of accommodation the next 2 nights.

On Thursday morning of 3rd December 1992, the party started off on the geological field visits in the Kuching-Bau area after breakfast. The first few outcrops exposed the Pedawan Formation along the new roadcuts between the Sungai Sarawak Kiri and the town of Siniawan. A short refreshment break in the historic town of Siniawan, a frontier town for the Bau region in the 18th and 19th century, was most welcome. For most participants, the stroll through the town, visits to the wooden shops, and watching the locals cross the Sungai Sarawak Kanan in their long boats and dug-out canoes was like walking back in time. We then proceeded to the Bau-Krokong area to examine several exposures of the Bau Limestone as well as its relationships with the Pedawan Formation. Discussions were mainly centered on the paleoenvironments and paleogeography of these Jurassic-Cretaceous formations and their economic significance.

Bukit Young Gold Mine was the host to the lunch held at Dewan Suarah Bau. Before lunch, participants visited the Museum at this Dewan Suarah where many exhibits of the Bidayuh people were magnificently displayed. After thanking the management of the Bukit Young Gold Mine for the sumptuous lunch, the party then proceeded to north Kuching.

En route, we made a stop at one of the pottery factories on the Kuching-Serian Road. We were guided through the factory where we were shown the various stages of the manufacturing process of pottery. Before departure, we were led into the show room for souvenir-shopping.

Our planned visit to the Bako Peninsula was cancelled because the low river level at Sungai Bako did not permit the transport of our large bus on the ferry. As a small compensation, we stopped at Kampong Buntal, a fishing village which overlooks Buntal Bay. From there, we had a panoramic view of the geology of the Bako Peninsula.

Our last geological stop for the day was the Kayan Sandstone exposure at Bukit Puteri, at the southern part of the Santubong Peninsula. This exposure stirred up many discussions; two broad groups of argument were suggested for the deformational/truncation features of these rocks. One group favour the sedimentary origin while another group preferred a tectonic origin.

On our return to Kuching, many participants stopped at the Fort Margherita to visit the Police Museum and the new Riverside Park. Many chose to take the "bot penambang" to cross the Sungai Sarawak and walked back to the hotel.

The party departed for the Kuching Airport early on Friday morning, 4th December 1992. Our flight to Miri on a small Fokker Friendship plane was relatively slow as there were stopovers in Sibul and Bintulu. However, the low flying allowed a clear birds' eye view of the coastal region of Sarawak. The clear morning sun provided just the right lighting for taking photographs from the plane.

Upon our arrival in Miri at about 11.00 in the morning, we were transferred to the Richmond Inn, a small, quiet hotel close to the town center. After checking in and an early lunch, the participants went on an excursion around Miri, ably led by Boniface Bait.

The first stop was the Grand Old Lady of Miri, the first oil well in Sarawak located on top of Miri Hill. Due to a sudden downpour, the briefing on the geology of Miri was first made in the bus. When the rain eased after 10 minutes, the party was happy to leave the bus to have a better view of the ground even in the drizzle. On request, the briefing was repeated as many participants could not hear or see the illustration charts earlier in the bus. However, immediately after the second briefing, heavy rain started again. The party then decided to go to the other localities in Canada Hill, Riam Road, and Tanjong Lobang. At these localities, the different stratigraphic units of the oil-bearing Miri Formation were magnificently exposed. By the time we finished at the last outcrop at Tanjong Lobang, the sun was out brightly, and we decided to have another visit to the Grand Old Lady on the top of the Miri Hill before returning to the hotel.

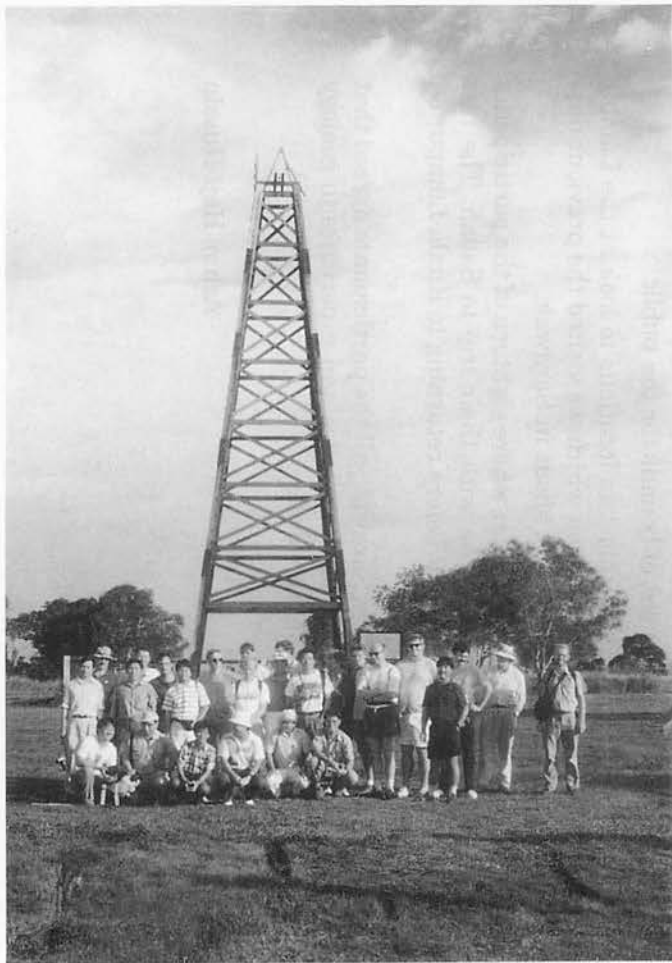
Early on Saturday, 5th December 1992, the party departed for the Batu Niah area. We spent about two hours studying the Subis Limestone at the Geragok and Sekaloh quarries. After a quick lunch at a restaurant near the Batu Niah junction, we headed for the Niah National Park headquarters where we had to register for our visit there. We browsed through the park museum before crossing the Sungai Niah. Although the round trip walk to the Niah Caves, an important archeological site, took about three hours, all the participants were happy to be surrounded by the shady green tropical forest. The Niah cave was magnificent, and we witnessed some birds' nests collecting by the locals. It was a pity that the Painted Caves, another spectacular archeological site, was undergoing renovation and hence was out of bounds for the public.

On our return to Miri, we stopped at another two locations to look at the Lambir Formation, the age equivalent of the Miri Formation which we visited the previous day. It was an excellent way to end our geological walk about in Sarawak.

On our way back we stopped by the Miri Airport where eighteen of the participants boarded a plane for Kota Kinabalu to continue on with their trip to Sabah. The rest returned to the Richmond Hotel to stay the night before returning to Kuala Lumpur on Sunday, 6th December 1992.

Although it was only a short 3-day trip in Sarawak, all the participants agreed that it was very fruitful as we were able to share our knowledge and experience in geology and made more friends from many parts of the world.

Azhar Haji Hussin



1. Grand Old Lady of Miri. The first producing well in Sarawak discovered in 1910.
2. Miri Hill. Photographers all in a row on top of Miri Hill.
3. Rian Road. Faulted Miri Formation.



Post-Symposium fieldtrip # 2 Areas of interest in Sabah – Report (Laporan)

The Sabah field trip was participated by 21 geoscientists of different fields from the petroleum industry to paleomagnetism. The leader was Prof. C.S. Hutchison while the coordinator was Mr. Tunggah Surat.

On the first day, the 6th December 1992, several stops were made to see the Crocker Formation including one near Kundasang where the Formation is in contact unconformably with the Pinosuk Gravel. Stops were then made at the Granodiorite Stock near Tamparuli and the Trusmadi Formation near the Kinabalu Park. The last stop of the day was made at the ultrabasic outcrop on the road cut to Poring.

The second day (7th December) started very early (5.30 am!), in order to catch the first flight to Sandakan. The flight was very pleasant especially when all the participants were seated on the left side of the plane to catch a glimpse of the magnificent view of Mount Kinabalu in the early morning sky.

After unloading the luggage at the hotel, the participants were brought to Tanjung Papat to observe the contact between the base of Sandakan Formation and the underlying Garinono Formation. After lunch, field visits continued along the Labuk Road westward observing the chaotic Garinono Formation.

On the last day (8th December), participants were able to enjoy their day with the orang utans at the Sepilok Orang Utan Rehabilitation Centre.

Tunggah Surat



Participants arriving at the Kota Kinabalu International Airport.



Participants trying to unravel the puzzling Crocker Formation.



Participants getting acquainted with the orang utan (with a baby!) at the Sepilok Orang Utan Rehabilitation Center, Sandakan.

ABSTRACTS OF PAPERS

Keynote address 1

Plate tectonics and petroleum habitats

DAVID G. HOWELL

U.S. Geological Survey, Menlo Park, CA 94025

Numerous basin classification and basin formation schemes have been offered in the literature to define the habitat of petroleum occurrences. Many classifications are seemingly tailored to specific settings while others are intended to be global in concept. Classifications based on plate tectonic settings are useful in explaining how basin geometries, kinematic histories and dynamic forces are mutually integrated. Using the U.S. basins as a template, and looking at basins world-wide, one sees how late tectonic processes affect the development of petroleum habitats.

CONVERGENT SETTINGS: The foreland basins of the Rocky Mountains and the various foreland settings cratonward of the Appalachian–Ouachita–Marathon orogen reflect the two most common types of hydrocarbon settings stemming from convergent tectonics. For the first type, convergent stresses are transmitted within the lithosphere a long distance from any plate margin; other examples world-wide include Tarim, Jungar, Ordos, Sichuan, Neuquin, Oriente, Ebro and Aquitaine basins. The second type of convergent basins are those that lie along plate margins and reflect collisional tectonics; examples world-wide include foreland basins regions of Persian Gulf, Ural–Volga, North Slope, and sub-Andean basins.

Source rocks of intermontane basins are generally, but not exclusively, organic-rich lacustrine debris that accumulated contemporaneously with basin subsidence. Conversely, plate-margin forelands are generally built across an older passive margin containing immature, organic-rich marine strata that accumulated prior to the episode of convergent tectonics. In most foreland basins, expelled oil and gas may migrate into the fold and thrust portion of the orogen, but the largest accumulations of oil occur near the peripheral bulge on the continent side of the foreland basin. Where foreland basins are superposed over preexisting deep basins, major gas plays exist. Examples include preexisting aulocogens, such as at Anadarko, and preexisting rift basins, such as at the Qatar play.

A third, seemingly anomalous, convergent-type basin is the so-called impactogen. These basins lie some distance away from regions of collision, on either the upper or lower lithospheric plates, and are oriented parallel to the direction of maximum stress; i.e. crustal extension is perpendicular to the direction of convergence. Lake Baikal (north of the Himalayan orogeny) and the Rhine graben (north of the Alpine orogen) are examples, albeit, neither are prolific hydrocarbon habitats.

RIFT SETTINGS: The Gulf of Mexico represents a continental rift basin; other examples world-wide include

Campos, Niger delta, Sirte, Brunei, Sabah and South China Sea. The numerous basins that lie within the archipelagic setting of the southwest Pacific, bounded by the islands of Palawan, Hainan, Sumatra and Timor, reflect a complex interplay of microplate tectonic processes; nonetheless, the oil-rich basins of eastern Sumatra and Java, Malaya and West Natuna, Tarakan, Brunei and Sabah entail rifting of continental crust.

Source rocks accumulate in anoxic silled troughs during early phases of rifting. Salt, another rock type formed during the early phases in rifting is an important element making up seals and contributing to structural closures as the salt becomes allochthonous. Other trapping mechanisms are associated with rift-related structures and the displacement of gravitationally unstable sediments that accumulate during the drift phase of rifted margins.

Rifting is also responsible for continental sags, such as the Illinois basin or the West Siberian basin. These basins overlie regions of aborted continental rifting during which the lower crust was tectonically thinned and invaded by dense mantle material, both processes effecting regional subsidence within the craton.

TRANSCURRENT MARGINS: The basins along the California margins reflect the formation of basins associated with transform motion between two plates; world-wide other examples include the Bohai and Dajing basins of eastern P.R. China. Crustal thinning attendant with transpressional tectonics result in rapid subsidence. These basins are commonly sealed, promoting the accumulation and reservation of source rock. With minor changes in plate motion or where faults bend the crust may be exposed to transpressional forces which create structural closures as the basins event.

In summary, the formation of basins and associated petroleum habitats can be fully explained in terms of the fundamentals of plate tectonics, and of all the basin types, plate-margin foreland basins are the most prolific hydrocarbon settings. In these basins, the organic-rich source rock are deposited prior to the continental collision. The effects of the younger collision result in both foreland sedimentation, which stimulates petroleum maturation in buried sediments, and the architecture of foreland basins, which provides a safe haven for huge accumulations of both oil and gas. In all of the other basin types, either reflecting intracontinental convergence, continental sags over aborted rifts, continental rifting or translational motions, the oil habitat, from source to reservoir, is wholly within the formation cycle of the individual basins.

Keynote address 2

World petroleum resources – where, why, and how much?

CHARLES D. MASTERS

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Concepts of recoverable world petroleum resources have remained relatively constant over the past few decades. Numerous authors have suggested ultimate petroleum resources as being about 2,000 BB of oil and 10,000 TCF of gas. We continue to confirm that overall quantity of oil and gas while focusing on 1) the significant contribution to resource quantity that derives from the growth of

discovered reserves, 2) the narrow geographic distribution of most of the world's petroleum, and 3) the resultant geographic sources and limits to future production that derive from these resource realities. Perhaps the most important generalization from our work is the REALMS Hypothesis that offers geologic reasons to support the occurrence of about 68% of the world's oil and gas in the Tethyan

Realm (including most of SE Asia), 23% in the Boreal Realm, 4% in the So. Gondwana Realm, and 5% in the Pacific Realm. Given the geologic limits on resource occurrence, a future production scenario, to the year 2010, suggests a concentration in the Middle East of more

than 50% of world crude oil production. Natural gas, being much less mature in its development and more widely distributed, can serve, to some degree, to balance the future distribution of hydrocarbon energy.

Keynote address 3

Tectonic framework of the Southeast Asian Tertiary basins

CHARLES S. HUTCHISON

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Sundaland was a large peninsular landmass, which extended from Eurasia into the Indian-Pacific Ocean at the end of the Cretaceous. It may be subdivided into two tectonically distinct regions, separated by the Cretaceous-Palaeogene Rajang marginal basin of Borneo, which accumulated a thick turbidite fan, sourced from the Mekong(?) River.

Sundaland north of the basin was cratonized during the Triassic Indosinian Orogeny, which sutured together disparate terranes of Gondwana and Cathaysia ancestry, resulting in major Early Mesozoic granites and extensive Late Mesozoic continental strata.

Sundaland south of the basin was not cratonic. It was dominated by Cretaceous volcano-plutonic arcs, ophiolite and deep water strata, microcontinents(?) and important mélangé zones, together reminiscent of present day eastern Indonesia. Elimination of Early Cretaceous marginal basins by convergent tectonics is thought to have been the accretionary process for outgrowth of the landmass, from the cratonic core of the Sunda Shelf to as far eastwards as Sulawesi. Its non-cratonic nature resulted in major Late Miocene uplift of melanged ophiolitic terrains to subdivide formerly larger basins (e.g. Meratus).

The dramatic reorganization of the spreading pattern of the Indian-Pacific Ocean, 45 Ma ago (anomaly 19-20), coincided with the collision of India. Its progressive indentation into Eurasia caused clockwise oroclinal bending of Sundaland, effected by right-lateral shear on the Indosinian orogenic grain, resulting in crustal extension in the more bent regions coupled with compression elsewhere. The great Sunda arc-trench system was initiated along the margin of Sundaland, with diminished subduction northwards beneath Sumatra because it was actively

dragged by India away from the impinging Indian Ocean lithosphere. It has no clearly defined Benioff Zone.

The active faulting and rifting caused river offset and capture throughout Sundaland, and the formation of major lakes, which became the beginnings of the Sundaland Tertiary basins. They first accumulated Eocene alluvium, followed by good lacustrine source rocks, before widespread marine inundation by Late Oligocene. However, basins on and to the north of the Malay Peninsula remained non-marine.

Although most basins date back to the Eocene, others were delayed till the Oligocene. The South China Sea marginal basin spreading extended from Oligocene to Middle Miocene, an extensional history shared by the Natuna, Malay and Penyu basins. The Sulu Sea marginal basin began its spreading only in the late Early Miocene, with its inter-connected rift system extending into Borneo as the Maliau and Tarakan basins.

The Rajang Basin was compressed between non-cratonic southern Sundaland and the Dangerous Grounds - Miri Zone part of Sundaland, which was pushed southwards by the Oligocene-Early Miocene opening of the South China Sea Basin. Palaeomagnetic data indicate major counter-clockwise rotation for Borneo, the mechanism of which has yet to be found—continental Australia was too far south to have caused it.

The Rajang Group was uplifted to form the Sibiu Zone orogenic belt, erosion of which fed major deltas (e.g. Baram Delta), which built out over the Dangerous Grounds terrane forming the Middle Miocene to Pliocene basins of N.W. Borneo. The compression also caused topographic inversion in the West Natuna and south Malay basins.

Keynote address 4

Evolution of the island arc and marginal basins of the Western Pacific

DAVID A. FALVEY

Australian Geological Survey Organisation

The modern island arcs and marginal basins of the Western Pacific commenced evolving towards the end of the Cretaceous with the formation of the Tasman Basin and the rifting of the Australia-Pacific convergent plate boundary from eastern Australia. Further marginal basin expansion and island arc fragmentation took place throughout the early Tertiary, with the arc system reaching its greatest easterly/northeasterly extent by the end of the Oligocene. At the beginning of the Miocene the process of arc reversal began, first in the northwestern extremity of the arc system (now the New Britain Arc). Reversal of the Solomon Arc occurred in the mid Miocene and of the New Hebrides/Fiji Arc in the late Miocene.

The processes of backarc seafloor spreading, arc fragmentation and arc reversal have, together with climatic factors, shaped the petroleum potential for the present Western Pacific island arc terranes. Limited exploration drilling, plus reconnaissance multichannel seismic surveys conducted through the early 1980s suggest that thick volcanoclastic forearc or intra-

arc depocentres have low potential. Instead, the areas marginal to these depocentres and adjacent to major islands may have significant potential. On such basin edges, the complex tectonic history will favoured the growth of marginal reef systems bordered by deep graben and half-graben basins. The marginal marine and coastal environments have been, in large part, intensely productive of organic material favourable to petroleum generation. Stripping mechanisms, such as cyclones and tsunamis, harvest this material and deposit it in the deep basins adjacent to reef bodies, with subsequent maturation and migration into reefal reservoirs. This marginal play has not been tested. Promising shallow-water target areas include: in northeastern Papua New Guinea—shore edge of New Ireland basin and nearshore borders to the Queen Emma and Bougainville basins; in Solomon Islands—Manning Strait, eastern Iron Bottom Sound and Mbokokimbo basin; in Vanuatu—southwest Vanikolo basin, western East Santo basin; in Fiji—shoreward Bligh basin; in Tonga—Eua Channel area.

Keynote address 5

3-D seismic benefits from exploration through development: an Exxon perspective

M. G. JOHNSON

Exxon Exploration Company, Houston, Texas, USA

Exxon has participated in over 370 3-D seismic surveys in 13 countries since the late-1970's. From the western margin of the Pacific Basin, Malaysia, Australia and China are included in our worldwide distribution of experience which is led by western Europe, the Gulf of Mexico and Canada. These surveys have added significant value to our upstream operations and we consider 3-D seismic to be the single most important technology to ensure effective and cost-efficient exploration and development of our oil and gas fields. Exxon is applying 3-D seismic technology in established exploration trends, the early phases of field delineation, development decision making, as well as field exploitation. Through a series of Exxon case studies including the Seligi Field in the Malay Basin, the Tern Field in the North

Sea and the Ram/Powell Discovery and Grand Isle 16 Field in the Gulf of Mexico, this paper demonstrates that 3-D seismic surveys are proving to be excellent investments to help identify and evaluate quality new exploration opportunities, provide critical information about whether new discoveries can be economically developed and optimize ongoing projects. Our use of 3-D seismic surveys has led to the addition of new reserves, drilling fewer dry or marginal exploration wells and optimization of the number and placement of delineation, development and secondary recovery wells. These benefits are a result of superior structural definition, more detailed reservoir descriptions, reservoir fluid content characterizations and quantitative interpretation methods.

Keynote address 6

Regional data processing and analysis as a basis for co-operative resource assessment

RICHARD SINDING-LARSEN

Norwegian Institute of Technology, Trondheim, Norway

The Committee for Co-ordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas (CCOP) is an intergovernmental organization with the following member countries: China, Democratic Kampuchea, Indonesia, Japan, Malaysia, Papua New Guinea, Philippines, Republic of Korea, Singapore, Thailand and Viet Nam. The Hydrocarbon Resource Assessment Program undertaken by CCOP involves countries with different levels of development. Its objectives therefore differ significantly from programs undertaken within regions that represent the same development level.

The CCOP Resource Assessment Program was designed to help the CCOP countries improve their capacity and procedures for mapping and assessment of energy and mineral resources in sedimentary basins. The CCOP Resource Program started with national data compilations that could be fit into a regional framework. At the same time, different methodologies for analyzing the resource potentials of the region were demonstrated and discussed during a series of workshops throughout the

Program. The Program started with the compilation and production of geological resources maps and cross sections at the basin level. It supported the demonstration and introduction of methods for assessing resources by using the play concept, and assisted in systematizing the necessary play data for resource assessment. The products of the Project include maps, cross sections and explanatory notes as well as a preliminary play atlas, which are intended to help identify areas for new plays, encourage exploration and facilitate the management of national resource programs within the individual CCOP countries. Mineral and energy resource management based on adequate resource data and data system is important to the CCOP countries because of their need for resource data on which they can base realistic national plans for resource development. Recognition of this need has led to an increasing effort to develop resource data files and data systems relative to non-renewable energy and mineral resources.

Paper 1

Giant oil accumulations and their areal concentration efficiency

KINJI MAGARA

United Arab Emirates University, Al Ain, U.A.E.

The ratio of the areal concentration (barrels of oil equivalent/sq km) of accumulated oil in the richest sedimentary basin to that in the poorest basin, among those basins having "giants" and "supergiants", is more than 500 to 1. On the contrary, the ratio of the richest to the poorest petroliferous basin in terms of the total organic concentration may be less than 20 to 1. Such a large discrepancy between these two ratios suggests that the organic concentration alone cannot account for oil concentration in commercial reservoirs, because significant quantities of oil may have been lost to the surface and also disseminated throughout the sedimentary sequence in the geological past. Most of the disseminated oil cannot be produced economically by the present-day technology.

For a better petroleum assessment, the author stresses the importance of the petroleum accumulation/preservation

efficiency in commercial reservoirs; this may be evaluated as combining, 1) the organic concentration of the source rock, 2) the duration of oil generation, 3) the thickness of the oil-generating "window", 4) the total geologic age involved, and 5) the fluid expulsion efficiency and the presence or absence of undercompacted intervals. Other parameters such as the trap, reservoir and cap rock, and also the types of organic matter in the source rock, would have a great influence on the efficiency of oil concentrations in commercial reservoirs as well. However, most of them are related to the geologic conditions of each specific area or basin, and thus are more difficult to generalize than those mentioned above in the context of the global distribution and concentration of oil reservoirs.

Estimates of offshore hydrocarbon resource potential in Tertiary Sedimentary Basins and areas along the western rim of the Pacific Basin

KEITH ROBINSON

U.S. Geological Survey, Box 25046, Mail Stop 940, Denver Federal Center, Denver, Colorado 80225, USA

Estimates of undiscovered recoverable petroleum resources were made in 1991 for some of the major offshore Tertiary sedimentary basins and areas bordering the western rim of the Pacific Basin. Included are basins within the territorial waters of South Korea, China, Vietnam, Cambodia, Thailand, Malaysia and Brunei.

With the exception of adjoining onshore basins of China and possibly Indo-China, most Tertiary basins in the study area with sufficient size, depth, and sediment volume favorable for the generation and accumulation of hydrocarbons, are located in offshore areas. Several offshore basins also extend partly onshore, including the southern Yellow Sea sub-basin and East China Sea basin of China, the Red River (Song Hong) and Mekong (Vung Tau) basins of Vietnam, the northern Thai Chao-Phraya rift extension of the Gulf of Thailand basins, and the Sarawak and Tarakan basins in Eastern Malaysia and Brunei.

Locally, problems exist with the plurality of basin nomenclature. In addition, many of the major basins are subdivided into distinct geologic sub-basins or provinces on the basis of unique geological features. Numerous exploration prospects are present. The plays consist of individual or

combination stratigraphic and structural traps. The structural plays are formed by fault-bounded horsts, grabens, and half-grabens and by gently folded to highly faulted anticlines. Other plays include prospects associated with synsedimentary growth-fault and rollover features, structurally controlled deep-marine turbidites, carbonate platforms, pinnacle reef complexes, and fractured-basement reservoirs.

Estimates of undiscovered resources have been made for all individual, identifiable, geologically unique basins, sub-basins or provinces with significant hydrocarbon exploration potential. The resource estimates were made from published data, using a quasi-quantitative volumetric play analysis method based on area, trap size, degree and success of exploration, play types, effective pay thickness, lithology, recovery factors, reservoir characteristics, seals, source rocks, maturation, migration, and known reserves.

Excluding natural gas liquids, the totals, within each major Tertiary basin, for aggregated estimates of undiscovered recoverable hydrocarbons in all geologically unique sub-basins or provinces, are presented.

Tarakan Basin, NE Kalimantan, Indonesia: a century of exploration and future hydrocarbon potential

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Nearly a century of exploration in the Tarakan Basin of NE Kalimantan, Indonesia, has yielded four major oilfields, with a total cumulative production to end-1986 of 312 MMBO, plus one large gas field and five minor oil accumulations. Reserves reside mainly in stacked, predominantly fluvial, thick sandstone reservoirs of Pliocene and Pleistocene ages. Multiple reservoirs (up to 90 zones) also occur within shallow marine sandstones of Upper Miocene to Pliocene age. Traps are primarily downthrown, independently-closed, roughly north-trending anticlines, ranging between 960 and 2600 acres. Most major accumulations are located on Tarakan and Bunyu islands, with only one on the mainland but as yet none offshore.

Over 86% of produced reserves had been discovered prior to 1923 (Pamusian, 1901 and Bunyu, 1923). Both structures were easily identified by their surface expressions and oil seeps. Recent exploration (post 1970), with over 30 exploration wells drilled onshore and 16 offshore, added the medium-sized Sembakung oil field and the large Bunyu Tapa gasfield. The lack of success offshore is largely attributable to the rarity of sufficiently large, independently-closed structures at shallow depths, within the Plio-Pleistocene sand-prone levels so productive in the largest onshore fields.

Migration timing is partly constrained, at least on Bunyu Island, by the presence of Pleistocene reservoirs, indicating extremely late migration, into structures which are either early Pleistocene or possibly re-activated Pliocene or earlier features. Bunyu and Tarakan Islands were depocenters during the late Miocene and Pliocene and were only inverted in late Pleistocene times. Precise dating of tectonic phases is rendered difficult by a lack of age-diagnostic fossils and by laterally discontinuous seismic events which do not correlate laterally with wells nor onshore outcrops.

Technical problems have been partially solved by high-quality seismic data, new wells and isotope age dating. Untested plays include closures at older stratigraphic horizons, growth-fault plays in the deep-water area and stratigraphic traps. This review presents a summary of the Tarakan Basin stratigraphy and structure in relation to the exploration history and an assessment of the currently perceived hydrocarbon potential. The combination of high technology and understanding of basin dynamics will hopefully be the key to success, before the close of a century of exploration.

Tertiary coal measures as source sequences for oil

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Prolific oil provinces occur in Tertiary coal measures in SE Australia, Indonesia and Malaysia. Oils associated with coal measures have distinctive properties: typically paraffinic, waxy,

high API gravity, low sulphur, high pristane to phytane ratio and a distinctive suite of resin related triterpanes. Although extracts from coal measures sediments show a resemblance to

oils probably generated from them, systematic differences are common.

Organic matter in coal measures occurs as coal seams and as dispersed organic matter (dom). Coals and dom form a continuous series, boundaries are arbitrary. Most coals are autochthonous and most dom is allochthonous. Within coal measures, ratio of coal to dom is greater than one. It ranges up to about ten and about four is typical.

Tertiary coals are unusual compared with older coals in having a ratio of vitrinite to inertinite of about 90:1, and because most inertinite is of fungal origin. Liptinite is abundant in some, but not all, Tertiary coals. Resinite and suberinite are the dominant liptinite macerals. A few Tertiary coals have canneloid affinities, the main non-vitrinite maceral being referable to bituminite. Algal-rich coals occur but are uncommon. Some Tertiary basins in Southeast Asia have lacustrine sequence rich in lamalginate. Typically, the algal and coaly facies are spatially separated; few source rocks are of mixed higher plant and algal origin.

Many SE Asia coal measures have abundant optically discrete bitumens and oil drops. Bitumens range from exsudantinite veins to lenses and some impregnate coal. A paragenetic sequence occurs; liptinite macerals are first affected, followed by detrovitrinite, telovitrinite and, in extreme cases, by inertinite. Bitumen impregnation has a marked effect on vitrinite reflectance, so recognition of bitumen impregnation is important in assessing maturation and hydrocarbon generation history.

Bitumen abundance may indicate source potential of coals but it could indicate extent of migration from coals. Coals of similar type and rank but with different thermal histories contain variable amounts of bitumens. Migration from coals appears efficient in the early stages of maturation and bitumen-rich examples may represent coals where the migration process has been "frozen". Loss of liquids through cleat fractures in coals is likely mechanism for primary migration. Humic matter at deposition contains up to 90% moisture. At vitrinite reflectance of about 0.8% moisture content is about 2%. Carbon dioxide, dehydration water and methane are also expelled. Early fluid expulsion is probably associated with the major phase of oil generation and expulsion from coals. Above vitrinite reflectance of 0.65% migration is less effective and bitumens are retained. At higher ranks, petroleum liquids are generated, but migration of liquids into adjacent reservoirs is less probable.

Generation of migratable hydrocarbons from coals is a function of thermal history rather than of type. Average composition of suites of coals from different sets of coal measures shows a small range, and type control on source potential does not vary markedly between different coal measures sequences. Maturation control, is considered to be critical. Rapid coalification has occurred for most Tertiary coal measures and is probably the most important characteristic for prospective sequences. Oil generation from coal measures is biased to coals rather than dom and effective generation and migration occur earlier from coal measures sequences than from algal-rich source rocks.

Paper 5

Paleogeographic development of the Southwestern Pacific Basin

GEORGE W. MOORE

Department of Geosciences, Oregon State University, Corvallis, Oregon, USA.

Early Paleozoic paleogeography was revolutionized in 1991 by a new understanding that during the late Proterozoic East Gondwana (including Antarctica, Australia, Southeast Asia, and China) had rifted away from western North America. This gigantic continental fragment swung like a door through the proto-Pacific. By the beginning of the Cambrian, when precursors to the worldwide animal groups suddenly acquired protective hard parts, wide seas isolated the fragment from the other continents and led to locally distinctive Cambrian faunas.

The tectonic swing continued on, and local compass directions passed through a large circuit. Finally, during the Middle Cambrian, East Gondwana came against the back side of Africa. The various shield areas of Africa and South America were shoved together, and the new continent of Gondwana was in place.

But the relentless push of the trailing oceanic ridge did not cease with the consolidation of Gondwana. As the intercratonic subduction zones wheezed into inactivity, the convergence transferred to the trailing rifted margin of Australia and Antarctica.

The consolidation of Gondwana as a whole had taken place mainly along two oceanic closures, one near the present east coast of South America, and the other near the east coast of Africa. When closure was complete in the Ordovician, these sutures intersected approximately at right angles with the

newly created ragged continent-ocean boundary between Gondwana and the original Tethys.

Almost immediately, a new spreading axis formed along this boundary, passing both along the margin, and in places cutting off subcontinental masses that extended away from its general trend. During the Silurian, North and South China pulled away from present-day northwestern Australia and India. Subsequently, the spreading axis jumped in successive stages farther and farther into the body of Gondwana. During the Devonian, Indochina and Malaya were pulled off; during the Permian, Tibet and Sibumasu (Burma-Thailand); during the Jurassic, western Burma and Sumatra; and during the Cretaceous, Australia and India, the very heart of Gondwana.

Ridge push from these evolving spreading axes soon generated subduction zones within and at the opposite side of Tethys, and the waves of rifted subcontinents moved with the oceanic crust that separated them and docked successively at the margin of the developing continent of Laurasia. Indochina and Malaya joined with South China to form Cathaysia during the Carboniferous, Cathaysia then joined with North China during the Permian, and this whole assemblage became attached to Siberia during the Triassic. Tibet and Sibumasu also joined with Laurasia during the Triassic, and West Burma, Borneo, and Sumatra arrived during the Jurassic and Cretaceous. The final major fragment to land was India, in the Eocene, and Australia continues its approach.

Although the data is still fragmentary, we find that most Tertiary paleomagnetic directions from Region 1 do not show significant rotations from the expected dipole direction. Exceptions to this are found in central and western Thailand, Sumatra, and southeastern Korea where the anomalous directions are related to motions along major strike-slip faults which locally cut Region 1. In contrast, reported paleomagnetic directions from Region 2 are recorded for the Philippines, Sulawesi, eastern Indonesia arc and portions of Borneo. Here the rotations observed are related to local tectonic events which have occurred during the Tertiary. In this region we find examples of paleomagnetic rotations caused

by accretion, collision related bending, strike-slip faults, and small plate or microplate rotations. With the exception of the mounting reliable data from east Asia, pre-Tertiary paleomagnetic data from the other portions of Region 1 and from Region 2, are somewhat limited and of questionable reliability. Furthermore, because of the limited amount of pre-Tertiary structural data and reliable geologic mapping that exist for Indochina, "Sundaland" and the pre-Tertiary portions of the Philippines and eastern Indonesia, the use of pre-Cenozoic paleomagnetic data for large scale tectonic synthesis of this region such be regarded as suspect.

Paper 13

The nonlinear inversion of paleogeothermal evolution: example from the north part of South China Sea

XUE AIMIN

The Institute of Geophysics, Chinese Academy of Sciences, Tatan Road, Beijing 100101, P.R. China.

The paleogeothermal history of the north part of South China Sea is studied with the nonlinear inversion method and the detailed structural and thermal evolution models. The thermal model implies the variation of basal heating flow with time, thermal conductivity with sediment porosity and composition. The heating flow does the variation with the geohistory as the nonlinear function of time. But for the effective calculation, the linear function of heating flow as age in a small piece of time has been considered as follows:

$$Q_n = Q_{n-1} (1 + b_n (t_n - t_{n-1}))$$

Q_n is the heating flow in time t_n ; t_n is the time of tectonic changing violently; b_n is the slope of Q_n against time t_n .

Based on the minimum square technique, I make the objective function as follows:

$$\Phi(b_1, b_2, \dots, b_n) = \sum_{i=1}^N (\bar{R}_0(z_i) - R_0(z_i))^2$$

$\bar{R}_0(z_i)$ is the measured vitrinity reflectance at z_i while $R_0(z_i)$ is the modelled one at z_i and it is the function of TTI and can

be computed using Lopatin Method or Arrhenus Equation. From objective function and heating flow model, the nonlinear inversion of heating flow can be getting on.

The application in the nonlinear inversion model is illustrated for the north part of South China Sea. The temperature measurements, thermal conductivity, heating flow, stratigraphic and areal and well geophysical data in the area were collected and processed to built framework of models of burial, structural and thermal histories. The results show the area has undertaken at least three extensions since the Later Mesozoic period, as the heating flow has different features in different periods. Also the variation of temperature and thermal maturation of source rocks have been evaluated and the results show almost pre-Cenozoic source rocks give over-matured features and Earlier Tertiary source rocks in some areas also do. The Eocene, Oligocene and Miocene source rocks are now entering the "Oil Window" environments.

Paper 14

Cenozoic structure and stratigraphy of the Eastern Continental Shelf and Upper Slope of Vietnam

S. WIRASANTOSA¹, J. S. WATKINS¹ & G. WHITE²¹Department of Geophysics, Texas A&M University, College Station, TX 77843.²Halliburton Geophysical Services, Inc., PO Box 5019, Sugar Land, TX 77487-5019.

The eastern margin of Vietnam between 10°N and 16°N is characterized by two structural and stratigraphic regimes. Between 10°N and 11°30'N normal faults generally trend northeast-southwest, whereas between 11°30'N and 16°N normal faults trend north-south. Strain-ellipse analysis suggests that faulting in the northern area may have resulted from left-lateral motion accompanying the southeastward extrusion and clockwise rotation of Sundaland during the collision of India and Asia. The origin of the northeast-southwest faulting between 10°N and 11°30'N is unknown. Regionally, the net throw is down to the east or southeast.

Both sets of faults have associated horst-graben sequences. Sediment thicknesses within these basins range from 0.5 seconds to more than 4 seconds two-way-travel time or 15,000 ft or more. Basin fill consists of both posttectonic and syntectonic sediments. We have inferred on the basis of global sea level changes and associated megaregional unconformities the following 5 sequences in the posttectonic section of our seismic data: Upper Oligocene-lower Miocene, lower Miocene-middle Miocene, middle Miocene-upper Miocene, upper Miocene-Pliocene, and upper Pliocene-Holocene. These sequences have been divided into a number of seismic facies from which depositional environments have been inferred.

(Not Presented)

Paper 15

A preliminary research into the plate collision, rotation and divergence pattern of China and its periphery since Mesozoic

FEI QI

China University of Geosciences, Wuhan, China 430074.

Based on 42,000 data from 6000 points, a set of computer generated maps have been compiled, showing the distribution

of sedimentary types, igneous rocks and thickness and association of strata over China and its periphery at 20 Ma interval.

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The Tertiary megasequence stratigraphy of the South China Sea petroleum basins

ANDREW G. LODGE

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The South China Sea and its associated petroleum bearing basins developed in response to Tertiary rifting and sea floor spreading. The South China Sea represents one tectonostratigraphic region in which four Tertiary megasequences can be correlated between and within each individual basin fill. These megasequences are tectonically controlled.

The earliest megasequence sedimentary fill (MT1) is Mid-Eocene to Early Oligocene in age and is controlled by syn-rift continental extension. The second megasequence (MT2) represents the basin fill to the sea floor spreading episode and is Late Oligocene to Early Miocene in age. The third megasequence (MT3) is Mid to Late Miocene in age and is dominated by progradational depositional systems. This megasequence is terminated by a regional unconformity associated with the collision of the Australian and Philippine plates with Indochina. The latest megasequence (MT4) is a resumption of the progradational systems, modified by intermittent compression.

Although each megasequence can be identified across the region the stratigraphic response and implications to petroleum exploration vary from basin to basin. The basins to the northwest of the sea floor spreading centre (typified by the Pearl River mouth Basin) display "classic" divergent margin configurations. The restricted continental environments associated with the syn-rift MT1 half graben development were ideally suited to petroleum source rock preservation. The marine transgression

associated with the MT2 boundary established the widespread development of reservoir bearing (retrogradational) depositional systems. MT3 and MT4 are predominantly progradational systems; their megasequence boundaries provided the opportunity to flood the systems and develop regionally extensive seals.

The conjugate margin, as typified by the NW Sabah depocentre, is convergent. MT1 and MT2 are fore-arc megasequences. The cessation of sea floor spreading created the "Deep Regional Unconformity" at the base of MT3. Major deltas with their inherent petroleum potential prograded into the South China Sea. The base of MT4 or "Shallow Regional Unconformity" is marked by uplift and folding. The MT4 stratigraphy is again delta dominated.

The depocentres on the western margin of the South China Sea (e.g. South Con Son, E. Natuna and Offshore Sarawak) were controlled by active and reactivated transfer zones. MT1 and MT2 display the characteristics of the Pearl River mouth Basin whilst MT3 and MT4 have affiliations with NW Sabah. Consequently, they potentially offer twice the petroleum potential of the other margins.

The identification and correlation of four megasequences across the South China region permits prediction of the petroleum potential from one basin to another.

Tectonic implications of Cenozoic magmatism in Southeastern and Eastern Asia

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Cenozoic magmatism post-dates opening of the South China Sea Basin and is associated with fracture intersections in Indochina, Thailand, and China, initiated at ca. 15 Ma BP and 0.5 Ma BP. New geochemical data allow systematic modelling of relationships between melting and lithosphere dynamics in the region. Extrusion tectonics (Tapponnier *et al.*, 1982) predicts rotation of tectonic units along regional strike-slip features such as the Red River and Chao Praya faults and NW-SE opening of the South China Sea in response to the early Tertiary Indo-Eurasian collision. Alternative proposals (e.g. Harder *et al.*, 1992) suggest that extrusion was minimal and rotation of the regional stress field occurred rather than tectonic rotation. In the absence of deep mantle plumes we believe recent melting is best explained by asthenospheric upwelling beneath lithosphere extensional axes at mantle potential temperatures (T_p) of ca. 1280°C. Extension must have been extreme and rapid, and source enrichment necessarily attributed to a shallow recycled crustal source and accreted asthenospheric melt. Post-spreading basalts from pull-apart basins in the South China Sea northern Hainan Island indicate distinctive petrologic relationships: large melt fractions (quartz and olivine tholeiite) beneath extensional east-west

fissures and low melt fractions (alkali basalt and basanite) at bounding strike-slip faults. Similar patterns are observed in Vietnam and other parts of Indochina. Petrogenetic conditions have been estimated for Vietnamese and Hainan basalts from experimental data and trace element models. Quartz tholeiites were generated by 12–18% melting of plagioclase/spinel lherzolite at ca. 1250°C. and < 10 kbar pressure. Olivine tholeiites were formed by 10–15% melting of spinel lherzolite (1300°C., 10–15 kbar), and alkali basalts and basanite by 5–8% melting of spinel lherzolite (1350°C., <20 kbar) at or not far below the mechanical boundary layer of lithospheric mantle. These conditions are consistent with thermobarometric estimates from entrained xenoliths. The range and spatial association of primitive melts is consistent with mantle decompression paths beneath pull-apart systems. Isotopic compositions also suggest tholeiites were generated at the base of the lithosphere while alkali basalts tapped a more MORB-like asthenospheric source. Assuming uniform (pure shear) extension stretching factors (β) > ca. 2.5 are needed for 'normal' mantle T_p . Even if these are unrealistically large, diverse regional orientations suggest major stress redistributions following opening of the South China Sea.

Tectonic features and evolution of the China Sea and adjacent regions

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The China Sea and adjacent regions consist of a series of tectonic units such as fragments, sutures and subduction zones. They went through the formation of the continental cores, forming platform and platform stabilization to the formation of Pangea.

Since Permian, blocks disintegrating from Gondwana collided with south-western area of China, forming Tethys-Himalayan tectonic zones, which caused three openings and closings of tethys oceans. Meanwhile, Hainan-Hida Yuli-Ryoke and Manila sutures were formed in south-east continental margin of East-Asia because of the active of Kula plate and subsequent Pacific plate. The old structural framework of China was reconstructed due to the WNW-ESE trending compression stress imposed on the eastern part of Eurasian plate by the mentioned-above tectonic movement. The active margin was formed in the south-eastern margin of ancient east China Sea and the north margin of ancient south China Sea.

Through Cretaceous to mid-Oligocene, a lot of fault-subsidence basins controlled by tensional-shear faults was located in south-eastern areas. Tensional faults occurring in east China

Sea resulted in the formation of skip-like downwarp, which showed the original formation of shelf-basins in the area. Because of the first spreading of the South China Sea, the NE trending rift-valley and the south-west oceanic basins were formed. Moreover, extension and subsidence occurring in south-east China resulted in a series of downwarp deposit basins developed over previous fault-subsidence and rift-valley basins since mid-Oligocene. The mid-ocean basin was formed during the second spreading of the South China Sea in this time. Subduction, convergence and backarc spreading were present in the margin of Eurasian plate. Three different structural units occurred from southeastern Japan to the Philippine Arc: (1) The subduction of Nanka Trough and Liukiu Trench made the backarc spreading of Japan ocean basin and Okinawa Trough. (2) The collision between ocean crust and continental crust was presented in Taiwan. (3) The Philippine Arc exhibited the framework of westward subduction of the Philippine Trench on the east flank and eastward subduction of the Manila Trench on the west flank. The China Sea eventually formed.

Paper 11

A single mechanism for Cenozoic extension in and around Indonesia

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²Department of Geological Sciences, University of Illinois at Chicago, Box 4348, Chicago, Illinois, U.S.A. 60680.

Some of the most striking geological features of southeast Asia are the large Tertiary basins and major strike-slip faults on and around the Indochina peninsula. These features include sedimentary basins in almost every orientation intersected by strike-slip faults of different orientations. Previously, these structures have been explained by a variety of differing mechanisms. Here we use a single mechanism to explain the formation of all the major basins around the Indochina peninsula and the major strike-slip faults. This single mechanism is the collision of Indian plate with the Eurasian continent and the rotating stress regime created by this collision.

The rotating stress mechanism began during the Eocene when the Indian plate first contacted the Eurasian continent forming the Ranong fault in Thailand. As the stress field increased and propagated northward from the collision zone the stress field in Indochina rotated. Here the maximum compressive stress axes are nearly east-west and the maximum tension axes are north-south. This creates the Three Pagodas and Mae Ping faults. Further to the southeast the tension axes of the stress field are still north-south but the compressive axes become vertical. This

resulted in the opening of the Malay, West Natuna, Penyu, Con Son and Mekong basins in a north-south extensional regime. To the north, the Red River fault underwent left-lateral displacement; possibly opening or extending the basins in the Beibuyan Gulf. As the stress field continued to propagate northward from the collision zone the stress field in Indochina continued to rotate. As it rotated the maximum compressive stress axes becomes northwest-southeast and basin inversion occurred. First in the West Natuna basin and then as the stress field continued rotation inversion occurred in the Malay basin. At the same time the maximum tension axes became nearly east-west initiating or reactivating extension in the Thai basins from the Pattani trough through the intermontane basins of northern Thailand. At the same time the direction of motion on the Red River fault became right-lateral and the Bacbo or Yinggehai basin opened.

The first part of the rotating stress model is similar to that of Peltzer and Tapponnier (1988), however the rotation of the stress field is considerably faster than that implied by their model with left-lateral motion ending during the Early Oligocene and right-lateral motion responsible for extension in the Gulf of Tonkin.

Paper 12

Paleomagnetic evidence to define a stable East Asia and Sundaland

ROBERT McCABE¹, STEVEN HARDER¹, VIVAT PAIJITPRAPAPON², NGUYEN GIANG³, & EKO LUMADYO⁴

¹Department of Geophysics, Texas A&M University, College Station, Texas 77843, USA

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³Geophysics Society of Vietnam, Hanoi, Vietnam.

⁴UNOCAL Indonesia, Jakarta, Indonesia.

Tertiary paleomagnetic data and marine magnetic anomaly data from east and southeast Asia define two broad regions: 1) (Region 1) a stable continental region composed of east Asia,

Indonesia, and the continental portions of Sundaland; and 2) (Region 2) the various island arcs, continental fragments and oceanic basins that occur to the southeast of the continental block.

Although the data is still fragmentary, we find that most Tertiary paleomagnetic directions from Region 1 do not show significant rotations from the expected dipole direction. Exceptions to this are found in central and western Thailand, Sumatra, and southeastern Korea where the anomalous directions are related to motions along major strike-slip faults which locally cut Region 1. In contrast, reported paleomagnetic directions from Region 2 are recorded for the Philippines, Sulawesi, eastern Indonesia arc and portions of Borneo. Here the rotations observed are related to local tectonic events which have occurred during the Tertiary. In this region we find examples of paleomagnetic rotations caused

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$$\Phi(b_1, b_2, \dots, b_n) = \sum_{i=1}^N (\bar{R}_0(z_i) - R_0(z_i))^2$$

$\bar{R}_0(z_i)$ is the measured vitrinity reflectance at z_i while $R_0(z_i)$ is the modelled one at z_i and it is the function of TTI and can

be computed using Loptin Method or Arrhenus Equation. From objective function and heating flow model, the nonlinear inversion of heating flow can be getting on.

The application in the nonlinear inversion model is illustrated for the north part of South China Sea. The temperature measurements, thermal conductivity, heating flow, stratigraphic and areal and well geophysical data in the area were collected and processed to built framework of models of burial, structural and thermal histories. The results show the area has undertaken at least three extensions since the Later Mesozoic period, as the heating flow has different features in different periods. Also the variation of temperature and thermal maturation of source rocks have been evaluated and the results show almost pre-Cenozoic source rocks give over-matural features and Earlier Tertiary source rocks in some areas also do. The Eocene, Oligocene and Miocene source rocks are now entering the "Oil Window" environments.

Paper 14

Cenozoic structure and stratigraphy of the Eastern Continental Shelf and Upper Slope of Vietnam

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The eastern margin of Vietnam between 10°N and 16°N is characterized by two structural and stratigraphic regimes. Between 10°N and 11°30'N normal faults generally trend northeast-southwest, whereas between 11°30'N and 16°N normal faults trend north-south. Strain-ellipse analysis suggests that faulting in the northern area may have resulted from left-lateral motion accompanying the southeastward extrusion and clockwise rotation of Sundaland during the collision of India and Asia. The origin of the northeast-southwest faulting between 10°N and 11°30'N is unknown. Regionally, the net throw is down to the east or southeast.

Both sets of faults have associated horst-graben sequences. Sediment thicknesses within these basins range from 0.5 seconds to more than 4 seconds two-way-travel time or 15,000 ft or more. Basin fill consists of both posttectonic and syntectonic sediments. We have inferred on the basis of global sea level changes and associated megaregional unconformities the following 5 sequences in the posttectonic section of our seismic data: Upper Oligocene-lower Miocene, lower Miocene-middle Miocene, middle Miocene-upper Miocene, upper Miocene-Pliocene, and upper Pliocene-Holocene. These sequences have been divided into a number of seismic facies from which depositional environments have been inferred.

(Not Presented)

Paper 15

A preliminary research into the plate collision, rotation and divergence pattern of China and its periphery since Mesozoic

FEI QI

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Based on 42,000 data from 6000 points, a set of computer generated maps have been compiled, showing the distribution

of sedimentary types, igneous rocks and thickness and association of strata over China and its periphery at 20 Ma interval.

Nov-Dec 1992

According to this set of maps, some preliminary conclusion can be drawn concerning the plate tectonics around China since Mesozoic under the guidance of mobilism.

1. The distribution of climate controlled formation - coal and evaporites in China was evidently moving northwards from Mesozoic to Cenozoic, suggesting a clockwise rotation of China continent, if the climate zone did not change over the period. The total rotation angle is estimated to be 35°.

2. According to the occurring time of various igneous rocks and rock types, it can be inferred that welding of the south plate to the north plate of China took place in late Tertiary, that the final combination of China continent with Eurasia was in Jurassic, that the India plate, which was separated from Gondawana in

Cretaceous, collided against the south-west part of China continent at late Tertiary and the collision was developing from west to east. This major collision is responsible for the rise of Himalaya Fold Belt and the compressional deformation of the west part of China. The NW-wards subduction of the Pacific plate started at early Jurassic, which led first to the compression and following by extensional rift subsidence in east part of China and the opening of Japan Sea after Eocene.

In general, China continent has been experiencing complex tectonic evolution since Mesozoic, such as collision, rotation and divergence, forming multiple structural deformation and rifting, which form the tectonic framework of the China Basins.

Paper 16

The tectonic significance of transform faults within a portion of the Greater Sarawak Basin

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Synthetic Aperture Radar (SAR) data was utilized to aid in the recognition and tectonic importance of transform or major strike-slip faulting within the Baram Delta area of the Greater Sarawak Basin.

High resolution SAR data acquired over northern Sarawak, East Malaysia was utilized as a preliminary reconnaissance of regional tectonism and its effect on the surficial expressions of the structural elements and its spatial control on lithostratigraphic terrain units. SAR is an excellent remote sensing tool for structural interpretations, particularly in the dense jungle forest covered terrain of tropical latitudes. Since SAR is an active remote sensor, it can penetrate cloud cover and tropical haze. In addition, SAR's side-looking geometry enhances subtle but significant topographic features that in addition to its fine resolution enhances geologic interpretation.

The identification of major northwest to north-northwest trending transform faults are interpreted from SAR imagery to impart local strong tectonic foliation and to warp major regional fold axes. These major strike-slip faults border the tectonostratigraphic provinces within the Greater Sarawak Basin, both onshore and offshore. It is postulated that the recognized West Baram Line and the Tinjar Fault Trend may be the southerly extensions of the sinistral Red River Fault zone identified in mainland Asia. Transform faults also act as loci for volcanic activity, subvolcanic and igneous intrusion, shale diapirs, mud volcanoes and hydrocarbon seepages. The depositional facies edge of the Middle Miocene Setap Shale Formation is controlled by the transform fault Belait Line with a deeper marine facies to the northeast. SAR is an effective remote sensing tool for interpretation of the complex evolution of a Tertiary sedimentary basin margin under difficult exploration conditions.

Paper 17

Statistical analysis of the structural evolution of western Qaidam Basin

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Qaidam Basin is located in the northern bordering zone of the famous Qinghai-Xizang Plateau, and the tectonic evolving history of the plateau should be typically recorded by the sediments in the basin. However, traditional methods for studying tectonic evolution of a sedimentary basin are mostly qualitative, and, therefore, not capable of delineating quantitatively the tectonic evolution process, though recent geophysical methods can provide detail images of the surface structures. In this paper the tectonic evolution of the basin is studied by using three statistical parameters derived from five structural surfaces in the western part of Qaidam Basin.

The parameters comprise the degree of roughness of structural surface (R), the azimuth of long axis of the second order polynomial trend surface (LA), and the simple average crustal subsidence rate (SSR) of each evolutionary stage. The degree of roughness describes the roughness of a structural surface. It is well known that an undisturbed sedimentary bedding is smooth and horizontal, though there may be 1 to 5 degrees of inclination. A surface will be roughened by tectonic deformation, and the intensity of deformation can be approximated by the roughness of the surface. The second order polynomial trend surface derived

from a generally concave basin structural surface will always be an ellipse, from which the long trend axis is found parallel to the contemporaneous compressive stress axis, and the short trend axis manifests the extensional stress. Subsidence rate, the third parameter, will characterize the vertical component of the tectonic movement.

The tectonic evolution of western Qaidam Basin is successfully studied, though the resolution of the study is limited by the number of and intervals among the structural surfaces. Values of R show that the younger the surface the larger the value. LA of the three older surfaces are surprisingly identical, illustrated a N-S extensional stress, the youngest surface has, however, a perfectly different stress field, characterized by E-W extension, and the fourth surface shows reasonably in a transitional character. All four stages defined by the five structural surfaces have different values of SSR. The first stage, which is the oldest, has the lowest SSR, the highest one comes from the third stage and youngest stage the second.

Based on these values, the tectonic evolution of western Qaidam can be summarized as follows: From Jurassic to Miocene, the basin with slow subsidence rate and gentle deformation was

controlled by the N-S extensional stress. During early to middle Pliocene, the stress field was transitioning from N-S extensional to N-S compressive, and the deformation and subsidence were enormously intensified. Since Late Pliocene the basin gradually

died out under the N-S compression with still rather high values of roughness and subsidence. This evolution pattern is in accordance with the development of the Qinghai-Xizang Plateau.

Paper 18

Fission track analysis of Khorat Group sediments, Khorat Plateau, Thailand

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Fission track analysis of the Khorat Group on the Khorat Plateau provides important new information on the subsidence history, provenance, uplift and tectonic history of the Khorat Group which forms a potential petroleum exploration target in Thailand and adjacent areas. This work is part of an integrated basin analysis study on the Mesozoic and Cenozoic of Thailand which includes sedimentology and petrographic studies of the

Khorat Group. 13 large samples of sandstone from the Khorat Group have been analysed in a transect across the Khorat Monocline and Phu Phan uplift on the Khorat Plateau. Fission track analysis is used to constrain subsidence and inversion histories for the Khorat Plateau, an important structural element in Eastern Thailand.

Paper 19

The Bouguer gravity variation over South East Asia as derived from satellite altimeter data

CLIVE A. FOSS & JOHN SAVAGE

ARK Geophysics

A Bouguer gravity map of the marine areas of South East Asia has been created by applying water-depth corrections to the free air gravity dataset which is derived from satellite altimeter measurements. Structures within the major bounding plates of the Indian and Pacific Oceans are sharply defined. These features include the Ninetyeast and Investigator Ridges of the Indian Ocean and the Kyushu-Palau Ridge of the Pacific Ocean. The strong gravity expressions of the Java and Philippines trenches are also well defined. Over the thicker and more complex crust of the Eurasian plate the gravity signatures are less clear, although major structural trends and basin boundaries can be seen. The gravity field over the marginal seas within the area indicates that the Celebes Sea has the most uniform and clearly oceanic crust. Over the Sulu, Andaman and Banda Seas there are gravity expressions of their crustal inhomogeneity. In the Gulf of Thailand the north-south trends of the Western Basin, the Ko Kra Ridge and the Pattani Trough are all marked by gravity expressions, as are the Malay, Penyu and West Natuna Basins and the Khorat Swell and Tenggol Arch to the south. To the east the Natuna Arch, the Con Son Swell and the Mekong Basin all have clear gravity effects. The South China Sea has a complex

gravity signature of intersecting northwest-southeast and northeast-southwest trends, with gravity values increasing in an almost stepwise manner towards the inferred axis of crustal extension. Some of the sharper northwest-southeast negative gravity features to the west of the Palawan and Borneo Trenches may be due to younger grabens controlled by the same structural fabric of the underlying crust.

There are not as yet any large regional marine gravity datasets within South East Asia suitable for comparison with the satellite derived data, but such a comparison can be made between two datasets over the adjacent North-west Shelf of Australia. The major gravity features of this area correlate very well between the two datasets confirming the basic reliability of the satellite data. Anomalies over both the offshore Canning Basin and the Browse Basin are expressed in both the marine and satellite data, but there is considerably more detail in the regional marine data which suggests that the present state of satellite gravimetry is best suited for the location and delineation of major basins, but that it is not very sensitive to intrabasin structures which can be mapped with marine gravity.

(Not Presented)

Paper 20

Tectonic outline of the Sunda Shelf – a satellite gravity study

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The sea surface, in this context often referred to as the marine geoid, is affected by density variations within the Earth. Geologic features of high density, e.g. seamounts or basement highs, will produce bulges in the marine geoid, whereas features of low density, e.g. trenches or sedimentary basins, will produce depressions. Thus, the sea surface will act as a gravity meter. High precision measurements of the marine geoid with satellite radar altimeters started already in the 1970's, but it was not until a few years ago it was realized that the measurements along the satellite tracks can resolve undulation as short as 5 to 10 km with a precision of 1–2 cm. This is equal to approximately 1–2 mgal when converted to gravity units. Depending upon the distance between satellite track the overall anomaly resolution of gravity

maps computed from satellite altimeter data is in the order of a few tens of kilometers. The structural outline of the Sunda shelf is based on sea surface undulations computed from radar altimeter data from three satellites. Long wavelengths ~50–200 km, where processed in order to study regional undulations. The overall noise level has been estimated to about 2.5 cm, which equals 0.4 to 1.5 mgal in the regional satellite gravity field.

The regional satellite gravity field of the Sunda Shelf reveals major density variations. Gravity lows are found, as expected, over the Malay, the Ho Chi Minh and West Natuna basins. The Mekong basin, which is shown to consist of at least three subbasins, is outlined by negative gravity values, too. The most pronounced gravity low is found over the Cay Dong Basin west

of Vietnam. The extension of this negative anomaly suggests an onshore continuation possibly related to the Mekong Basin, although the strong gravity gradient of this low does not exclude a different origin. The gravity high separating the Cay Doung and Malay basins, may be the prolongation of the Nan River Suture Zone. This density high, presumably consisting of ophiolitic mafic and ultra-mafic rocks in an arc setting with metasedimentary rocks, extends in a southeasterly direction

forming the northeastern border of the Malay Basin. The Conson Density High, which separates the Mekong and the Ho Chi Minh Basins in the south, could be an extension of the Nan River Suture Zone, disrupted and offset by north-south strike-slip movements. The West Natuna Basin is separated from the Sarawak Basin by a density high identified as the Natuna Arch. The eastern border of the Sunda Shelf is demarked by the most pronounced density high in the area, possibly related to the Mesozoic Andean Arch.

Paper 21

Structural trap styles of the Malay Basin

MOHD. TAHIR ISMAIL AND KURT W. RUDOLPH
Esso Production Malaysia Inc.

The Malay Basin has experienced three major tectonic events: Middle to Late Oligocene extension, Middle to Late Miocene compressional inversion and Pliocene through Recent extension. The superposition of these events has resulted in a variety of structural trap styles including basement-supported and non-basement-supported traps. Six trap styles within proven play areas and trapping commercial hydrocarbons in the Malay Basin are described.

Basement-supported traps occur on the basin flanks and are dominated by extensional deformation. The simplest traps are *anticlinal basement drapes* which result from compactional drape over basement highs. These traps occur on basement arches that separate extensional sub-basins of the basin flanks. *Basement-supported fault closures* and associated anticlines resulted from normal-fault displacement and block rotation during extensional deformation. These structures are comprised of faulted anticlines, high-side fault-dependent closures, low-side fault-dependent closures, and low-side fault-bend fold anticlines.

Non-basement-supported traps occur predominantly in the central portion of the Malay Basin and are related to

compressional inversion and associated faulting. The most common traps are *asymmetrical compressional anticlines*. These traps are strongly elongated east-west and result from inversion of antecedent Oligocene half-grabens. These structures are usually cored by high-angle reverse faults beneath the steeper flank and have normal faults oriented either orthogonal or oblique to their long axis. *Symmetrical to slightly asymmetrical compressional anticlines* are generally broader, and more equi-dimensional than asymmetrical compressional anticlines. They occur predominantly in the deepest portion of the basin and are dissected by large north-south oriented normal faults. *Non-basement-supported fault closures* are low-relief structures that resulted from mild antiformal compression and are segmented by orthogonal (north-south) normal faults. Finally, *anticlines and fault closures associated with north-south normal faults* also occur. They are comprised of high and low-side fault closures and anticlinal fault-bend folds. These traps are usually elongated in the north-south direction and are associated with north-south fault trends that may have complex *en echelon*, splay or antithetic-synthetic relationships.

Paper 22

Thermal studies in oil basinal areas of Indonesia

SANDJOJO SUBONO & SISWOYO

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The influence of heat flow in hydrocarbon maturation has been evaluated. Two extreme cases of basin were observed: the Central Sumatra basin, a hot back-arc basin in which the average heat flow is high (127 mW/m²), and the Natuna basin, a relatively cool intra cratonic basin, where the mean heat flow value is less than 80 mW/m².

The measured heat flow values have been correlated with age of the last tectono-thermal event, other geophysical, geological and geochemical information. A numerical model is then applied to quantify the rate of sedimentation, subsidence history, source rock maturity, direction and rate of hydrocarbon migration.

The model is based on thermal and lithostratigraphic data. Heat transfer is described using a numerical one dimensional method of finite difference, and is developed to allow the quantification of organic matter maturation by entering the heat flow factor (HTFI).

The explicit presentation of heat flow in the HTFI formula enables us to differentiate two neighbouring wells with the same lithology but have different heat flow value. In this case, the depth to the oil ceiling in each well should be different.

Empirical manipulation has been made to describe the relationship between heat flow and the depth to the top of early maturation zone, using exponential fit and linear regression approach.

From several resulted cross sections showing the relationship between heat flow and tectonic setting, it is discovered that the heat flow values of the basement high in the Central Sumatra basin are generally higher than those in the depression zone. The inverse of that is recognized in the Natuna basin, where the basement highs exhibit relatively lower heat flow values compared with those of surrounding lows.

Paper 23

Development of the Sorong Fault Zone region, Eastern Indonesia

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The Sorong Fault Zone (SFZ) is a major left-lateral system separating Australia from the Philippines Sea Plate and the

Molucca Sea. The fault zone juxtaposes continental, ophiolitic and arc rocks of Australia and Pacific origin. New

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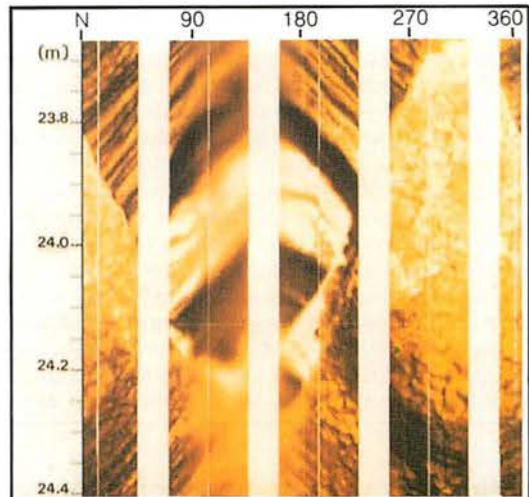
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Formation imaging using microelectrical arrays has benefited the oil industry since its introduction in the mid-80s. The FMI*, Fullbore Formation MicroImager tool, is the latest-generation electrical imaging device. It belongs to the family of imaging services provided by the MAXIS 500* system with its digital telemetry capability.

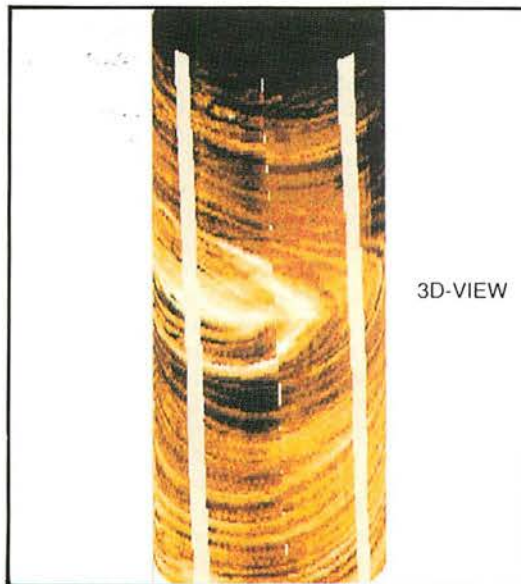
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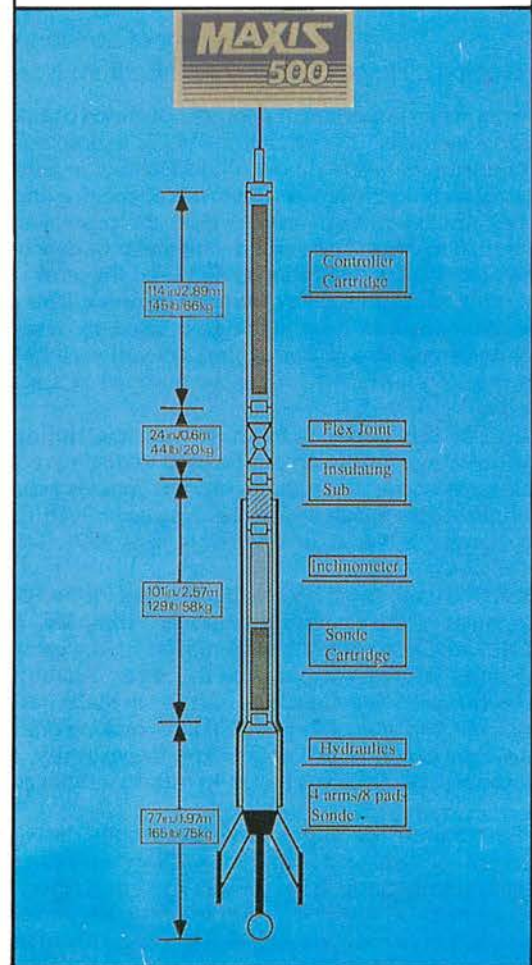
The tool's multiple logging modes allow wellsite customization of results to satisfy client needs without compromising efficiency.



Fault without associated drag



"Bullseye" structure



palaeomagnetic and geological results provide evidence of the history of their amalgamation.

Continental crust in the SFZ was derived from the Australia margin. Many reconstructions show westward translation of fragments from New Guinea by strike-slip faulting but an alternative possibility is separation from Australia by Mesozoic rifting. Cretaceous rocks from Sula record counter-clockwise rotations with palaeolatitudes suggesting that microcontinental fragments were far north of the Australian margin in the late Mesozoic. Tertiary movements of Australia northwards has caused accretion of these fragments to the SE Asian margin.

Pacific crust has a basement of ophiolitic and arc rocks. Ophiolites are remnants of an early Mesozoic intra-oceanic arc rather than Pacific ocean floor. They are overlain by, and imbricated with arc volcanic and sedimentary rocks of Late Cretaceous-Eocene age; arc plutonic rocks intrude the ophiolites. This arc is correlated with the Paleogene arc of New Guinea, parts of the eastern Philippines, and ridges of the north Philipines Sea. A regional unconformity at ~45 Ma corresponds to Pacific Plate reorganization event. Older rocks are overlain by shallow water Eocene limestones and an Oligocene extensional sequence

including basaltic pillow lavas and volcanoclastic turbidites. Fragments of Australia and Pacific origin have a common stratigraphic history after the early Miocene.

Rocks of Pacific origin formed at low latitudes. Our data suggest southward translation until ~25 Ma and northward translation during the Neogene. Areas north of the SFZ show clockwise rotation with the Philippines Sea Plate. Rotation appears discontinuous: we interpret a total rotation of ~90 since ~50 Ma as ~45 at ~45 Ma with a further ~45 after ~25 Ma. Composite islands within the SFZ include continental, arc and ophiolitic rocks recording latitudinal shifts similar to the Philippines Sea Plate and both counter-clockwise and clockwise rotations interpreted as block movements in the left-lateral SFZ.

These results indicate Pacific-Australia arc-continent collision at ~25 Ma and creation of the SFZ. Subsequent Neogene convergence north of the SFZ occurred by subduction. In contrast, Neogene movement of Australia northwards has occurred without subduction although accompanied by movements of small fragments and local 'collisions'. This implies northward movement of the plate boundary in the SFZ region at a similar rate to that of Australia.

Paper 24

The timing and tectonic significance of mélangé formation in Eastern Sabah, Malaysia

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Mélanges are an important, if poorly understood component of many orogenic belts. In the circum-Pacific region, mélangé formation appears to be an almost ubiquitous accompaniment to subduction-accretion processes: so much so the presence of a melange belt has often been used to infer the presence of an ancient subduction zone. The definition of mélangé depends on the scale of observation. Hamilton (1979) used the term almost interchangeably with subduction-accretion complex. This usage should be avoided, and here mélangé is used to describe a chaotically-deformed assemblage of blocks of various lithologies in a more ductile matrix, which can be mapped at a scale of 1:25000 or less.

The aim of this paper is to show how the timing and processes of mélangé formation can be used to distinguish, and in some cases reconcile, the various tectonic models proposed for the evolution of the Sabah region (e.g. Hutchison 1988, Rangin *et al.* 1990, Rangin, Silver *et al.* 1991, Daly *et al.* 1991, Tongkul 1992)

In western Sabah, small bodies of mélanges formed during the development of the Crocker accretionary complex. In the east of Sabah, a much larger mélangé terrain is found, a composite of several units known variously as the Ayer, Kuamut and Garinono Formations. Together these East Sabah Mélanges cover an aggregate outcrop area of some 12000 km², making one of the largest melange terrains in the world. Importantly, these mélanges cannot be linked directly to subduction-accretion processes.

The East Sabah Melanges have been considered as a composite unit (Tahir and Tan 1986). New mapping and biostratigraphical data has generally confirmed this interpretation, but also shows the complexity of the processes of mélangé formation (a combination of slumping, diapirism and tectonic disruption; Clennell 1992). The three-fold subdivision into Ayer, Kuamut and Garinono Units can be retained usefully in a modified form, because these names refer to geographical domains in which lithologically different, but stratigraphically equivalent, sedimentary units were disaggregated to form the melanges. The differences in melange block types, matrix types and structure reflect the differences in the bed thickness,

mechanical competence and bulk composition of the sedimentary and igneous units which formed them. Examination of the mélanges, and the surrounding coherent rocks, shows that the mélanges formed in a composite basin (known as the Central Sabah Basin in Hutchison 1989) floored by faulted and deformed ophiolitic and magmatic arc basement.

New constraints on the biostratigraphy and lithostratigraphy of eastern Sabah have enabled the time of formation of the mélanges to be constrained more accurately than before. The time of formation correlates exactly with the Deep Regional Unconformity (*sensu* Levell 1987) offshore western Sabah, as suspected by Hutchison (1988). This unconformity is now believed to be a result of uplift as a consequence of collision of the Dangerous Grounds block with the Northwest Sabah margin (shown by seismic surveys of Hinz *et al.* 1989). These collision is too distant to explain all the features of the Sabah Mélanges, however, a consequence of the block collisions was to effect processes in the Sulu Sea. The direct trigger for the formation of the Sabah mélanges was accelerated spreading in the southeast Sulu Sea which led to rifting in Sabah. Indeed, eastern Sabah was a part of the Sulu Sea basin at the time the melanges formed (Hutchison, pers. comm., 1990). Since this time the Sabah Basin has become isolated, probably by the propagation strike-slip faults in the Upper Miocene (Hinz *et al.* 1991) and so has uplifted rapidly to its present position. The amount of burial and uplift is recorded in the geological structures, and in the organic matter and clay mineralogical maturity, of the eastern Sabah sediments.

During uplift the mélanges were remobilised, during diapirism and faulting, and as a result foundering of sandy Tanjong Formation sediments deposited in the so-called circular basins. This shows the inherent gravitational stability of large volumes of incomplete lithified, mud-rich sediments. The mélanges were also overthrust by, and imbricated with the upper levels of the Sabah ophiolite in a number of localities, and in the south of Sabah imbricated with a sequence of Neogene volcanoclastic sediments. These later deformations attest to Upper Miocene north-south compression in eastern Sabah, possibly as a result of rearrangement of subduction polarity beneath the Sulu Archipelago (Rangin, *et al.*, 1991).

This paper outlines work carried out in the Sabah area as part of a Ph.D. project on the origin of mélanges. This work was sponsored by Shell International under the supervision of Dr.

Tony Barber of London University and Dr. Felix Tongkul of University Kebangsaan Malaysia (Sabah).

Paper 25

Basin reactivation associated with the mid-Cenozoic initiation of subduction, Taranaki, New Zealand

P. R. KING, J. M. BEGGS, T. A. STERN, G. P. THRASHER, & R. A. WOOD

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The concept that incipient subduction processes influence basin development is applied to Taranaki Basin. It may also be applicable elsewhere in the western Pacific, where many basins occur in the vicinity of subduction zones.

Taranaki Basin, which contains all of New Zealand's producing oil and gas fields, initially formed as a series of rift basins associated with the breakup of the Gondwana supercontinent at the end of the Cretaceous. In the early Cenozoic, a subsiding landmass to the south and east was flanked by a mainly transpressive clastic system. Geohistory analysis of well sequences shows that tectonic-induced rates of subsidence within the basin began to increase from about the late Eocene, and accelerated in the mid Oligocene. The shoreline advanced across the basin margins, causing a virtual termination of clastic sediment supply by late oligocene times and consequent deposition of carbonate sediments in both shelf and bathyal settings. Clastic supply resumed in the early Miocene, resulting in depocentre infilling and sediment progradation across the basin.

We envisage that the mid Cenozoic subsidence in Taranaki

was driven by incipient subduction of the Pacific Plate beneath the northern New Zealand region. Two possible mechanisms are considered. One is hydrodynamically-linked platform subsidence of a wavelength in the order of 700–1000 km. The alternative involves a mechanical coupling between the Australia and Pacific plates resulting from shear stresses at the subduction thrust, in a manner similar to that proposed for Plio-Pleistocene subsidence within the adjacent South Wanganui Basin. This subsidence has a wavelength of around 200 km. A foreland thrust-loading model for initial mid Cenozoic subsidence in Taranaki Basin is discounted, judging from the sedimentary facies and subsidence history of areas bordering the basin. However, early subduction-related subsidence with wide regional extent was later accentuated within Taranaki by west-directed thrust loading in the early to mid Miocene, by which time subduction was well-established to the northeast.

All known hydrocarbon accumulations in Taranaki Basin are trapped in Neogene structures that formed in intra-arc or behind-arc settings with respect to Pacific Plate subduction.

Paper 26

Tertiary tectonic evolution of the NW Sabah continental margin

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The NW Sabah continental margin can be sub-divided into 6 tectono-stratigraphic provinces on the basis of differences in structural styles and sedimentation histories: (1) Rajang Group Fold-Thrust Belt, (2) Inboard Belt, (3) Baram Delta, (4) Outboard Belt, (5) NW Sabah Trough and (6) NW Sabah Platform.

The Tertiary sedimentary sequence was deposited during two main phases of basin development:

- (1) A pre-early Middle Miocene phase of generally deep-marine clastic sedimentation.
- (2) A post-early Middle Miocene phase of clastic shelf/slope deposition, which prograded northwestward over the underlying sediment wedge and is separated from the latter by a major regional unconformity.

Evidence for Palaeogene subduction of South China Sea oceanic crust beneath NW Sabah is incomplete. The subduction hypothesis (Hamilton, 1979) is based on the following main elements:

- (1) The Rajang Group Fold-Thrust Belt of turbidites and associated ophiolites, interpreted to represent an accretionary prism.
- (2) The sub-linear NW Sabah Trough, interpreted to represent the sea-bed expression of a subduction trench.

A major missing element in this hypothesis is a volcanic arc of the correct age.

Factors suggesting a trench orientation which is non-conformable with the NW Sabah Trough are:

- (1) The Baram Delta Toe Thrust Zone which shows features that strongly suggest present-day activity as a result of gravitational tectonics. This zone had previously been thought related to subduction, but is now ascribed to delta tectonics.

- (2) Sudden termination of both the NW Sabah Trough and the West Baram Delta against the Luconia Block, whereas the Rajang Group Fold-Thrust Belt extends southward into Sarawak. The Trough becomes less well expressed towards the Palawan area.
- (3) Extensive NNE-SSW oriented left-lateral wrench tectonics of the Inboard Belt.
- (4) Extensive offshore protrusion of the Rajang Group Fold-Thrust Belt (thrust-sheet complex, Hinz, 1989) along the axial plane of the sharp inflection of the structural strike of the Rajang Group Fold-Thrust Belt (NNE oriented 'NW Borneo Trend' to ESE oriented 'Sulu Trend').

The geodynamic interpretation of the observed relationships is that of a Palaeogene subduction system broadly parallel to the structural strike of the Rajang Group Fold-Thrust Belt. The NW Sabah Trough represents the downfaulted southeastern margin of the NW Sabah Platform, overlain to the southeast by the Baram Delta Toe Thrust and the Rajang Group thrust sheet complex. The inboard Belt wrench tectonics trend parallel to the postulated trench (cf. the Semangko fault of the Sumatra subduction system) as a result of oblique subduction. Counter-clockwise rotation of Borneo from Eocene to Middle Miocene resulted in increasingly oblique subduction. The Baram Delta sediment prism masks the Palaeogene trench, which becomes inactive further south.

The following four-stage model for the tectonic evolution of the NW Sabah shelf is proposed:

- (1) Late Eocene to early Middle Miocene oblique subduction of South China Sea oceanic crust beneath NW Sabah with deposition and subsequent imbrication of deep-marine sediments into an accretionary prism.

- (2) Collision of the South China Sea attenuated continental crust with Sabah, and cessation of ocean-floor spreading in the early Middle Miocene, led to regional uplift and erosion of the accretionary prism, resulting the Deep Regional Unconformity. This was followed by northwestward progradation of clastic sediments over the Inboard Belt from Middle Miocene to early Late Miocene.
- (3) Resumption of convergent forces between Borneo and the NW Sabah Platform in Middle late Miocene was accompanied by major tectonic activities. The Inboard belt

was subjected to strong compressional deformation associated with major N-S wrench zones, resulting in the Shallow Regional Unconformity. Two new depocentres were formed seaward of the Inboard Belt: the Baram Delta and the Outboard Belt.

- (4) From Late Miocene to Recent, a thick prograding clastic wedge built out towards the northwest in both depocentres, whilst the Inboard Belt was continuously eroded. A Late Pliocene phase of locally developed deformation affected the Inboard Belt, Outboard Belt and Baram Delta.

Paper 27

The role of advanced seismic interpretation in development planning for the Kinabalu Main Field, offshore NW Borneo

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The Kinabalu Field was discovered in early 1989 about 80 km off the west coast of Sabah, NW Borneo. Hydrocarbons are trapped on the downthrown side of a major growth fault in a very simple monoclinical structure with no known internal faulting. The Miocene siliciclastic reservoir sequence comprises extensive shallow marine sands and shales. By a combination of structural simplicity and extensive lithology, many shales form field-wide seals and create a complex fluid system with numerous separate hydrocarbon accumulations.

Despite the generally favourable aspects of the field, the benefit of reducing uncertainties in structure, reservoir and aquifer quality and extent as well as fluid distribution and properties prior to designing a major development plan was recognised. This led to an appraisal campaign consisting of a well which was extensively logged, cored, and tested, and the

acquisition of a 3D seismic survey. This data set provided a sound basis for detailed Petroleum Engineering studies. In particular, interpretation of the 3D seismic data beyond structural information has confined initial uncertainties.

The paper discusses the contribution of advanced 3D seismic interpretation to integrated Petroleum Engineering studies for field development planning. The techniques used to define gross bulk volume and related uncertainties, to determine initial fluid contacts and to quantify the reservoir and aquifer development are highlighted. The conclusion from this work is that detailed 3D seismic studies can give a valuable contribution to development planning at an early stage in the field life, by providing data that would otherwise only be obtained by additional appraisal wells or from production history at a later stage for the field life.

Paper 28

Structural framework and hydrocarbon potential of the Southern Sandakan Basin, Eastern Sabah, Malaysia

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The Sandakan Basin is the largest and southernmost of the three basins in the southwest Sulu Sea. The basin covers more than 40000 km², mostly offshore, and possesses up to 6-8 km of mainly Lower Miocene to Recent sediments.

The Sandakan Basin has a complex Tertiary tectonic history including several episodes of subduction and volcanic arc formation, probable obduction in onshore areas of Sabah, punctuated compression and transpression, and periods of extension and growth faulting.

The Southern Sandakan Basin can be divided into three diverse structural provinces separated by major tectonic dislocations. There is evidence from structural orientations in the three provinces of at least 45° of counterclockwise rotation of this area since the Oligocene. A stable but episodic north-northwest to south-southeast oriented compression appears to have been active during this rotation.

Deltaic sedimentation with outer-shelf reef growth dominated the Upper Neogene, and ubiquitous reservoirs and intraformational seals characterise this interval. Source rocks are dominantly terrestrial, and are similar to those in the Baram and Mahakam deltas elsewhere in Borneo. They are believed to be both oil and gas prone. There are at least three source kitchens in the basin, the largest and most prospective lying some 50 km

east-northeast of Sandakan.

Hydrocarbon exploration has been confined to 15 wells. Gas, condensate and light oil flowed from two wells in the southern sector. Two other wells in this sector could not be tested due to problems with overpressuring, but seismic evidence suggests that at least one of the two was located in a large hydrocarbon accumulation. A further three or four wells has oil and/or gas/condensate shows. Poor seismic data quality at the time of drilling (predominantly 1970 to 1975) resulted in at least 10 of the 15 wells being invalid tests. Modern seismic data reveals a host of new structural play types, and indicates the potential for downflank or more optimally located updip wells in compartmentalised structures which have already been drilled. Other plays include large stratigraphic features basinward of the Upper Miocene delta fronts.

Strong affinities in stratigraphic and structural style are observed between the Baram Delta and Sandakan Basin, particularly in the presence of structures at the intersection of growth faults and folds, where most Baram Delta oil fields are located. This, and the fact that the equivalent late Miocene section which is oil productive throughout Borneo is yet to be tested in a valid trap, suggests that the Sandakan Basin could become a significant hydrocarbon producing province.

Sequence stratigraphy of the Middle Miocene-Pliocene, southern offshore Sandakan Basin, Eastern Sabah, Malaysia

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The southern Sandakan Basin may be divided into three structural provinces. The northern province is characterized by north-south growth faults, the central province by wrench related northeast-southwest flower structures and the southern province by a zone of relatively unstructured sediments. A sequence stratigraphic study of the Middle Miocene to Pliocene section within these provinces resulted in the recognition of numerous Type 1 sequence boundaries. They are usually identified by landward truncation and associated onlaps in the northern and central provinces and pronounced shelf edges in the basinward southern province. The intervening sequences and their component systems tracts (highstand, transgressive and lowstand) have been regionally correlated from landward coastal plain to basinward bathyal facies.

The study has resulted in the identification of three units, each bounded by Type-1 third-order sequence boundaries and comprising one or more sequences. Unit 1 (Middle Miocene-Lower Late Miocene) is defined by moderate progradation, moderate aggradation, thick but areally restricted shelfal deposits, steeply-dipping oblique-sigmoidal clinoforms, well-defined basal onlaps and pronounced shelf edges. Unit 2 (Middle Late Miocene) is characterised by high progradation, low aggradation, thin but areally extensive shelfal deposits, gently-dipping shingled- sigmoidal clinoforms, well-defined toplaps and pronounced shelf edges. Unit 3 (Upper Late Miocene-Pliocene)

is represented by high aggradation, low progradation, thick shelfal members and sigmoidal clinoforms, and lacks shelf edges.

The positions of the prominent Unit 1 and 2 shelf edges indicate a progressive progradation towards the southeast. Later Pliocene progradation is probably towards the east as suggested by N-S growth faults in the northeastern part of the study area, and is interpreted to have occurred within a ramp setting.

Comparison of the locally derived coastal onlap chart with a recognized global sea-level chart highlighted some differences. The main difference is major Upper Miocene progradation in the study area versus Upper Miocene aggradation in the global sea-level chart, testifying to the importance of the interplay between local tectonics and sedimentation rates in individual basins.

The sequence stratigraphic interpretation led to the recognition of two leads in the southern province, both associated with lowstand system tract sediments. The first is a slope fan deposit in Unit 1, and is interpreted from a high amplitude event with associated gull-wing features onlapping the sequence boundary at the slope setting. The second is a basin floor fan in Unit 2 identified by gently mounded seismic events with bidirectional downlaps, located on a sequence boundary in a basin floor setting. Both are considered potentially attractive targets for petroleum exploration but require further definition for detailed mapping.

Geology of the Bayah area: implications for Tertiary evolution of West Java, Indonesia

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The geological setting of the Bayah area in the Paleogene is indicated by the presence of alternating sedimentary and volcanic rocks. The sedimentary rocks consist of the fine to coarse clastic sediment, which suggest, as a result of the regressive conditions, were deposited in a shallow basin. In the Neogene time sediments with open marine characters and contemporaneous volcanic rocks were deposited in the transition area at the southern border of the basin. The clasts of Neogene sedimentary rocks were derived from a southern source area. The boundary between the Paleogene and the Neogene sequences is characterized by an unconformity which indicated in the field by an erosion surface. Three further tectonic phases can be recognized in this area. They occurred in the Late Paleogene, Late Middle Miocene and Latest Miocene age.

The Tertiary volcanic rocks can be divided into a lower sequence of Late Eocene to Early Oligocene age (LOA) and upper sequence of Oligocene to Miocene age (UOA). All the rocks,

except for one sample from the LOA, are rocks typical of a calc-alkaline island arc. The LOA consists of basalts and basaltic andesites with characteristics that suggest a more primitive magma than those the UOA. The LOA rocks probably correspond to fractional crystallization and contamination, with component of low-Th concentration, of intermediate lower crust. The LOA was generated in the fore-arc region and appears to be related to a period of slower subduction. The UOA, which range from basalt to rhyolite composition, correspond to an increasing of the differentiation processes. They experienced contamination of the parental magma with terrigenous sediment and occur in the high levels in the crust.

The evolution of this area is strongly influenced by the motion of the Indian Plate, colliding with the Eurasian Plate. During the Paleogene the area was situated in the fore arc and in the Neogene was located in the transition area between back arc and volcanic arc.

Hydrocarbon habitat in offshore Southeast Asia: comparison between the Mekong, South Con Son, Natuna and Malay Basins

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Hydrocarbon exploration in the Tertiary basins of the South China Sea has been conducted since 1968. This has resulted in

the discovery of over 3.5 billions barrels of recoverable oil and 20 TCF of gas in some 38 major oil gas fields. About 70% of these

reserves are located in the Malay Basin, 14% are in the Natuna Basin, 8% are in the Mekong Basin and 8% are in the South Con Son Basin. Some 20% of the total oil reserves have been discovered since 1989, suggesting that despite the long history of exploration in the basins there is still scope to discover further significant reserves.

The tectonic history of the South China Sea can be split into 2 phases: pre-Tertiary and Tertiary. During the Palaeozoic and Mesozoic, rifted fragments of Gondwanaland amalgamated to form South East Asia which collide and sutured to South China. In the Tertiary phase: India collided with Eurasia; Australia moved northwards and collided with the Pacific plate; and the Pacific/Philippines plate moved westwards and subducted below Eurasia. The consequences of these plate interactions are a complex assemblage of strike-slip faults, extension, inversion, subduction and seafloor spreading. The Malay, Natuna, South Con Son and Mekong basins are interpreted as Oligocene rifts formed by extension within a strike-slip regime. Structural development was influenced by pre-Tertiary trends, especially suture zones, and was modified by continued tectonic movement throughout the remainder of the Tertiary. Structural features in the South China Sea basins are generally consistent with a dextral strain ellipsoid.

The Tertiary stratigraphy of the South China Sea can be correlated in broad terms between the basins. Two components are identified: an Oligocene synrift megasequence and a latest

Oligocene to Recent postrift megasequence. In the Mekong and South Con Son Basins two synrift sequences are identified. The postrift can be divided into three sequences in all the basins by a top Oligocene/early Miocene transgression and a mid-Miocene unconformity. The transgression represents a major regional sea-level rise; the unconformity is the result of a structural inversion which reaches a maximum in West Natuna and decreases progressively into the South Con Son, Mekong and Malay basins.

Hydrocarbon plays in the South China Sea basins are comprised of similar components; knowledge of the variations and controls on these components, between and within basins, is key to understanding the hydrocarbon habitat. Lacustrine algal source rocks are developed in the synrift. Postrift sources include oil and gas-prone mudstones and coals deposited in a lakeshore/coastal plain environment and an oil-prone algal source. Source rocks tend to be interdigitated with reservoirs. Synrift reservoirs include fluvial and alluvial sandstones. Reservoirs are also developed in basement wash and fractured basement in the Mekong basin. Postrift reservoirs consist of fluvial, lacustrine deltaic and shallow marine sandstones. Some 80% of the discovered oil is in Early Miocene and latest Oligocene postrift sections. Traps include inversion anticlines, hanging wall and footwall tilted fault blocks, faulted anticlines, hanging wall rollovers and drape structures. Traps typically involve stacked reservoirs with complex fluid contacts.

(Not Presented)

Paper 32

Hydrocarbon generation from peat? Comparison of rock-eval pyrolysis data from cold-temperate and tropical peats and coal

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Rock-eval pyrolysis was used to examine differences in the hydrocarbon content of woody and herbaceous peat types forming from different plant communities under different climatic settings. The objective was to determine properties inherited from the peat phase which might influence the occurrence and distribution of hydrogen-rich vitrinites observed in many coal seams which are thought to provide a source of oil. The sample suites (n=41) came from vertical profiles in 2 Holocene peat deposits with ash contents <5%: a 6 m peat in Bruce Bay, South Island, New Zealand and a 12 m peat in the Baram River area, Sarawak, East Malaysia. Random vitrinite reflectance ranges from .23 to .40, increasing with decomposition and decreasing moisture content (from 95 to 85%). To determine hydrocarbon potential, the results were compared to rock-eval data from Pleistocene-Holocene Chatham Island peat known to produce wax (n=8) and from Pliocene to Oligocene coals (n=14; Rv=.4-.6)

from Indonesia. For the peat, S1 peaks ranged from 4 to 59, S2 from 49 to 230, S3 from 29 to 126 mg HC/gm; TMax ranged from 389 to 423°C. On average no significant trends could be observed between general peat types, but the more herbaceous New Zealand peats yielded larger S1 peaks than the woody Sarawak peats. On a HI/OI plot, all peats straddled the Type III kerogen line, with more samples plotting above the line. More interesting differences occurred between the peats and coals. All peats contained more free hydrocarbon (S1) and CO₂ (S3) than the coal, but less pyrolyzable hydrocarbon (S2), except for the lignite. On a plot of S1 to S1+S2, all peats show a direct correlation between free and total hydrocarbons, but the coals show no correlation and fall beneath the 10 mg HC/gm S1 line. The drop in magnitude of free hydrocarbons (from 5-60 to <10) from peat to coal suggest that an abundance of easily generated hydrocarbons are lost during early burial and before thermal maturation.

Paper 33

Terrane analysis and tectonics of the Nan-Chantha Buri Suture Zone

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The Nan-Chantha Buri Zone in eastern Thailand has been interpreted to mark a continental suture zone between the Shan-Thai and Indochina cratonic terranes located to west and east respectively. Recent detailed geological, paleontological and

petrological studies have shown that the zone is identified as a serpentinite mélange zone.

The Indochina terrane bounding the eastern side of the suture zone is composed of coherent units such as volcanic-arc

sequences and calcareous sediments on a continental shelf. On the other hand, the western margin of the Shan-Thai terrane bounding western side of the suture zone is composed of chert clastic sequence consisting of chert unit occasionally accompanied by greenstone and coarse clastic unit in ascending order. The sequence is tectonically piled up to form an imbricate structure. Because of this geologic structure, chert unit and coarse clastic unit alternately occur. This subterranean of the Shan-Thai terrane was formed by successive offscrape-accretion mainly during Late Triassic time.

Characteristic "rock mixture" of chaotic and "block in matrix" fabric are found in the Nan-Chantha Buri suture zone. Eastern part of the zone is mainly composed of large blocks of Middle and Late Permian limestone and chert. Middle part of the zone consists largely of sheet-like bodies of metamorphic rocks. Western half of the zone is a typical serpentinite mélangé zone and is characterized by chaotic complex which are complicated admixtures incorporating a great variety of rocks of oceanic, island-arc and continental affinities and of various ages. The geochemical data of the basaltic rocks

indicate that they are remnants of ancient oceanic crust. Fusulinids of eastern side of the zone are representative assemblage found in Cambodia and those of eastern side are comparable to fusulinids in Sara Buri. Most of radiolarian fossils extracted from red chert blocks indicate Early to Late Permian age. Zircon U-Pb dating was carried out on one granitic rocks from the melange zone. The four data points define a discordia yielding an upper intercept date of 486.5 ± 5 Ma, which is Early Ordovician.

Rocks in the suture zone generally dip toward the west and stretching lineations generally plunging towards the west are observed. The kinematic indicators such as a partially rotated pebble and an asymmetric microstructure have been observed in outcrops and thin sections made parallel to the stretching lineations. The sense of rotation determined from these structures is regionally from west to east.

From these facts, it is concluded that the Indochina and Shan-Thai terranes separated from Gondwanaland at different time respectively, and their amalgamation may have occurred near the edge of the Eurasian Continent during Late Triassic.

Paper 34

Australia-Philippines cooperative marine seismic and sniffer survey in four Philippine offshore sedimentary basins

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During March-May 1992, the Australian Bureau of Mineral Resources (BMR) and the Philippine Office of Energy Affairs (OEA) conducted a joint marine seismic and sniffer survey in four Philippine offshore sedimentary basins. A total of 2750 km of 192-channel seismic and geochemical sniffer data, plus gravity, magnetic and bathymetric data was obtained. This was comprised of 580 km in NE Palawan Shelf and 730 km over the Cuyo Platform; 490 km in Tayabas Bay and 950 km in Ragay Gulf. Work in Ragay Gulf was so difficult that shooting was suspended at night. This was due to the coastal areas being so densely fished at night that BMR's research vessel, *Rig Seismic* could not safely enter these areas after dark. During these hours the geochemical sniffer programme was continued over identified anomalies and an additional 2300 km of sniffer, gravity and bathymetry data were recorded.

The ship-board seismic monitors have shown many faults and folds, and deep depocentres with up to 4-6 seconds of stratified section. All seismic data were recorded within specifications, so the quality of the processed sections is expected to be excellent.

Geochemical anomalies were recognised in the NE Palawan

Shelf and Ragay Gulf. These were particularly significant in Ragay Gulf and were related to (1) previously identified prospects, (ie. R-1 and R-2 in the OEA-World Bank Report, and the Alibijaban prospect identified in Far East Resources and Command's Reports), (2) faults and (3) deep diapir structures. They fall into two distinct anomaly types; type 1 is characterised by high methane, ethane and propane with traces of butanes and pentanes, indicating dry to wet thermogenic gas; type 2 consists of high methane and traces of C₂₊, indicating very dry gas.

In order to better understand the flux rate of hydrocarbon release and the component fractionation and magnitude of the source of the seep, we revisited Ragay Gulf after seismic shooting was completed, and sampled eight geochemical vertical profiles and obtained 28 gas samples for isotope analysis.

The newly acquired data will be processed in BMR, integrated with existing seismic and well data from previous industry sources, interpreted and analysed for petroleum potential. The final analysis, together with basic data will then be presented to the exploration industry, initially in the Philippines and Australia, and later internationally, in order to promote further exploration.

Paper 35

The Tertiary tectonic evolution of Southern Sumatra, Indonesia

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Physiographically the southern part of Sumatra can be divided into four zones, from the west to east: Mentawai, Bengkulu, Bukit Barisan and Jambi-Palembang Zones. They are trend northwest-southeast. These zones have been established as a result of the subduction activities during Tertiary times. They occurred since the (middle) Paleogene from the southwest produce a different tectonic setting for each zoning.

The Mentawai Zone is a non-volcanic arc, occupied by the Oligocene-Miocene mélangé complex and fine to coarse clastic "trench" sediments. The Bukit Barisan range is a continental,

volcanic arc which was formed by the subduction of the Indian-Australian Plate to the Eurasian Plate. The volcanic rocks of this range are characterized by andesitic to basaltic compositions, typical of a calc-alkaline island arc setting. Between the Mentawai Zone and Bukit Barisan range is the Bengkulu Zone which comprises of turbidite sequences of the fore arc region. East of the Bukit Barisan range is the Jambi-Palembang Zone. This zone is characterized by the transgressive and regressive sedimentary rocks deposited in back arc basins. The Bengkulu and Jambi-Palembang Zones have a good hydrocarbon potential.

Oil quality variations in the Malay basin — geochemical insights

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Malay Basin oils are largely sourced from non-marine organic matter in depositional environments ranging from older, algal dominated assemblages to young, coal-swamp related mixtures of terrigenous organic detritus. These source environments generate low sulphur oils which are generally rich in wax. In the producing fairway of the Malay Basin, oils are of relatively high maturity having API gravities in the 45–50° range with pour points generally -10°C to +20°C. Recent drilling on the northern flank of the basin has identified some crudes with API gravities as low as 20° and pour points as much as +42°C.

Petroleum geochemistry has been applied to a wide range of these crudes and several groups are recognized based on the interplay of source type, maturity and biodegradation. Some oils on the northern flank are of lower maturity and therefore more waxy, others are partially biodegraded and have had their heavy waxes negatively enriched by this process. Total wax removal has affected other oils and left them with very low API's and pour points. The occurrence of crudes with this wide variety of physical properties has an impact on the planned development of this area and attempts to predict the occurrence of particularly difficult oils can guide exploration.

Paper 37

Tectonism, magmatism and sedimentary basin development in the Mesozoic-Early Tertiary period, New Caledonia

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The paper will cover the development of the Mesozoic crust on the margin of the Australian plate, the change in nature of the volcanism during the Mesozoic, uplift and early Cretaceous deformation. Late Cretaceous transgressive coal measures are associated with bimodal volcanism typical of an

extensional environment in two sedimentary basins. Massive sulphide deposits are associated with rhyolites in one of these extensional basins. The setting and environment of the two sedimentary basins will be compared.

Paper 38

Petroleum generation in the West Aceh Basin, Sumatra

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Although various attempts have been made to evaluate the West Aceh Basin for petroleum, exploration has proven unsuccessful for assessing liquid hydrocarbon. However, studies of the organic petrology and geochemistry which might establish the origin, distribution and character of hydrocarbon source rock as well as thermal history within this basin has not been conducted.

The West Aceh Basin is a typical Indonesia Tertiary tectonically active forearc basin containing thick sedimentary rocks in which Oligocene to Pliocene coal bearing sequences

were deposited.

This study seeks to integrate and evaluate organic petrology and geochemistry data which might improve the petroleum success ratio. Therefore, a suite of coals of different rank were examined in order to evaluate the evidence of liquid hydrocarbons produced from these coals and petroleum generation within this basin. Coal petrography methods used include vitrinite reflectance, fluorescence intensity studies and maceral analysis where as geochemistry techniques used involve Rock-eval, Gas-Chromatography and Pyrolysis-GC.

Paper 39

Source rock and hydrocarbon geochemistry, offshore NW Sabah, Malaysia

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A subsurface geochemical study has been undertaken on Miocene and Pliocene sediment and hydrocarbon samples from wells in the northern Sabah subbasin of the Brunei-Sabah Basin. The objectives of this study were to identify source rock intervals and hydrocarbon families, to attempt a correlation of oils and source rocks, and to gain an understanding of the maturation and migration of the area.

All oils in the region belong to one family and characterised by the presence of oleanane and resin triterpane biomarkers. Source rocks are typically lean and dominated by vitrinite kerogens. These terrestrial kerogens dominate marine as well as

fresh water palaeo-environments. Stratigraphic variations occur in the biomarker content of the source rock extracts. These variations can be correlated between marine and fresh water environments as both are dominated by terrestrial kerogens.

The correlation of biomarkers obtained from source rock extracts and reservoir oils, indicate that essentially all northern Sabah subbasin oils have been derived from Middle Miocene sediments. Analysis of the maturation of these sediments indicates that the onset of oil and gas generation with extensive expulsion typically occurs at around 15,000 to 17,000 ft. However, early oil generation, but with no effective expulsion, can occur as

shallow as 3,000 ft. Gas but no oil also appears to be derived from the less deeply buried Upper Miocene sections.

In the outbound areas Middle Miocene-derived oil and gas has often vertically migrated up faults and fractures to charge Upper Miocene reservoirs. In the inboard areas, migration has

been primarily along Middle Miocene reservoir conduits. Inboard traps are mainly shallow and faulted such that gas is preferentially leaked to the sea-floor. This situation has led to Sabah retaining relatively little gas versus oil when compared to neighbouring Sarawak.

Paper 40

New targets for oil and gas exploration in Fiji, Solomon Islands and Vanuatu

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New work by SOPAC has shown that the same Tertiary reefal carbonates forming reservoirs for oil and gas in South East Asia are valid for hydrocarbon exploration in the arc-related basins of the South Pacific.

Earlier work by regional development organisations and by the oil industry in the 1970's and 1980's showed that the arc-related basins contained sediment thicknesses in excess of 5 km ranging in age from Oligocene to Recent. However, the basins were thought to have marginal hydrocarbon potential owing to the lack of knowledge regarding reservoirs and source rocks.

The new study shows that the growth of Miocene and Pliocene reefal carbonates exposed on the islands is closely related to eustatic sea-level changes. Consequently, reef development in shallow water conditions may have been far more widespread

than was previously thought. This is supported by new, reprocessed seismic data from the offshore basins which has revealed the presence of numerous possible reefal build-ups and resedimented mounds of similar age to the onshore Tertiary reefs. These features provide new targets for oil and gas exploration.

The hydrocarbon potential has been further improved by source rock studies. Source rocks for oil and gas (kerogen types II and III) have been sampled in Fiji and Vanuatu. Indeed the likelihood that oil has been generated in the offshore basins is confirmed by oil seeps and shows in neighbouring Tonga and in offshore Fiji. Source rock maturation modelling suggests that the top of the oil window is currently at a depth of 2-3 km.

The new reefal exploration targets and source rock potential considerably enhance the hydrocarbon prospectivity of the region.

Paper 41

Microplankton biostratigraphy in tropical Tertiary deposits of offshore NW Borneo

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The present paper reviews the potential of microplankton as a tool to date and correlate marginal to fully marine Tertiary deposits from offshore NW Borneo, and to assess the depositional environments of these strata.

Traditionally palynological investigations in tropical Tertiary deposits of SE Asia have been focused upon applying the so-called quantitative approach using terrestrial derived pollen and spores. The application of microplankton in correlations was limited and microplankton data was mainly used for calculating the microspore/microplankton ratio, a parameter to determine the relative distance towards the palaeocoast. Despite the vast amount of literature on Tertiary microplankton, information from SE Asia is rather limited. Apart from some taxonomical papers on Paleogene taxa (Matsuoka, 1981-1984), to date only one microplankton zonal scheme has been established in the Neogene

of Sumatra (Brown, 1988), whereas a zonal scheme covering the Eocene-Oligocene from Southeast Kalimantan (Brown, in prep.) is pending.

Although the published information is rather limited, it is suggested that stratigraphical ranges (LADs and FADs) of cosmopolitan Tertiary microplankton taxa may contribute to distinguish the tops of the Pliocene, Middle and Early Miocene, Late Oligocene, "Middle" Oligocene and Eocene in offshore NW Borneo.

From an environmental point of view it becomes increasingly evident that dinoflagellate taxa show clear preferences.

Preliminary investigations in Paleocene/Eocene to Pliocene deposits demonstrate the presence of distinct quantitative changes in successive microplankton assemblages, which may form a frame for establishing a microplankton zonal scheme in offshore NW Borneo.

Paper 42

Sequence stratigraphy of Tertiary sediments offshore Sarawak (Balingian and Luconia provinces)

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The Oligocene to Recent sediments offshore Central Sarawak comprise a coastal plain/shelf 'wedge' overlying an intensely deformed substratum of Paleogene and older deepwater sediments. Internally, this wedge displays one transgressive/regressive megacycle with smaller scale cyclicity superimposed on this basic pattern.

The transgressive limb of the megacycle consists of Sarawak Cycles I to III, each of which are transgressive in nature and predominantly controlled by regional tectonic processes. In basin marginal settings, these cycles are separated by distinct angular unconformities involving strong rotation of the subcropping strata.

The regressive limb of the megacycle consists of Sarawak Cycles IV to VIII which are largely highstand progradation units capped by, locally distinct, lowstand surfaces of erosion. The cyclicity is in this case interpreted to be predominantly controlled by late Miocene to Recent (glacio-eustatic) sea level changes.

Around the transgressive culmination of the megacycle widespread carbonate deposition, controlled by slight structural elevations of the sea floor, is observed.

Carbonate growth is symmetrically arranged around a zone of maximum regional flooding and affected by proximity to clastic input: landward carbonate deposition starts later and stops

earlier, basinward carbonate deposition starts earlier and stops later.

Genetic stratigraphic aspects play an important role in the hydrocarbon prospectivity (eg. source rock and reservoir/seal

pair are directly related to the development of the transgressive caps of the lower cycles and sealing of the carbonate reservoirs is crucially dependent on the impingement of the regressive tops of the young cycles onto the top carbonate surface).

Paper 43

Tectonic control on the development of the Neogene basins in Sabah, East Malaysia

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Two main structural trends, namely NE-SW and NW-SE are thought to have controlled the development, distribution and shape of the Neogene basins in Sabah. These two trends are thought to be related to earlier deformations on pre-Neogene rocks. Earlier NW-SE and N-S compressions during the early Miocene associated with the opening of the South China Sea produced elongate basins trending NE-SW in western and eastern

Sabah. and NW-SE in northern Sabah. A later NE-SW extension during the middle Miocene associated with the opening of the Sulu Sea producing horst and graben structures modified the earlier formed basins in eastern and central Sabah. The interactions between earlier and later produced NW-SE and NE-SW faults controlled the development of the nearly circular-shaped Neogene basins in central Sabah.

Paper 44

Geothermal evolution modelling with apatite fission track data – the geothermal history analysis of Hefei Basin, Eastern China

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The geothermal evolution modelling with apatite fission track data has been studied. Two modelling techniques, the Monte Carlo Method and Simple Method, were used. The Monte Carlo Boxes used to generate random numerical data gave initial values for geothermal inversion. The Simplex Method is for searching appropriate geothermal temperature. The combination of the two methods can avoid tripping in a local minimal position for the objective function. The inversion to theoretical models by the distribution of length and variation of annealing ages of apatite fission track indicated that precision are good enough to gain a well-understood profile of thermal evolution.

In the paper, the geothermal history analysis in Hefei Basin in Anhui Province, Eastern China is given from the inverted thermal profiles by apatite fission track data. The events of structural uplift of Dabie Mountain and the subsidence of Hefei Basin are also clearly shown. The southern part of the basin, which is near to or partly belong to part of the Dabie Mountain was uplifted since Tertiary era until now. The northern parts of the basin have a large range and great thickness of oil rocks of Cretaceous and early Tertiary age, although now it remains only in some areas.

Paper 45

Oil, geology, and changing concepts in the Southwest Philippines (Palawan and the Sulu Sea)

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The Southwest Philippines; Palawan, its offshore shelves, Reed Bank, and the southwestern Sulu Sea encompass 350,000 km² (126,000 sq. mi.). This region contains the better areas to search for significant oil and gas deposits in the Philippines.

The largest oil field yet found in the Philippines was discovered and confirmed in 1991-1992. West Linapacan field has a resource range of 50 million to 200 million barrels of oil. Other recent discoveries of potential significance are Octon and the Calauit-Calauit South fields with resource potentials in the range of 20 to 50 million barrels recoverable. A significant, but as yet unevaluated in terms of long term production testing is the 1992 discovery at Shell's Malapaya-1. This is a deep water test with a reported hydrocarbon column of several hundred feet.

The Southwest Philippines' oil producing trend, about 40 km off the northwest coasts of Palawan and Busuanga is a northerly trending belt 200 km in length. Oil reservoirs in the Philippines fields are Oligocene to Lower Miocene platform limestones, reefs and both silicic and carbonate turbidite sequences. A 540 km gap occurs between the Philippines production at Nido and the closest oil fields to the southwest in Sabah. Untested prospects and leads are present along the South China Sea coast of Palawan.

The Southwest Sulu Sea overlies three poorly explored Tertiary sedimentary-structural basins (Balabae, Bancuan, and Sandakan basins). Geology and oil shows suggest the possible presence of commercial oil fields. Prospects and prospect leads are numerous. One well in the Malaysia sector of the Sulu Sea (Nympe Norde 1) suggests economic potential.

Deep-water exploration targets (untested reefs and structural traps) are present in the South China Sea offshore Palawan. Large gas-condensate reserves are indicated at Camago in 2700 feet of water. A recent test of a major deep water reef prospect, Sarap-1, provided an exploration disappointment in 1991. Other reefs (Cliff Head) in deep water with better source rock association remain to be tested.

Besides economic interest, the Southwest Philippines has been the spawning ground of several concepts and theories about the origin and evolution of the overall region. Some theories and concepts are reviewed. The "Ulugan Bay Fault" is disputed and recommended for elimination from future maps based on later field work and offshore geophysical studies. Redefinition as an anomalous area is alternative.

Two schools of thought on the origin of much of Palawan are reviewed. Was continental crust from the South China Sea

area subducted beneath Palawan or is Palawan a complicated type of thrust pile composed of protocrust types that have been thrust to the northwest from the Sulu Sea region?

Some future exploration areas, plays, and prospects are illustrated.

Paper 46

Sedimentology of the Miocene Semirara Formation, Philippines

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This paper describes the sedimentology of the Semirara Formation in the type locality, Semirara Island, which lies south of Mindoro on the western side of the Philippines Volcanic Arc. The Semirara Formation is mostly composed of continental clastic deposits. The outcrop is dominated by fluvial channel sandstones interbedded with thick coals and estuarine and floodplain siltstones. Palaeocurrent analysis indicates that the rivers flowed towards the North and the petrography of the sandstones indicates that there were derived from a continental landmass rather than the volcanic arc. It is suggested that the Palawan Block was being uplifted and eroded during the Miocene and shedding sediments northwards into a rapidly subsiding basin which developed under a sinistral strike slip regime along the northern trailing edge of the indenting Palawan Block.

Coal in the Semirara Formation is currently being worked in an open cast coal mine, associated sandstones and organic rich mudstones form potential reservoir and source rocks for petroleum exploration in adjoining areas. In the open cast coal mine at Unong 400 m of section have been measured. The section contains 190 m of sandstones with minor conglomerates, 158 m of siltstones and 42 m of coal. The sandstones are mostly fluvial channel sandstones deposited by a variety of rivers which can be summarised as four types; 1) Mixed load meandering rivers, 2) Sand-bed meandering rivers, 3) Large sand-bed braided rivers and 4) Shallow braided streams. The fluvial sandstones are interbedded with thick coal seams, up to 20 m thick, and siltstones which are interpreted as freshwater swamp and floodplain deposits. Occasional marine incursions are also recognised indicating an overall depositional setting on a coastal plain.

Paper 47

Hydrocarbon occurrences in the Cooper and Eromanga Basins in Central Australia

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The Cooper Basin and Eromanga Basin together form the largest proven onshore hydrocarbon province in Australia. The geology, including the stratigraphy and the structural framework of these basins, and the prospectivity elements which constrain

the exploration for oil and gas are reviewed. Examples of conventional and unconventional exploration concepts tested, discoveries made to date, and the remaining hydrocarbon potential in these basins are highlighted.

Paper 49

Coal in the western Pacific Basin, an overview

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Coal comprises about 50 percent of the conventional energy resources of the world and about 70 percent of fossil energy resources. Asia contains about 50 to 70 percent of the total estimated coal resources of the Earth. The western Pacific Basin area of the Circum-Pacific Region contains about 20 percent of the world's total coal resources and is estimated to contain about 50 percent of the presently recoverable coal reserves of the world.

Coal supplies about 27 percent of the world's primary energy production and provides about 5 percent of the primary energy production of the western Pacific Basin area. Among the nations of the area, China, Australia, New Zealand, and Vietnam produce more coal than they consume. Japan, both Koreas, the Philippines and Thailand consume more coal than they produce. Within the area as a whole, coal production and consumption are both about 30 percent of the world totals. Between 1961 and 1990, primary

energy consumption in the area increased by about 150 percent, and coal consumption increased by almost 170 percent. Both energy and coal consumption are expected to increase over the next three decades as nations of the region expand their economics and focus on indigenous coal resources as a basic energy supply.

Within the western Pacific Basin, the amount of information concerning coal resource potential ranges widely. Some nations place all their estimated coal resources in the proven-in-place reserve category (Japan), while others place only a few percent in that category (Malaysia). While estimates vary, depending on the philosophy and practices used, it is probable that, in many cases the available coal database is inadequate for reliable resource assessment. Increased exploration and development activities are needed to permit realistic and accurate evaluation of energy-planning options in the region.

Coal as an energy resource in Malaysia

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Malaysia is well-endowed with energy resources, both renewable and non-renewable. Our known oil resource can last 14 years at the current rate of consumption, gas more than 80 years and coal much longer based on the projected energy utilization plans. The location and distribution of some of these energy resources do not parallel those of population and energy demand centers. The four fuel energy strategy of the country assures adequate and secure energy supplies while at the same time promotes diversification and reduced dependence on oil. In the medium term, gas will emerge as the dominant fuel particularly in electricity generation, accounting for 71% of the generation mix, complemented by hydropower (18%), coal (8%) and oil (3%). This will be a dramatic change from the present composition of 43% oil, 25% hydropower, 21.5% gas and 10.5% coal. This change is inevitable because gas is abundant, easily available and accessible, easily handled and used and has less adverse effects on the environment. Large investments are already in place to encourage its greater use. Gas is also an

economic fuel at the moment because of competitive pricing.

Use of coal as an energy source for cement manufacture and in power generation is relatively new. Our experience shows that the environmental problems associated with coal use can be effectively dealt with mainly through regular monitoring. Even at the prevailing low gas price, the electricity corporations still find coal to be competitive and they are seriously considering it as the fuel for their future plantup. After the year 2000 when gas price may be pegged to oil, electricity generation with coal may be the cheapest option.

We can foresee coal playing a greater role in the electricity generation mix after the year 2000. The coal resources in the country is as yet little tapped; they can be developed to meet the increased demand arising from the greater coal use in electricity generation. A major consideration of greater coal use is its effects on the environment. If future clean coal technologies can mitigate or reduce various adverse effects on the environment, it will pave the way for even greater use of coal to and beyond 2000.

Neogene tectonics and orogeny of Indonesia

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The present tectonic configuration of the Indonesian archipelago is thought to have been developed during Neogene times, and it shows typical triple junction convergence due essentially to the interaction of three megaplates: the westward-moving Pacific Plate, the northward-moving Indo-Australian Plate and the south-southeastward-moving Eurasian Craton.

The archipelago is built up of at least 5 distinctive crustal elements that includes: 1) Sunda Shield (SE Eurasian Craton), 2) Indian (Oceanic) Plate, 3) Australian Craton, 4) Pacific Plate and 5) Transitional Complex. Each unit consists of several distinctive tectonic units (provinces, zones or belts).

This tectonic convergence was subsequently followed by the development of *orogenic belts* in most parts of the region, which kinematically can be divided and recognized into 4 types:

1. **SUNDA OROGENY** in western Indonesia due essentially to a back-arc thrusting in Jawa and Nusatenggara, and transpressional movement of the Barisan Fault System in Sumatera. The orogeny gave rise to the development of the Southern Mountain Ranges in Jawa and the Barisan Mountain

Ranges in Sumatera, which are coincident with the fold and fault belt. In Sumatera the belt shows a typical *flower structural setting*.

2. **BANDA OROGENY** in Sulawesi and its surroundings due essentially to the development of a Tethyan type convergence together with the transcurrent movement of the Palu-Koro Fault System, which gave rise to the development of mountain ranges in Sulawesi.

3. **MELANESIAN OROGENY** in Irian Jaya & Papua New Guinea and Sahul Platform due to the development of thin-skinned tectonics causing the development of the Central Irian Jaya Fold and Thrust Belt coincident with the Central Irian Jaya Mountain Ranges.

4. **TALAUT OROGENY** in the northern Maluku region due to the development of double arc collision coupled with the transpressional movement of southern extension of the Philippine Fault System giving rise to the development of the imbricated Talaut-Tifore ridge in the form of *flower structure*, which partly emerged above sea level.

Sedimentological and mineralogical analysis of the turbidite sandstone beds at the eastern margin of the Niigata Neogene backarc oil basin, Northwest Japan; with special reference to the coexistence of shallow-marine and deep-marine turbidite sandstone beds

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The study area, a part of the eastern margin of the Niigata Neogene backarc oil basin, is a very interesting area to clarify the sedimentological relationship between shallow-marine and deep-marine sediments, as the Neogene sediments are widely distributed under the control of north-south trending folds with many useful thin tuff marker-beds. Recent detailed stratigraphic works have disclosed the lateral change from deep-water

formations in the west to shallow-water formations in the east.

In the early Pliocene age, two kinds of turbidite sandstones, submarine-fan turbidite in the west and shelf turbidite sandstone in the east, were formed at the same time and resulted in coexistence of two kinds of sandstone-mudstone alternations in the study area.

These two kinds of turbidite sandstones were both

transported westward but from different sources, as heavy mineral components of them are fundamentally different from each other. The western submarine-fan turbidite was transported through the submarine canyon, whose head was located near the mouth of the main river which supplied sediments mainly from the upper area of the provenance area (mostly of Mesozoic sedimentary rocks and Cretaceous granitic rocks). The eastern shelf turbidite, on the other hand, was transported, probably during the time of storms, through many small channels from

the coastal area, where small rivers supplied the sediments mainly from the lower portion of the provenance area (mostly of Neogene volcanic rocks).

As shown in this study, heavy mineral analysis of sandstones is very useful for analysis not only of provenance but also of sedimentological process, especially in case of sandstones deposited in the Neogene active margin basins, as many volcanic origin minerals are added to the basement-origin minerals.

Paper 55

Lithosphere structure and dynamics of the Banda Arc Collision Zone, eastern Indonesia

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The processes leading to continental collision and accretion are still relatively poorly understood. The Banda Arc in eastern Indonesia is one of the few parts of the world presently undergoing the initial stages of an active collision. Prior to about 3 million years ago, the oceanic portion of the Indo-Australian plate north of Australia was being subducted towards the north under the southern margin of South East Asia. Since the arrival of the Australian continent at the subduction zone, the continental margin has been subject to inversion. A collision orogen has been formed immediately south of the volcanic Banda Arc creating

the outer arc islands including Timor. A multi-disciplinary regional study of geology and geophysics of this area has been undertaken in order to assess the structure and mode of deformation within this critical region. A compilation of all historical hypocentres and fault plane solutions shows the trajectory of the subducting slab and the existence of discrete zones of weakness within it. A deep seismic reflection profile recently acquired by BIRPS (UK) and MGI (Indonesia) is also presented here and shows for the first time the deep structure of a volcanic arc and an active collision zone.

Paper 56

Tectonic evolution of the Banda Arc, E. Indonesia: Southern Tethyan crust obduction metamorphism and fragmentation of eastern Gondwanaland

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The Banda Arc, a west facing horse-shoe shaped arc in eastern Indonesia, defines the locus of triple junction system between three major plates: the Eurasian, the Pacific and the Indo-Australian. Splinters of the Mesozoic southern Tethyan crust are now formed the base of the Banda Sea. On the surrounding islands, dismembered ophiolites can be found in high mountains. Recent studies in the metamorphic aureoles at the base of these ophiolites revealed that obduction has been a major mechanism in the emplacement of southern Tethyan crust onto the passive Australian continental margin.

The history begins with a spreading at or prior to M-25 anomaly. Part of this spreading system died due to intraoceanic thrusting near the ridge axis. This compressional tectonics was associated with inverted HP-HT metamorphism recorded in Timor. It occurred between M-10 and M-21 anomalies, which time interval is now missing in the southern Banda Arc sector. In concert with fragmentation of Australia from the Gondwanaland and its further northward drift since 50 Ma ago, the Tethyan crust and the accreted metamorphic sole was

obducted onto the Australian continental margin. Obduction took place around 38 Ma ago and coincident with regional disappearance of Oligocene strata in Timor. Collision of Australia with the thrust packages at its leading edge, against the island arc at 3 Ma ago has caused the emergence of southern outer Banda Arc islands.

At about 7.6 Ma ago, the Australia-derived Buru-Seram microplate was at a latitude 2° more to the south and positioned at 74° clockwise relative to its present position. Transensional pullapart tectonism was dominant in the eastern margin of Tethyan crust presently occupied by the Weber Deep. This tectonism has caused the hot young mantle materials of the NE Weber Deep, formed at 18 to 23 Ma, to be obducted onto the Buru-Seram microplate during 3.3 to 4.4 Ma interval. As Australia drifted further to the north and the west Pacific and Irian Jaya plates moved westward, the Buru-Seram microplate migrated and rotated anticlockwise to its present position. This has finally entrapped portions of the Tethyan crust now forming the base of Banda Sea.

Paper 57

A new investigation of some continental scale gravity lineaments in Australia

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Introduction

Major continental lineaments have long been recognised. One of the earliest and most important documentations was produced by the American worker W.H. Hobbs in 1911. Hobbs investigated basement fractures in many parts of the world

and observed their influence on surface topography and drainage patterns.

In Australia, the pioneering research by E.S. Hills between 1946 and 1956 showed that a number of continental scale morphotectonic lineaments where the underlying basement

structure could be seen to dictate the surface morphology. Many of these lineaments are recognisable on the large scale "Great Relief Model" of Australia constructed by Hills between 1942 and 1954.

Another noteworthy Australian researcher, E.S.T. O'Driscoll, has studied continental lineaments since the late 1960's and has identified and developed the relationship between economic ore localization and major lineaments. He demonstrated the ore/lineament relationship in both Australia and other parts of the world.

Australian Gravity Lineaments

It can be readily observed that the location and orientation of gravity lineaments recognized by O'Driscoll often coincide with surficial morphotectonic lineaments documented by Hills, i.e. deep seated features are coincident with the geomorphic surface expressions.

As a component of the current study at Melbourne University on Australian lineaments, the author has reviewed and further examined numerous Australian continental gravity lineaments.

O'Driscoll used a diffused gravity image, produced by oscillating the negative of a Bouger Free Air gravity image during photographic development, to identify a continental network of gravity lineaments. Ingredient maps of Bouger Free Air gravity data have also been used by O'Driscoll and the author as a useful tool in the identification of deep crustal lineaments. Gravity lineaments can be recognised as pattern disruptions in a particular data set. These disruptions reflect linear dislocations in the lower crust-upper mantle.

The present study has identified the effects of the continental lineaments (often referred to as lineament corridors), on the geology, surface morphology and structure of the intervening terrains.

An important and observable feature of a lineament or lineament corridor is that it forms the locational focus for a variety of tectonic processes that are intermittently repeated through time.

The effects of the lineaments on the geology show their great antiquity and fundamental influence on the tectonic development and history of the Australian continent. Numerous case studies show evidence for such resurgence along lineaments from as early as Proterozoic and up to Recent times.

Because the majority of major economic mineral and hydrocarbon accumulations in Australia occur at major lineament intersections, the study of such lineaments assumes an important economic significance.

Summary

This study has demonstrated that:

Linear, deep seated gravity discontinuities can be identified in Bouger gravity data sets and the effects of these can be recognised in the surface expression of geology and structure.

Lineaments form a locational focus for a variety of tectonic processes.

Lineaments exhibit great antiquity as there is evidence for resurgent activity along their length from the Proterozoic to the Recent.

Lineament intersections assume an economic significance due to the common ore/lineament association.

Paper 58

Strike slip duplexes: their role in basin formation and evolution, with reference to the North Sumatra Back Arc, Ombilin Intermontane and West Sumatra Fore Arc basins

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Interpretation of seismic data in the Aru Area (North Sumatra Back Arc Basin), detailed field mapping in the Ombilin Intermontane Basin and results of marine geophysical cruises in the West Sumatra Fore Arc Basin strongly suggest that the formation and development of those basins are closely associated with the strike slip duplex systems.

In the North Sumatra Basin, the strike slip duplex system was active during the Late Oligocene-Early Miocene to form N-S trending transtensional half grabens. The main depocenters are located in the western part of the Aru Area. Subsequently, deposition of lacustrine and fluvial sediments of Bampo and Prapat Formations took place. Inversion tectonics occurred in the Middle Miocene which resulted in the shifting of the depocenters towards east.

Similar mechanism appears to occur in the Ombilin Intermontane Basins. The formation of grabens through transtensional movements took place in Paleocene-Eocene times, during which the deposition of lacustrine, alluvial fans and fluvial

sediments of Sangkarewang and Brani Formations was also occurred. That episode was subsequently followed by inversion tectonics in the Early Oligocene, and associated with the deposition of the fluvial sediments of the Sawahlunte and Sawahembang Formations. Next transtensional episode was active in Late Oligocene-Early Miocene times. The deposition of the shallow-deep marine sediments of the Ombilin Formation was prevailed in the Neogene grabens situated to the southeast of the Paleogene depocenters.

Results of the marine geophysical cruises in the West Sumatra Fore Arc Basin and field mapping on Nias Island confirmed the occurrence of strike slip duplexes. N-S trending grabens were formed due to Late Oligocene transtensional movements in which sediments were deposited unconformably upon the Pre-Oligocene accretionary complex.

All basins are subjected to the Plio-Pleistocene orogeny which produced the present complex structures.

Paper 59

Geothermal energy and uranium mineralization potential of the Main Range granite province, Peninsular Malaysia

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A survey of available radioelement (U, Th and K) data suggests that the voluminous Main Range Batholith of Peninsular

Malaysia can be classified as high heat production (HHP) granite. Computed heat production values vary from 3.12 to 18.58 μWm^{-3}

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³ over the entire batholith. Heat production in individual pluton varies due to differing radioelement abundances caused mainly by magmatic differentiation. The mean heat production values of the different plutons range from 5.32 to 7.72 μWm^{-3} which are comparable to, and even higher than, the values of many known HHP granites.

An evaluation of the geothermal potential of the Main Range Batholith requires heat flow data which are not currently available. Consideration of the vertical extent of the radiothermal properties, however, provides some constraints on the possible magnitude of heat flow. The Main Range Batholith probably extends downwards to a depth of about 20 km as published gravity modelling studies indicate. The depth-distribution of the radioelements is uncertain, but no downward depletion is apparent for a vertical range of about 1 km. If the mean heat production values persist even up to 15 km depth, then the heat

flow for different plutons would range from about 80 to 110 mWm^{-2} without taking into account the contribution of "reduced heat flow". Similar values are also obtained if it is assumed that radioelement concentrations similar to the inferred parental magma composition (least differentiated) persist up to the base of the batholith. On the basis of above analysis, it has been possible to identify certain plutons that merit further investigations for geothermal resource studies.

Uranium deposits are not known to occur in the Main Range Batholith. Erosional loss of deposits is a possibility that needs a careful evaluation. For some plutons, however, the lack of uranium mineralization appears to be due to mineralogical control. The uranium mineralization potential should not, therefore, be evaluated mainly on the basis of whole-rock U contents.

Paper 60

Deep slim hole, diamond core drilling program proves effective for geothermal assessment in Hawaii

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The Hawaii State legislature, in 1988, funded a deep, slim-hole, diamond core drilling program, known as the Scientific Observation Hole (SOH) program, "to stimulate geothermal development and confirm the geothermal resources of Hawaii". This program was designed by the Hawaii Natural Energy Institute (HNEI) at the University of Hawaii at Manoa to assess the geothermal resources of the Kilauea East Rift Zone on the Big Island of Hawaii. The program is funded by the Hawaii Department of Business, Economic Development, and Tourism (DBED) and managed by HNEI.

To assess the geothermal potential of the Kilauea East Rift Zone (KERZ), a fence of four holes, three of which were drilled, were sited along the long axis of the KERZ within existing Geothermal Resource Subzones (GRZ). These holes were located to provide stepout drill coverage between existing and planned geothermal production wells, and to pair the SOHs with production wells to test for permeability across the rift zone.

Successful drilling techniques and casing procedures were devised as the rock section became known and its characteristics noted. Above 130°C (270°F) a complex stearate was added to the drilling fluids to maintain lubricity. Above 165°C (330°F) a mixture of soda ash, high temperature polymer, complex stearate,

and sepiolite virtually eliminated high torque and vibration problems normally associated with high temperature drilling.

The core and other data from the SOHs have proven to be extremely valuable for both active developers in siting production wells, and in the understanding of the subsurface geologic conditions. The first hole drilled, SOH-4, provided thermal and permeability conditions along the eastern portion of the True/Mid-Pacific Geothermal Venture's lease, and was instrumental in the location of True's #2 site. SOH-4 was drilled to a total depth of 2,000.1 metres (6,562 feet) and recorded bottom hole temperature of 306.1°C (583°F) at a depth of 1,950.7 meters (6,400 feet). The second hole, SOH-1, effectively defined the northern extent of the Puna Geothermal Venture's (PGV) HGP-A - KS-1A reservoir, doubled the proven reservoir size, and provided sufficient data to the lending institution for continued project funding. SOH-1 was drilled to a total depth of 1,684.3 meters (5,526 feet) and recorded a bottom hole temperature of 206.1°C (403°F). The third hole, SOH-2, was drilled on a PGV lease to a total depth of 2,073.2 meters (6,802 feet), recorded a bottom hole temperature of 350.6°C (663°F), and may have intersected a potential reservoir at a depth of approximately 1,624 meters (5,000 feet).

(Not Presented)

Paper 61

Geothermal systems within a "pulled-apart" segment of the Philippine Fault (Central Leyte): their characteristics and relation to volcanism and strike-slip tectonics

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The trace of the Early Pliocene to Recent Philippine Fault in Central Leyte forms a 55 km x 5 km "pull-apart" structure within which five discrete hot water-dominated geothermal systems have been delineated. These are: Mahiao-Sambaloran-Malitbog, Paril-Mahanagdong, Alto Peak, Anonang and Mahagnao geothermal prospects. Each of these is characterized by a low (<20 ohm-m) resistivity anomaly that encloses active thermal manifestations, hydrothermally altered ground and a volcanic center. The preliminary microtectonic data show that this area has been subjected to a regional E-directed (092°) compression and a localized NW-NE directed (060°-172°) extension.

Three major hornblende andesite- and dacite-forming volcanic events have been identified in this region: i) the Late Miocene (11 Ma) event is represented by the highly eroded Mamban, Cancajanag and Burauen Volcanics; ii) the Late Pliocene to Early Pleistocene (~1.6 Ma) event produced several small volume partly eroded volcanic cones and domes, which now show moderate-intense solfataric activity, and iii) the Late Pleistocene (<0.5 Ma) event formed two volcanic cones with well-preserved crater structures (Mts. Janagdan and Lobi). These volcanic deposits were emplaced onto a thick sequence of Mid-Tertiary to Recent sedimentary clastics and carbonate lenses that

overlie ultramafic and metamorphic rocks.

Hence, the geothermal systems within the "pulled-apart" segment of the Philippine Fault in Central Leyte are mainly associated with Late Pliocene to Early Pleistocene volcanism and zones of transtension. This set-up is accompanied usually by a large outflow of geothermal fluids such as in Mahiao-

Sambaloran-Malitbog, Paril-Mahanagdong and Anonang geothermal prospects. In contrast, a geothermal system dominated by compressional stresses and centered at a solfataric crater (Alto Peak) or a dome (Mahagnao) exhibits very limited outflow features and normally volcanic-magmatic signatures may be expected.

Paper 62

Geology, energy potential and development of Indonesia's geothermal prospects

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Indonesia's regional geologic setting creates suitable conditions for the occurrence of commercial geothermal resources. A complex interaction of the Indo-Australian, Eurasian, and Pacific megaplates, as well as smaller plates, has led to island arc volcanic activity and major faulting throughout Indonesia. The combination of volcanic island arcs with shallow crustal magmatic heat sources and fault related zones of fracturing and enhanced permeability provides Indonesia with the world's largest concentration of geothermal prospects.

Indonesian geological surveys have identified 142 high enthalpy geothermal prospects for a country-wide estimated potential of approximately 16,000 megawatts. The geothermal prospects are generally characterized by vigorous thermal manifestations associated with late Pleistocene to Recent andesitic stratovolcanos and dacitic volcanic centers. Two prospects on Java, Kamojang and Awibengkok, are regarded as commercial power generation centers. Kamojang, a vapor-dominated field, has an installed capacity of 140 megawatts and is operated by PERTAMINA

and PLN. The field has been producing reliably since 1983 with annual electrical generating capacity factors exceeding 80%. Awibengkok, a liquid-dominated field, is being developed by PERTAMINA, PLN and UNOCAL. A 110 megawatt power plant is expected to begin commercial operations in early 1994. Further expansion plans for both fields are currently under discussion.

Indonesia's electric power sector is experiencing rapid growth. PLN, the State Electric Company, and private power companies are expected to add 21,825 megawatts of new generating capacity by the year 2000. Geothermal energy development for electric power generation will make up approximately 1,200 megawatts of this new capacity. Future geothermal developments will be located in Java, Sumatera, and Sulawesi. The expansion of geothermal capacity will free up petroleum resources for export to earn foreign exchange and for domestic transportation uses. The geothermal capacity will also add to the development of a more diversified and environmentally preferred electrical generation fuel mix.

Paper 63

The geophysical characteristics and evolution of northern and southern margins of South China Sea

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Data of about 40000 km gravity and magnetic measurements, 10000 km multi-channel seismic lines, 20 sonobuoy refraction seismic stations, and 5 heatflow stations have been obtained by our institute in the South China Sea (SCS) during the last ten years. Based on these and other data, the present paper discusses the tectono-geophysical characteristics and evolution of SCS.

On the northern margin of SCS, active explorations for oil and gas have been carried out by Chinese and foreign companies for the past decade. From the continental shelf to the slope, five parallel structure zones have been recognized and named, from north to south, the Wanshan fault-terrace, Northern depression, Central uplift, Southern depression, and Slope volcanic zone. The basement of the margin is the extension of onland Southeast China and consists of the Hercynian foldbelt east of the seaward extension of the NE-trending Lishui-Haifeng fault and the Caledonian foldbelt west of the fault. Both foldbelts were extensively disturbed by Yanshanian magmatic activity. More than 40 exploration wells in the Northern depression and Central uplift zones have encountered this pre-Tertiary basement.

Based on gravity data, the crustal thickness is 25-26 km for the Northern depression, greater than 29 km for the Central uplift, and 22 km for the Southern depression zone. A gradient belt of Moho surface is observed along the lower continental slope. The two seismic lines of Sino-American cooperative two-ship

experiment in this sea area gave similar results. The most important finding was a northward dipping fault that exists in the basement along the lower continental slope. This fault is regarded as a detachment fault by Hayes (1989) but as an extinct suture zone by Chinese scientists.

We found a high magnetic anomaly zone extending from the Dongsha Uplift NE-ward to the Penghu Islands and a magnetic quiet zone extending along the lower slope and the edge of the deep-sea basin NE-ward to the northward extension of the Manila Trench at about 21°N. The high magnetic zone is interpreted as the manifestation of a basalt belt. Four wells in the Dongsha Uplift encountered alkali basalt of 45.1-17.1 Ma in age, and in the Penghu Islands alkali tholeiitic basalt and alkali basalt of 16.2-8.2 Ma age are observed. These intraplate eruptions suggest that the northern margin of SCS was an extensional passive margin in the Cenozoic era. In contrast, large amount of Yangshanian granites along the South China coast are of I-type, and Late Yanshanian granites (76-130 Ma) in the basement on the shelf are likely of a similar type. These granites and associated volcanic rocks comprise a magmatic arc associated with the Mesozoic active continental margin along East Asia. The lithospheric fault was probably a segment of the Mesozoic subduction zone, while the thick crust in the Central uplift zone was formed by accretion along this subduction zone. The

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magnetic quiet zone might indicate the remains of the oceanic crust of the Paleo-Pacific.

The southern margin of SCS contains the Nansha block which includes the Liyue Bank (the Reed Bank) and the reef-and-shoal area to the west (the Dangerous Grounds), the Nansha Trough (the Palawan Trough), and the Palawan block. Our multichannel seismic profiles revealed a thick Paleogene sequence lying above thick Mesozoic strata. This Paleogene sequence consists of neritic clastics with clear stratification and widespread distribution. This sequence was later strongly deformed into asymmetric folds and eroded. The unconformity above this sequence has been recognized in several seismic profiles in the reef-and-shoal area. According to a correlation with limited and distant wells, this unconformity is tentatively dated Late Eocene. We name this deformation event the Nansha movement, which was contemporaneous with the first phase of the Zhu-Qong movement in the northern margin of SCS, but under a totally different stress regime. Above this unconformity, the Neogene sequence is thin and mainly as fillings of discrete half grabens in the reef-and-shoal area, but thick and continuous on the Liyue Bank, the Palawan shelf and the Zengmu Basin (the Great

Sarawak Basin). This indicates that the reef-and-shoal area has stayed mainly in an uplift state since Late Eocene time, different from the shelf area to its south and east.

The recognition of the Late Eocene compressional event in the Nansha block has significant geological implications in terms of the evolution of SCS. Differing from previous models, we suggest that the Nansha block collided with Paleo-Borneo and was uplifted in Late Eocene time, long before the start of the opening of SCS. Before the collision, the Nansha block was a shallow sea bordering the Paleo South China continent, where marginal rifting had been continuing since the Late Cretaceous. Not until Late Oligocene, the extension stress extended southward to the Nansha block and became strong enough to open SCS. Later in the Early Miocene, Borneo rotated counterclockwise probably about a pole near the center of the Borneo rather than west of Borneo. The narrow Nansha Trough Basin was formed by the elastic downwarp of the Nansha block under the load of the NW-ward overthrusting Sabah nappe, while the Zengmu Basin was formed by the extension west of the pole of rotation.

Paper 64

Heat flow distribution in the western margin of the Pacific

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Heat flow distribution in the western margin of the Pacific has been surveyed, because it is one of the important geophysical observations in the region. Particularly, the compilation of heat flow data in Southeast Asia and its marginal seas is the subject of our main concern.

In the present paper, we present an updated heat flow map of the western margin of the Pacific, north of 12°S. Special attentions are paid to the Southeast Asia part (95° to 120°E) x (10° to 20°N). Maps showing the temperature values at 1, 3, and

5 km depths are also produced, estimated from simple assumptions of the crustal heat generation and thermal conductivity. Although there remain large uncertainty of the assumptions and also data coverage is rather poor in some part, those maps are clearly indicative of the significant lateral differences of temperature, which may have a large impact on the assessment of hydrocarbon and other mineral resources in the region.

ABSTRACTS OF POSTERS

Poster 1

Southern Sandakan sub-basin – 7th oil province for Borneo

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The Sandakan Basin is the largest and southernmost of the three basins in the southwest Sulu Sea. The basin covers at least 40 000 km², mostly offshore, and possesses up to 6–8 km of mainly Lower Miocene to Recent sedimentary section.

The southern portion of the basin has a complex history involving Palaeogene arc-associated tectonism and sub-basin formation punctuated by obduction and transpressional events. Deltaic sedimentation with outer shelf reef growth characterized Neogene deposition; reservoir and intraformational seals are ubiquitous. Reactivation of northeast-trending structural arches which were, initially associated with volcanic edges, has resulted in polycyclic, northeast-southwest, anticlinal structuring. Wrench faulting and northwest-southeast oriented growth faulting in the Neogene modified existing, and created further structures.

Source rocks are deltaic, dominantly terrestrial in origin, are essentially confined to the Neogene, and are similar to those in the Baram and Mahakam deltas elsewhere in Borneo. They are believed to be both oil and gas prone. There are at least three

prospective source kitchens in the basin, the largest and most prospective lying east and northeast of Sandakan.

Exploration has been confined to 15 wells. Poor seismic data quality at the time of drilling (predominantly 1970–1975) resulted in at least 10 of these wells being invalid tests. Modern seismic data reveals a host of new play types including large stratigraphic features basinward of the Neogene delta front. Gas, condensate and light oil flowed from 2 wells in the Malaysian sector and oil and gas/condensate shows have been noted in most other wells.

Strong affinities in stratigraphic and structural style are observed between the Baram Delta and the southern Sandakan Basin, particularly the presence of structures at the intersection of growth faults and folds, where most Baram delta oil fields are located. This, and the fact that the equivalent section which is oil productive throughout Borneo is yet to be tested in a valid trap, suggests that the southern Sandakan Basin could become a significant hydrocarbon producing province.

Poster 2

West Batangas Basin – untested depocenter in Philippines South China Sea

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The West Batangas basin is one of the few remaining untested basins on the Philippine side of the South China Sea. Seismic data, onshore geology and local tectonic considerations suggest that this area is probably part of the rifted continental terrane which underlies the petroleum production area off Palawan about 350 km to the southwest. The basin contains a very thick, moderately deformed sedimentary fill exceeding 5

seconds two-way-time in its deepest portion, equivalent to possibly as much as 9000 m of Mesozoic and Cenozoic section. Thermal maturity in the basin is projected to have been adequate for significant oil and possibly gas generation. Potential source rocks, reservoirs and seals anticipated in the section, as well as a variety of structural and stratigraphic traps, justify exploratory drilling of this frontier area.

Poster 3

Thrust tectonics along the north-western continental margin of Sabah

PETRONAS

Widely accepted plate tectonic models suggest that an inactive subduction zone lies along the north-west continental margin of Sabah. In contrast, interpretation of reflection seismic data acquired by BGR shows an autochthonous continental terrane comprising an Oligocene to Early Miocene carbonate platform being progressively overthrust by an allochthonous rock

complex. Progressive compression resulted in the development of four structural zones: Imbricated thrust sheets (Zone III); two thrust sheet systems one on top of the other (Zone IV); a complex zone with multiphase deformation (Zone V); and piercement ridges (Zone VI).

Poster 4

A new geological map of Borneo island

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The geology and major structural features of Borneo island are presented on a new geological map compiled at 1:1 million scale. The compilation uses data from existing published maps by the Geological Surveys of Malaysia, Indonesia and Brunei and areas not covered by those maps are completed with data from various sources, mainly professional papers in journals. To simplify presentation, age-related letter symbols used in place of

Formation names. An explanatory booklet will accompany the map, giving Formation names and other geological and paleo-environmental data together with a bibliography of sources. The map is the first complete Geological map of Borneo to be published at 1:1 million scale since F.W. Roe's edition of 1951 and incorporates the results of more than 30 years reconnaissance mapping.

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Scientific exploration of the western margins of the Pacific Basin by the Ocean Drilling Program

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The Ocean Drilling Program (ODP) has completed 40 internationally-staffed expeditions during the past seven years of scientific ocean drilling. JOIDES Resolution, the scientific drillship of ODP, has travelled in the Atlantic, eastern and western Pacific, and Indian oceans, including high-latitude zones bordering East and West Antarctica, and the Mediterranean, Caribbean, Weddel, Sulu, Celebes, Philippine and Japan seas, in search of answers to important scientific problems designated by the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). These scientific objectives relate to the tectonic evolution of passive and active continental margins, origin and evolution of oceanic crust, origin and evolution of marine sedimentary sequences, and paleoceanography. In addition, ODP has continued improving existing coring systems and has made numerous advances in technology to improve the capture of scientific information.

ODP has completed several cruises in the western Pacific to investigate the stratigraphic history of the basin in these regions with implications for both tectonic and paleoceanographic events. The cruises bordering the western margin of the Pacific basin include Leg 124 (Southeast Asia Basin), Legs 125–126 (Bonin Mariana Arc-Trench), Legs 127–128 (Japan Sea), Leg 129 (Old Pacific Crust), Leg 130 (Ontong Java Plateau), Leg 131 (Nankai Trough), Leg 133 (Northeast Australia), Leg 134 (Vanuatu), and Leg 135 (Lau basin). Specific tectonic goals of these cruises include, amongst others, documenting the history of the forearc terranes, the timing, process, and products of rifting, and the development and composition of backarc environments. Specific paleoceanographic objectives include documenting variations in the rate of surface productivity, the origin of deep intermediate, and surface water masses, and oceanographic response to the above noted tectonic events.

Poster 6

Detailed sedimentological core logging – an essential step towards understanding reservoir architecture and performance

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Sedimentological core logging is often considered to be the preserve of geologists and is frequently of little interest to the reservoir engineer. However, this technique of recording core is an essential step towards the understanding of the internal architecture and behaviour of a reservoir. By defining depositional and diagenetic facies, the reservoir can be subdivided into "building blocks". The likely geometry of these blocks can

be interpreted, while their petrophysical and petrographical character can be assessed through laboratory analysis and field evaluation. Core logging can be applied as a tool for improved exploration, delineation, production, development, enhanced oil recovery and simulation strategies. This poster exhibit provides some practical examples of core logs and shows how they have assisted both geological and engineering operations.

Poster 7

The Philippine Sea geotraverse

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The studies on the Geotraverse Project are being carried out within the framework of the Soviet-Japanese-Chinese scientific cooperation. The profile runs across the North China Plain, East China Sea, Ryukyu Arc, Philippine Sea, Mariana

Trench and the Pacific. The work is aimed at the compilation of the geological-geophysical-petrochemical section of the tectonosphere, including the asthenosphere.

Poster 8

Geology and mineralogy of the Late Jurassic–Quaternary sedimentary cover in the oceans and on the continents

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The Atlas consists of 6 maps covering the whole globe (each of 4 sheets, 1:2500000) and one map covering the Pacific segment of the Earth (9 sheets, 1:1000000). Monograph (the Explanatory Note) — approximately 350 p. References more than 500 books and articles. The primary goal of the work is to compare the regularities in distribution of the mineral resources of the territories of the former USSR and the other regions of the Earth and between the continents and the oceans. It had been achieved with the help of: (1) recent data on the geology and the petroleum

and ore potential of the former USSR territory; (2) the Russia marine geological-geophysical studies of the Arctic shelf and the World ocean with special emphasis on more detailed studies of the Far East seas; (3) the deep-sea drilling data (Leg 1-130); (4) the publications in the World geological literature. The Monograph successively deals with the methods of general analysis, the geology and regularities of the distribution of the mineral resources in four large complexes of the sedimentary cover (the Quaternary, the Oligocene–Neogene, the Upper

Cretaceous–Eocene, the Upper Jurassic–Lower Cretaceous), the distribution of the hydrocarbon fields and the polymetallic ore and manganese deposits in different regions of the Earth.

The complexes are characterized by: (1) the distribution of the thickness and formation composition; (2) the quantitative parameters of sedimentation; (3) the peculiarities of hydrocarbon localization on the continents and in the oceans; (4) the types of the polymetallic ore and manganese deposits on the continents; (5) the conditions of the enrichment of the sedimentary cover in the deep-sea basins with polymetallic ores and manganese (17 horizons); (6) the regularities in distribution of the different type fields of the ferromanganese nodules and the polymetallic ores of massive sulfides in the oceans (the Quaternary complex). The oil and gas potential of these complexes in the deep-sea basins of the oceans and the marginal seas (including those framing the

Antarctic), and in the areas of the pericratonic downwarps and underthrust zones of the continents is estimated.

On the basis of the analysis of the change of the geodynamic setting of sedimentation during the last 150 Ma, the new model of division of oceans and continents by their oil, gas and ore potential (including the forecast of areas of high noble metals concentration) is validated in principle. The Atlas and Monograph can be helpful for geologists, geophysicists and geographers who study the problems of the evolution of the upper Earth's spheres and the genesis of hydrocarbons and metals. It can facilitate the determination of new directions in the search for mineral resources in the oceans and on the continents and geological-economic evaluation of the separate regions of the Earth. This work may also be used by universities and colleges in professional training.

Poster 9

Geological architecture of the Miocene carbonate buildups from the Central Luconia Gas Province, offshore Sarawak, Malaysia.

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In the carbonate province of Central Luconia, two types of buildups have been identified from seismic and well evaluations.

1. The pinnacle-type buildups are generally poorly defined on seismic due to the steepness and stringer development of their flank. These buildups are high relief, conical shape features situated on the flanks of the regional highs or developed in the basal areas. Reefoid carbonates formed during middle Miocene time in a proximal position to clastic influx. Diagenesis caused extensive dolomitisation of the coral/algal limestone. Well correlations show a large degree of heterogeneity between the wells.
2. The platform-type buildups are well expressed on modern seismic. These buildups are large, elongated and fairly flat-top structures located on fault-bounded regional highs. In spite of common external geometry, clear differences occur in internal layering. Three distinct architectures have been identified: the internal relief type, the flank zone type and the laterally extensive layer-cake type.

Seismic, wireline log and core interpretation were combined to analyse the depositional and diagenetic patterns of one platform-type buildup. This integrated approach reveals the fundamental control of relative sea level changes on the internal architecture of the buildup. The cyclic depositional pattern

includes:

1. Small-scale sequence (<10 ft) which can be recognised on core,
2. Reservoir unit-scale cycle (>200 ft) which are identifiable on logs and seismic.

The platform-type carbonates are made up of 3 depositional sequences deposited during the Tortonian and Messinian stages (late Miocene). Superimposition of two successive diagenetic cycles has been evidenced from petrographic and geochemical analysis. Dating using Sr isotope method indicates that minor dolomitisation is associated with period of subaerial exposure. The Messinian diagenetic cycle which is related to the 5.5 Ma sea-level lowstand, partly overprints the Tortonian diagenetic cycle which occurred during the 6.3 Ma sea-level lowstand.

Distribution of the reservoir rock types in the platform buildup can be predicted on a simple 1-D model. Preparation of 2-D and 3-D reservoir models in the near future is feasible assuming that reservoir cyclicity can be recognised in non-cored wells, estimation of the reservoir properties in the buildup margin/flank is correct and the impact of burial diagenesis on reservoir performance is properly evaluated.

Poster 10

University of London Group for Geological Research in Southeast Asia

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The University of London Group for Geological Research in Southeast Asia was established in 1982 by members of the academic staff of the University of London. At present the Group comprises some 40 academic and research staff, and research students who maintain an extensive range of geological and geophysical research programmes, both on-land and offshore, in the area from Northern Thailand, through Malaysia and Indonesia to Papua New Guinea and the northern margins of Australia.

Major current projects include:

1. Sorong Fault Zone: a multi-disciplinary study aimed at determining the origin and history of movement of the tectonic terranes, which form the islands between the Bird's
2. Australia-Banda Arc Collision Zone: aimed at determining the present structure of the collision zone and the history of sedimentation and tectonic evolution of the NW Australian Shelf, the development of the Banda Arcs and the progressive development of the collision zone in time and space.
3. Sumatran Forearc: aimed at determining the origin of the materials and the structural development of the Sumatran accretionary complex exposed in the outer arc islands offshore Sumatra and the development of the forearc basin.
4. Sumatran Fault System: aimed at establishing the origin and directions and amounts of movement of crustal blocks incorporated in the Sumatran Fault Zone and the effects of

Head of Irian Jaya and Sulawesi in eastern Indonesia.

these movements on the sedimentation histories of the Sumatran forearc and back arc basins.

Techniques employed in these studies range from measurement of logged stratigraphic sections, petrographic, sedimentological and biostratigraphic analyses of rock samples, chemical analysis of sedimentary, volcanic and ophiolitic rocks using XRF, ICP, electron microprobe and isotopic dating methods, gravity measurements and a comprehensive programme of palaeomagnetic determinations. Members of the group have participated in marine geological and geophysical cruises in the area, including ODP legs, utilising seismic (and deep-seismic) profiling, gravity and magnetic measurements and side-scan sonar imaging (GLORIA and SeaMARC II).

The research activities of the group are funded by The Royal

Society, the Natural Environment Research Council, the Overseas Development Administration, the University of London Central Research Fund and a Consortium of seven oil companies, as well as by national governments and oil companies for specific research projects.

The research programme is supported by organisations in Southeast Asia who provide administrative and logistic support as well as collaborating in the programmes. These include the Mineral Fuels Division of the Thai Department of Mineral Resources, the Indonesian Geological Research and Development Centre, Bandung, the Research and Development Centre for Oil and Gas Technology (Lemigas), Jakarta, Indonesian Marine Geological Institute, Chulalongkorn University, Bangkok and the Universiti Kebangsaan Malaysia, Kota Kinabalu, Sabah.

Poster 11

A satellite derived Bouguer Gravity map of Southeast Asia

JOHN SAVAGE AND CLIVE FOSS
ARK Geophysics

The earth's surface is distorted from the ideal ellipsoidal shape by (among other things) the uneven distribution of mass beneath. Where high density rocks are present the sea is drawn in from surrounding regions to form an outward bulge. Conversely, the comparatively less dense rocks of sedimentary basins tend to give rise to sea-surface depressions. Satellites carrying accurate radar altimeters map out the sea level as they orbit the earth and as the earth rotates beneath. The height variations can be transformed to Free Air Gravity. Because the ocean surface is the primary gravity sensor, there is no loss of resolution due to upward continuation effects. Although satellite derived gravity data cannot be expected to have as high accuracy or resolution as surface measurements, ARK has remarked good correlation between surface and satellite derived gravity data sets in various regions across the world. Satellite derived gravity are because of their wide coverage and ready availability ideal as a reconnaissance tool for detecting and delineating large offshore sedimentary basins, especially in virgin exploration areas.

A processed grid of Free Air gravity derived by Haxby and his coworkers at the Lamont-Doherty Geological Observatory has been used as the basis of the study presented here. The major

component of variation in Free Air Gravity maps results from water depth variations because of the large density contrast at the sea bed. This has been compensated for by applying a Bouguer correction using bathymetry data, which simulates replacing the sea water with rock of a given density. The resulting Bouguer Gravity map reflects the more subtle density variations in rocks beneath the sea bed, with for instance Bouguer Gravity lows over most sedimentary basins. It is on these Bouguer Gravity maps that interpretation has been conducted of the major crustal structure for the S.E. Asian region.

The resolution of the satellite data used is about 30 kilometers, varying slightly across the area according to the track density. Accuracy is more difficult to quantify because of oceanographic effects caused by wind, tide and currents, but is probably about 5 milligals. There is also a general degradation of the data close to land, which raises questions of the validity of some parts of the map.

This display presents the satellite derived Bouguer Gravity map of S.E. Asia, together with an interpretation of the major features seen on it, and with maps of selected regions within S.E. Asia showing the resolution that the method is capable of.

Poster 12

Structural control on facies distribution and economic deposits in the Ombilin Basin, West Sumatra, Indonesia.

CHRIS HOWELLS

Group for Geological Research in Southeast Asia, University of London, R.H.B.N.C., Egham, Surrey, U.K.

The Ombilin Basin is a Tertiary intramontane basin located within the Barisan Mountains, West Sumatra, Indonesia. It is filled with up to 4600 m (Koning & Aulia, 1985) of terrestrial and marine sediments ranging in age from the Lower Eocene to Early Miocene. The earliest part of the sedimentary succession consists of marginal fan-deltas which pass laterally into organic-rich lacustrine sediments. These sediments were deformed by an event at the end of the Eocene prior to deposition of economically significant coals with meandering river deposits that grade up into braided river deposits of Oligocene age in the northwest part of the basin. Localised uplift and erosion are reported (Koesoemadinata & Matasak, 1981) at the end of the Oligocene before deposition of marine sandstones, siltstones and isolated reefs in an outer neritic to bathyal environment during the Miocene (Koesoemadinata & Matasak, 1981).

During the earliest phase of sedimentation (Paleocene/Eocene), lateral input of sediment from the basin margins was dominant. A clear proximal to distal transition is seen from sub-aerial fan-top deposits through massive bedded debris-flow conglomerates to turbidites and lacustrine shales showing abundant soft sediment deformation and slump structures. The deformation at the end of lacustrine sedimentation (end Eocene/beginning Oligocene) was accompanied by a change to a dominantly axial drainage system and deposition of sediment by meandering and braided rivers.

Syn-sedimentary tectonics has controlled the distribution of facies and associated economic deposits and together with the change from lateral to axial drainage, has implications for oil and coal exploration. Similar intramontane basins occur throughout Southeast Asia.

Poster 13

Resources and climate-related study of the epicontinental seas of Australia and Southeast Asia

USGS

Poster 14

Photo Display

GEOLOGICAL SOCIETY OF MALAYSIA

Poster 15

Sedimentological aspects toward precise formation evaluation and testing

MOHAMED TAHA

Division Geologist, Schlumberger (Malaysia) Sdn. Bhd.

Sedimentary structures and orientation of reservoir rocks are of prime importance in defining the different origin and depositional sites of such rocks. It has been evidenced that the thickness, dip magnitude and orientation of such sedimentary structures can cause lateral permeability anisotropy and exert a great effect on the various types of open-hole logging tools. Such an effect can result in suppressing the resistivity values and generate unrealistic conventional formation evaluation results regarding fluid saturations within reservoir rocks.

The various kind of diagenesis that occur within depositional environments and during burial express a great effect on open-hole logs, especially resistivity tools. It has been found, for example, that bioturbation can suppress the resistivity measurements of sandstone reservoirs and generate unreliable results regarding hydrocarbon saturation within such reservoirs.

Testing fluvial sands, for instance, has to be carried out with care, especially with RFT tools. This is due to the fact that when fluvial channels migrate, they create lag deposits which may act as a vertical permeability barrier when cemented. Sedimentary features like slumps or over-turned bedding, load cast, and local

scours that present within a certain direction of the borehole wall can upset our RFT measurement and result in unqualifying potential reservoir rocks.

Thin laminated sequences and turbidite sediments can act as a high potential reservoir. However, and due to the low resolution of standard open-hole logs, such reservoirs normally tend to be missed, or will come with a very pessimistic potential on formation evaluation modules. Testing such sedimentary sequences using RFT tools is extremely difficult since we are dealing with 30–50 cm thick layers.

In conclusion, it seems that higher resolution and oriented open-hole logs are extremely needed for better evaluating reservoir rocks in terms of hydrocarbon saturation. In addition, it is very important to integrate the geological data that is extracted from borehole electrical images to formation evaluation modules. This can be achieved by defining the various types of heterogeneities and correcting open-hole logs responses by taking dip magnitude and azimuth of sedimentary features in consideration.

Poster 16

Fluvio-lacustrine deposits in a Tertiary intermontane basin, Thailand

DAMIEN M. STROGEN

Consortium for Geological Research in South-East Asia, University of London
Geology Department, Royal Holloway and Bedford New College, Egham, Surrey TW20 OEX, England.

Of the forty or more Cenozoic intermontane pull-apart basins within the basin and range province of Northern Thailand, the majority show a tripartite stratigraphic division of their sedimentary fills primarily constituted from fluvial and lacustrine deposits.

The Chiang Muan Basin is one such intermontane basin that is filled with an excess of 500 m of sediments. The sedimentary succession determined largely from borehole data consistently exhibits this broad tripartite division. The sediments of Mid-Miocene to recent age show a variety of lithologies and structures consistent with a transition from a lower fluvial through a lacustrine to an upper fluvial environment in response to an interaction of local tectonic and regional climatic change controls.

The lowermost coarse grained unit is a sand dominated, oxidised, red-bed sequence constituted both by the lateral input of sediment from alluvial fans and the axially derived sediments of sand braided and meandering rivers. These pass quite sharply upwards into the mud dominated unit which shows abundant pedogenic structures. This middle fine grained unit is derived largely from an axial meandering river system with localised palludal and shallow lacustrine environments. Coals, with rare and thin associated limestones, within this unit are largely restricted to a western sub-basin separated by a transverse fault from the main basin. Above this is the upper coarse grained red-bed unit containing the deposits of meandering river systems and low angle alluvial fans. This is largely similar to the lower unit and has at the top recent channel bed and terrace river deposits.

Ceramah Teknik (Technical Talks)

Liu Bingguang : Geology of gold deposits in Yunnan Province, China

Prof. Liu (Professor, Academia Sinica, Beijing) gave the above talk, a collaboration with the Geology Dept., University of Malaya on Monday 23 November 1992 at 2.30 pm.

Laporan (Report)

According to Prof. Liu, gold was discovered in the province of Yunnan, China not too long ago. The most well known gold deposit is found in the Jinchang Gold Mine of Mojiang County. The gold mineralization is found in what is known as the Ailao Mountain low pressure metamorphic belt. In the mine district, the Jinchang Formation consisting of quartzite, meta-arenite and slate take the form of an anticline trending northwest. The flanks of this anticline are occupied by the Yiwan-shui red formation while the axial region is invaded by Hercynian Jinchang magnesium-rich ultrabasic rocks consisting of enstatite-pyrolite, enstatite-peridotite and dunite which are affected by serpentinization, talcification and magnesitization. Dikes of Yanshan-Himalayan age of diabase, granite porphyry, gabbro and lamprophyre cut the older rocks in the mining district.

The Jinchang gold lode zone is found west of the ultrabasic body and it strikes NW. Its known length is 3,100 m and is from 50 m to 200 m wide. Individual ore bodies consist of gold-quartz veins, gold-quartzite-quartz veins and minor gold-talc veins.

The gold-quartz veins are hosted mainly in meta-arenite and slate and found in groups. Ore minerals found are electrum, argentite, pearceite, pyrite, hematite, galena and sphalerite. Gangue minerals are quartz, dolomite, calcite, and serpentine. Indistinct talcification is observed. The gold-quartzite-quartz veins are found confined to the quartzite and occurs as pods and statiform layers. Ore minerals are pyrite, stibnite, pyrrhotite and gersdoffite, while the gangue minerals are mainly quartz and fuchsite. Wallrock alteration consists of pyritization, silicification and deposition of the chrome hydromica.

The second gold deposit is the newly discovered Beiya gold deposit which has been classed as a contact zone intrusive body-type gold deposit as evidenced by Triassic carbonate rocks being intruded by Tertiary syenitic rocks within fault and shear zones. The intrusives take the form of stocks, boss, dikes and maybe accompanied by hydrothermal breccia. The main rock type being the micro-syenite porphyry. Mineralization takes the form of contact zone (endo- and exo-contact) ore bodies with veins carrying gold values. Minerals of the veins are pyrite, galena, sphalerite, chalcopyrite, hematite, cerussite and electrum. Grade of gold ranges from 2 to 5 g/tonne and Ag 10 to 60 g/tonne. This deposit is presently being developed for mining.

E.B. Yeap

GSM

Liu Bingguang : Gold Deposits of China

Prof. Liu (Professor, Academia Sinica, Beijing) gave the second talk, again a collaboration with the Geology Department, University of Malaya on Tuesday 24 December 1992. Prof. Liu started by mentioning that China ranks 5th or 6th in terms of gold production in the world. Most of the gold comes from hardrock gold deposits scattered throughout the whole of China.

The hardrock gold deposits in China can be classified into 5 different types, namely:

1. Greenstone-belt type
2. Fractured metamorphic rock-hosted type
3. Epithermal Carlin-type
4. Volcanogenic type
5. Contact zone of intrusive body type

1. Greenstone-Belt Type

This type is found in the North China platform and shows similarities to deposits found in Archean greenstone belt gold deposits in Canada and Western Australia. The Xiao-Qin-Ling gold deposit is hosted in Archean gneiss (Tian Hua Group) showing an EW structural trend. Surrounding igneous rocks consist of granite, syenite and diabase. It is believed that the gold mineralization took place much later (Yansan epoch) which is in contrast to other Archean greenstone belt gold deposits.

Ore bodies are quartz veins containing in addition, pyrite, galena, chalcopryrite, sphalerite and electrum (finess 913). Wallrock alteration includes K-metasomatism and silicification. Au grade range from 16-28g/tonne while Ag content range from 38 to 62 g/tonne.

The Shan-Dong gold deposits, located in the craton on the eastern part of the said province are located in mylonitized and ductile shear zones in Archean granite. These ore bodies show stratification. Ore minerals found are pyrite, chalcopryrite, sphalerite, galena, arsenopyrite, pyrrhotite, molybdenite, bismuthinite, electrum (finess 702-847). Wallrock alteration includes K-metasomatism, silicification and sericifization. Au grade is from 6-11 g/tonne while Ag content range from 11 to 1149 g/tonne.

2. Fractured Metamorphic Rock-Hosted Type

This type is found in Guangdong (South China) and Liaoning (North China) provinces. The Hetai gold deposits are found as veins in large scale mylonitized fault zone cutting (Sinian) quartzite, phyllite and low grade schist. These veins extend to considerable depths. Ore minerals include pyrite, pyrrhotite, siderite, arsenopyrite, tellurobismuth, ferraondolomite, chalcopryrite and electrum (finess - 851 to 945). Wallrock alteration includes sericifization and silicification. Au grade average 10.4 g/tonne and silver 3 g/tonne.

The Shidaogon gold deposits, in Liaoning province, is located on the eastern part of the North China platform. The deposits are hosted in Proterozoic muscovite schist, tuffaceous phyllites, meta-arenites and marble which are fractured (fragmental). They form belts and individual ore bodies may be stratiform, irregular in shape or found as veins. Ore minerals found are pyrite, pyrrhotite, scheelite, chalcopryrite, galena, arsenopyrite, quartz sericite and electrum (finess - 780 to 829). Wallrock alteration includes silicification, carbontization, K-metasomatism. Au grade ranges from 19-20 g/tonnes.

3. The Epithermal Carlin-Type

These are found in Sichuan and Guizhou provinces. The gold deposits are hosted in sedimentary rocks which are turbidites or continental slope facies rocks. These are large tonnage and low grade deposits and the gold grains can be very fine (0.5-5 μm).

The Bangi gold deposit in the Guizhou province is controlled by a fault located in an anticlinal cone. The ore bodies are found as veins and disseminations in Triassic to Permian pelites, marl and marlites cut by the fault. Ore minerals found are galena, quartz, pyrite, arsenopyrite, orpiment, realgar, cinnabar, marcasite, chalcopryrite, barite and electrum (finess 955-996).

4. The Volcanogenic Type

These are well developed in the fold belts in eastern China facing the Pacific Ocean and the Himalayas tectonic belt of China. These deposits are usually small.



Prof Liu Bingguang

The Yinkenshan gold deposit in the Zhejiang province is one example. Metamorphosed Proterozoic carbonaceous slate is overlain by Jurassic-Cretaceous dacite, dacitic breccia, granite-porphry and felsite-porphry forming a caldera structure. Most of the gold-bearing ore bodies are found in the underlying metamorphosed slate while the volcanics hosts polymetallic sulphide veins. Minerals found are rhodonite, rhodochrosite, pyrite, calaverite, galena, sphalerite, adularia and electrum. The average Au grade is 10.8 g/tonne and Ag is 19.8 g/tonne.

5. Contact Zone of Intrusive Body Type

The endo- and exo-contact zones of intrusive ore bodies can host gold deposits. The ore bodies are found as veins in the contact zones of the main alkali intrusive rocks such as syenite. These deposits are found in Yunnan province and Northern China. The Beiya deposit in Yunnan and the Dongping gold deposit located close to Zhanjikou City in North China are classed under this type. Associated minerals are pyrite galena, sphalerite, chalcopyrite, limonite, cerussite and electrum. Au grade ranges from 2–5 g/tonne and Ag ranges from 10–60 g/tonne.

E.B. Yeap

Liu Xingtu : China's Marsh Wetlands

Laporan (Report)

Prof. Liu Xingtu (Professor, Changchun Institute of Geography, Chinese Academy of Sciences) gave the above talk on 23 November 1992 at 5.45 pm at the Department of Geology, University of Malaya.

Prof. Liu started his talk by defining marsh wetland as being an area where the surface is always wet or covered by stagnant water, where helophytes and hygrophytes grow, the soil layer is extensively gleyed or there is peat formation and accumulation.

Next Prof. Liu elaborated on the classification system of marsh wetland in China into 3 categories namely, entrophic, mesotrophic and oligotrophic based on ash and pH values reflecting the nutritional status of the marsh wetland. They are further subdivided according to the hemi-helophytes, helophytes and hydrophytes. Based on the basis of marsh plant formation, China's common marsh wetlands can be subdivided into the following 12 groups – Wood-Carex, Kobresia-Carex, *Deyeuxia angustifolia*-Carex, Carex, *Cladium mariscus*, *Phragmites communis*, Scirpus, Mangrove, Pine-moss, Carex-moss, Pine-Sphagnum, Sphagnum.

Next Prof. Liu touched on the distribution of China's marsh wetlands which he indicated is widespread and unbalanced while those in east China show a zonal pattern.

He ended his talk by highlighting the environmental effects of marsh wetland, namely:

- (i) marsh wetland is a huge bio-reservoir which plays a part in reducing flood peak and evening flood course,
- (ii) regulate climate as observations show that the near daily relative humidity of marsh wetlands is 7–13% higher than that of cultivated dry farmland,
- (iii) purify water quality and
- (iv) rare waterfowls habitat and a place for fish spawning, breeding and fattening.

G.H. Teh

Prof Liu Xingtu



Timothy R. Astin : The role of diagenetic studies in hydrocarbon exploration

Laporan (Report)

The talk by Dr. Astin (Lecturer, Postgraduate Research Institute for Sedimentology, University of Reading) was held on 23 November 1992 at 5.30 pm at the Geology Department, University of Malaya, and it attracted about 30 members.

Dr. Astin's talk was useful for demonstrating the role of diagenetic studies in hydrocarbon exploration based on his study of the Bemolanga Tar Sands in Madagascar, which is the third largest tar-sand deposit in the world. The heavy tars were produced by bacterial biodegradation when the micro-organisms ate through the oil to remove the light material.

The sands were deposited as braided stream deposits with trough and tabular cross-beds in an alluvial fan setting. The dominant paleocurrent was from south to north. The fan is abutted against an upraised faulted block of metamorphic basement at the basin margin and bed thicknesses decrease away from the block with the environment changing from that of a pebbly alluvial fan to the cross-bedded sands of the alluvial plain.

The top of the tar-sands was sealed by shales probably due to a relative rise in sea-level. The oil was produced in the late Triassic and the base of the tar-sands was the former oil-water contact below which is a zone where oil is only found in the largest pores.

C.P. Lee



Timothy R. Astin



Ben M. Clennell

Ben M. Clennell : A reappraisal of the stratigraphy of Eastern Sabah

Laporan (Report)

Dr. Ben M. Clennell, who is currently with the University of Birmingham working on tectonic and hydrogeology of accretionary complexes, gave the above talk on 11th December 1992 at the University of Malaya. Dr. Clennell completed his Ph.D. on "The M \acute{e} langes of Sabah, Malaysia" in 1992.

Abstrak (Abstract)

The existing stratigraphical scheme for Sabah is a compromise between the earlier system of nomenclature into Groups, and subsequent attempts at chronostratigraphic subdivision.

The earlier scheme (largely devised by Collette, Haile and others) was unsuccessful because of the lack of biostratigraphical data, and misinterpretation of the chronostratigraphic meaning of different taxa. The old Indonesian letter classification that was used was subsequently found to be both inaccurate and misleading. This was made worse by the reliance on larger foraminifera as the primary age-determining group, because these fossils are easily reworked into younger sediments. There was also the problem of the same rock unit acquiring different names in different geographical localities (Note this appears to be of much less importance in Sabah than areas such in Sarawak or Sumatera). Some rock units were split into "Formations" artificially. For example, the Sabah Ophiolite was split into "Crystalline Basement" and "Chert-Spilitic Formation".

Later biostratigraphic work made use of the microforaminiferal record, which unfortunately is sparse in all but a few rock units. This led to a subdivision of the previously identified lithostratigraphy. As a result, some obvious lithostratigraphic boundaries lost their importance while other boundaries were created artificially, rather than being based on the main lithological differences.

The volcanic arc rocks of Sabah were largely bundled into the Segama group, and because of a lack of chronostratigraphic data, the division into an older and younger suite was not artificially delineated. Recent work indicates two main volcanic phases, but with a much longer and more continuous history of magmatism than previously thought.

The most notable problem however, was the m \acute{e} langes in eastern Sabah, which were somehow shoe-horned into three "Formations", namely the Ayer, Kuamut and Garinono Formations. The m \acute{e} langes are in fact a complex collage of dismembered sediments, ophiolite and arc rocks produced by a combination of sedimentary tectonic and diapiric processes. The time of the main m \acute{e} lange-forming episode is well delineated across eastern Sabah and it ties in both with major tectonic events (the opening of the Sulu Sea and collision at the Northwest Borneo margin) and with a major change in the depositional systems.

The work carried out by the author on the m \acute{e} langes also provided insights into the more general stratigraphic development of Sabah. New biostratigraphic work was conducted (palynology, nannofossils, microfossils), and earlier fossil assemblages re-interpreted with the benefit of newer zonal classifications.

A new appraisal of the stratigraphy of Sabah is called for, as the current definition of lithological units confuses the true geological and tectonic history of the area. The fact that many of the first-order lithostratigraphic units which can be recognised are time-transgressive and composed of different sub-facies (e.g. carbonate, clastic and volcanoclastic) should be recognised more clearly and not obscured by unwarranted subdivision.

BERITA-BERITA PERSATUAN News of the Society

Keahlian (Membership)

The following applications for membership were approved:

Full Members

1. N.E. Birkett
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2. Frank Yong
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19. Felix Tongkul
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Pertukaran Alamat (Change of Address)

The following members have informed the Society of their new addresses:

1. Lim Eng Hwa
214, Lorong Polis, Pandamaran, 42000 Port
Klang, Selangor Darul Ehsan.
2. Michael R. Pillow
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3. Hamidan Bin Mat Wajib
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P/8 Kawasan Perindustrian MIEL, Bandar
Baru Bangi, 43650 Kajang, Selangor Darul
Ehsan.

Perambahan Baru Perpustakaan (New Library Additions)

The Society has received the following publications:

- | | |
|---|---|
| <ol style="list-style-type: none"> 1. Memoires pour servir a l'Explication des Cartes Geologiques et Minieres de la Belgique, Memoire no. 32, 1992. 2. Geol. Survey of Japan, vol. 43, no. 6 & 7, 1992. 3. Geol. Survey of Japan, Report no. 279, 1992. 4. AAPG Bulletin vol. 76/8, 76/9, 76/10, 76/11, 1992. 5. AAPG Explorer, Sept, Oct, Nov 1992. 6. Report of investigation no. 83 & 84, 1992. 7. Reader's guide to the geologic map of Nansihchiao sheet, scale 1:5,000. 1992. 8. The University of Kansas, Paleontological contributions nos. 1, 2, 1992. 9. Journal of Geosciences, Osaka City University, vol. 35, 1992. 10. American Museum Novitates, no. 3040, 3042, 3045, 3048 & 3049, 1992. 11. Bulletin of the National Science Museum, vol. 18, nos. 2 & 3, 1992. | <ol style="list-style-type: none"> 12. AGID, no. 69/70, 1992. 13. SOPAC News, vol. 9, no. 2, 1992. 14. Commonwealth Science Council, Sept-Oct, 1992. 15. Geology and Mineral resources of the Lumut-Teluk Intan Area, Perak Darul Ridzuan by Wong Ting Woon. 16. Geology & mineral resources of the Tanjung Malim Area, Perak Darul Ridzuan by Gan Ah Sai. 17. USGS Bulletin (1991): 1973-A-G, 1857-J; (1992): 1999, 1917-J, 1964, 1917-G, 1927, 1992, 1866, 1983, 2001, 1921, 1787-Z, 1787-W, 1990-C, 1787-R, 2027, 1877, 1787-AA, 2004. 18. USGS Prof. Paper: 1992: 1406-B, 1066-O; 1991: 1411-C. 19. USGS Circular 1992: 1059, 1989, 1079, 1990, 1078, 1076, 1071, 1080. |
|---|---|



BERITA-BERITA LAIN
Other News

INTERNATIONAL VOLCANOLOGICAL CONGRESS

IAVCEI ANKARA 1994

September, 12-16

First Circular and Call for Papers

INVITATION

The Organizing Committee, in collaboration with the under sponsorship of the International Association of Volcanology and Chemistry of Earth's Interior (IAVCEI) extends a cordial invitation to all interested in volcanology to participate in the International Volcanological Congress to be held in Ankara, Turkey, in September 1994. The geological features of Turkey, related to complex orogenic and post orogenic events taking place in the Tethyan evolution of Anatolia, makes Ankara a suitable setting for such a congress. The Committee is encouraged by the interest already expressed by scientists of various countries. Turkey is characterized by widespread young volcanism and associated plutonic activity, emplaced in both compressional and extensional regimes, and related geothermal systems and zones of mineralization. Ophiolites and natural conservation areas are also foci of attraction. The objectives of the Congress are

- * To exchange information and experience among specialists
- * To spread knowledge to wider groups of earth scientists
- * To bring together leading scientists for discussion of recent developments and problems
- * To provide an overview of the research carried out in different fields of volcanology in relation to tectonics and geophysics

TIME TABLE

Pre-Congress Excursions : September 5-11, 1994
Congress : September 12-16, 1994
Post-Congress Excursions : September 17-23, 1994

SCIENTIFIC PROGRAMME

The programme will include symposia with oral and poster presentations and pre- and post-symposium excursions. Oral presentations will include invited papers and papers selected from the submitted abstracts. The programme will emphasize presentation of data in posters accompanied by parallel short discussion sessions (complete list of Conveners will be given in the second Circular)

CONGRESS THEMES

1. Volcanic Activity in Relation to Tectonic Setting

Conveners

S. Aramaki (Japan), J.A. Pearce (UK),
F. Innocenti (Italy)

- * Rift-related volcanic activity
- * Collision-related volcanic activity
- * Subduction-related volcanic activity
- * Volcanic activity in the Mediterranean region
- * Mechanics and dynamics of ascent and eruption of magmas

2. Subduction-Related Magmas

Conveners

A. Gourgaud (France), Y. Yilmaz (Turkey),
J. Davidson (USA)

- * Isotopic and geochemical characteristics of island arc and continental margin volcanics
- * The source of arc magmas: the roles of oceanic crust, continental crust, mantle wedge and mantle diapirs
- * Melting in the continental lithosphere
- * Problems of alkaline and calc-alkaline volcanic associations

3. Magmatism Within Plates

Conveners

M. Wilson (UK), L. Gülen (USA)

- * Isotopic and geochemical models of magmatism in rift systems
- * Role of various lithospheric and asthenospheric source components in the petrogenesis of the primary magmas

4. Pyroclastic Flows and Falls

Conveners

J.L. Bourdier (France) M. Fytikas (Greece)
M.N. Gündoğdu (Turkey)

- * Mode of emplacement and rheology of pyroclastic flows
- * Subaerial pyroclastic falls
- * Pyroclastic eruptive systems

5. Tephrochronology and Geochronology

Conveners

M. Satir (Germany), W.D. Huff (USA)

- * Advances in tephrochronology and geochronology
- * Long distance correlation of tephra
- * Obsidian dating

6. Submarine Volcanism

Conveners

H. Schmincke (Germany)

- * Volcanic processes in mid-ocean ridges and back-arc basins
- * Submarine pyroclastics and marine ash layers
- * Petrogenesis of submarine lavas
- * Magma storage reservoirs

7. Volcanic Hazards

Conveners

R.W. Johnson (Australia), R.I. Tilling (USA),
F. Barberi (Italy)

- * Lava, pyroclastics, nuées ardentes, lahars and toxic gases
- * Environmental impact
- * Hazard assessment; volcanic precursors

8. Volcano-Geophysics

Conveners

P. Gasparini (Italy), R. Schick (Germany)

- * Seismological monitoring in volcanic environments, earthquakes of volcanic origin
- * Prediction of volcanic eruptions
- * Heat flow studies in volcanic regions
- * Tomographical studies of magma reservoirs

9. Experimental Petrology

Conveners

A. Kilinç (USA), M.Z. Çamur (Turkey)

- * Experimental approach to magma genesis
- * Partial melting under different physical conditions
- * Experimental studies concerning mantle evolution
- * Mantle differentiation and continental growth
- * Volatile distribution in magma chambers, role of CO₂ and H₂O in magma genesis

10. Ore Deposits Related to Volcanism

Conveners

P.M. Black (New Zealand), L.A. Larson (USA)

- * Relationship between volcanism and mineralization
- * Volcanogenic massive sulphides
- * Epithermal deposits
- * Gold deposits associated with geothermal activities
- * Geothermal energy and gas systems

11. Tethyan Ophiolites

Conveners

E.M. Moores (USA), J. Malpas (Canada),
A. Panayitou (Cyprus)

- * Volcanism in the Tethyan ophiolite belt

12. Conservation Problems of Volcanic Sites

Conveners

J. Keller (Germany), G. Pasquare (Italy),
M. Sözen (Turkey)

- * Conservation of natural monuments in volcanic regions
- * International cooperation for solutions
- * Cappadocia

13. Other Topics

A general session will be held for the subjects which are not included in the above Congress themes.

EXCURSION PROGRAMME

Reasonable comfort and economy will be prime considerations in organizing the excursions.

Pre-Congress Excursions

5-11 September, 1994

1. Neogene magmatism, geothermal fields and related ore deposits (Western Anatolia)
2. Strike-slip tectonics and related volcanism in Erzincan area (Eastern Anatolia)

Post-Congress Excursions

17-23 September, 1994

3. Neogene-Quaternary volcanics of Cappadocia
4. Neo-Tethyan arc volcanism in Eastern Pontides
5. Ophiolites and Quaternary volcanics (Hatay)

GENERAL INFORMATION

LANGUAGE

The official language of the Congress is English. There will be no simultaneous translation.

REGISTRATION FEE

The registration fee will be around US\$250. There will be a special fee for students. Accompanying persons will pay a reduced fee.

ACCOMMODATION

Hotel accommodation will be arranged upon request by the Tourist Bureau of METU. Hotel

rates range from \$40 to \$100. More expensive luxury hotels are also available. Limited accommodation will be available for young participants in the student dormitories and the guest houses in the Campus.

DEADLINE

The enclosed preliminary registration form should be returned to the Organizing Secretary by April 1, 1993.

The Second Circular and full details will be sent only to applicants who responded to the First Circular.

FINANCIAL ASSISTANCE

Financial assistance will be provided for graduate students, young scientists and for those from volcanically active developing countries.

CORRESPONDENCE

Please address all correspondence to

Dr. Ayla Tankut
Organizing Secretary
International Volcanological Congress
IAVCEI Ankara 1994

Department of Geological Engineering,
Middle East Technical University 06531 Ankara,
TURKEY.

Telephone : 90 (4) 210 10 00 Ext. 2682-2679

Facsimile : 90 (4) 286 86 28

Telex : 42761 odtk tr

E-mail : atankut@trmetu.bitnet

KALENDAR (CALENDAR)

1993

► April 1993

◆◆◆ April 1-3

FRACTALS AND DYNAMICS SYSTEMS IN GEOSCIENCES (International Meeting), Frankfurt/Main, Germany (Jörn H. Kruhl, Geology-Paleontology Institute, JW Goethe-University, Senckenberganlage 32, D-6000 Frankfurt/Main, Germany. Phone: 0049-69-7982695)

◆◆◆ April 1-30

COMPUTER SIMULATED MINERAL EXPLORATION (22nd Workshop), Fontainebleau, France. (L. Zanone, Ecole des Mines de Paris, CGGM-IGM, 35, rue Saint-Honoré, 77305 Fontainebleau Cedex, France. Phone: (33 1) 64 69 49 30; telefax: (33 1) 64 69 47 01; telex: 694 736F)

◆◆◆ April 4-8

REMOTE SENSING AND GLOBAL ENVIRONMENTAL CHANGE (25th International Symposium), Graz, Austria. (Dorothy M. Humphrey, ERIM, P.O. Box 134001, Ann Arbor, MI 43113-4001, USA. Phone: (313) 994-1200, ext. 2290; telefax: (313) 994-5123)

◆◆◆ April 5-8

GLOBAL WARMING, int'l. mtg., Chicago. (Sinyan Shen, Natural Resource Management Division, SUPCON International, One Heritage Plaza, Woodridge, Ill. 60517-0275. Phone: 708/910-1551; 419/372-8207. Fax: 708/910-1561)

◆◆◆ April 17-20

INTEGRATED METHODS IN EXPLORATION AND DISCOVERY (International Conference), Denver, Colorado, USA. (SEG Conference '93, P.O. Box 571, Golden, CO 80402, USA. Telefax: (303) 279-3118)

◆◆◆ April 21-25

GEOSCIENCE EDUCATION AND TRAINING (International Conference), Southampton, UK. (Mrs. Esther Johnson, GEOED Conference Secretariat, Department of Geology, University of Southampton, Southampton S09 5NH, UK. Phone: (0703) 593049; telefax: (0703) 593052; telex: 47662 SOTONU G)

◆◆◆ April 19-23

REMOTE SENSING, int'l mtg., Enschede, The Netherlands, by international Institute for Aerospace Survey and Earth Sciences, and others. (Myriam Fahner, Box 6, 7500 AA Enschede, The Netherlands. Phone: 31-53-874 255. Fax: 31-53-874 436) Deadline for manuscripts: March 11.

◆◆◆ April 25-28

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS (Annual Meeting), New Orleans, Louisiana, USA. (Convention Department, AAPG, Box 979, Tulsa, OK 74101, USA. Phone: (918) 584-2555; telefax: (918) 584-0469)

► May 1993

◆◆◆ May 5-8

PROTECTING THE EARTH - CHALLENGES TO SCIENCE AND TECHNOLOGY (1st International Fair and Congress), Köln, Germany. (Alfred-Wegener-Stiftung zur Förderung der Geowissenschaften, Wissenschaftszentrum Ahrstraße 45, Postfach 20 14 48, D-5300 Bonn 2, Germany. Phone: 02 28/302-260; telefax: 02 28/302-270; telex: 885 420 wzd).

◆◆◆ May 5-8

GEOTECHNICA '93 (International Symposium), Cologne, Germany. (Hans Teetz, Cologne International Trade Fairs Inc., 21st Floor, 666 Fifth Ave., New York, NY 10103-0165, USA. Phone: (212) 974-8836; telefax: (212) 974-8838)

◆◆◆ May 15-21

ENVIRONMENTAL HYDROLOGY AND HYDROGEOLOGY (2nd USA/CIS Joint Conference), Arlington, Virginia, USA. (Americal Institute of Hydrology, 3416 University Avenue, SE, Minneapolis, MN 55414-3328, USA. Phone: (612) 379-1030; telefax: (612) 379-0169)

◆◆◆ May 17-19

GEOLOGICAL ASSOCIATION OF CANADA/ MINERALOGICAL ASSOCIATION OF CANADA (Joint Annual Meeting), Edmonton, Alberta, Canada. (J.W. Kramers, Alberta Geological Survey, P.O. Box 8330, Station F, Edmonton, Alberta T6H 5X2, Canada. Phone: (403) 438-7644; telefax: (403) 438-3644)

◆◆◆ **May 25–June 15**

BASIN TECTONIC AND HYDROCARBON ACCUMULATION (International Conference), Nanjing, China. Professor Shi Yangshen, Department of Earth Sciences, Nanjing University, Nanjing, China. Phone: 86–25–634651, ext. 2890; telefax: 86–25–302728; telex: 34151 PRCNU CH. Or David Howell, U.S. Geological Survey, 345 Middlefield Road, MS 902, Menlo Park, CA 94025, USA. Phone: (415) 354–5430; telefax: (415) 354–3224)

◆◆◆ **May 31–June 2**

APPLIED MINERALOGY, int'l. mtg., Perth, Western Australia. (Jim Graham, ICAM '93, Private Bag, P.O. Wembley 6014, Australia. Phone: 619/387-0371)

▶ **June 1993**◆◆◆ **June 1–5**

GEOTECHNICAL ENGINEERING (International Meeting), St. Louis, Missouri, USA. (Norma R. Fleming, 119 ME Annex, University of Missouri, Rolla, MO 65401-0249. Phone: (314) 341-6061; (800) 752-5057. telefax: (314) 341-4992)

◆◆◆ **June 7–16**

SUBCOMMISSION ON CARBONIFEROUS STRATIGRAPHY 1993 FIELD AND GENERAL MEETING (International Symposium), Liège, Belgium, and field excursions to Belgium, Germany, and the Pyrenees in France. (Dr. M. Streel, Paléontologie, Université de Liège, 7 Place du Vingt-Août, B-4000 Liège, Belgium)

◆◆◆ **June 20–27**

ZEOLITES (International Meeting), Boise, Idaho, USA. Sponsored by International Committee on Natural Zeolites. (F.A. Mumpton, Dept. of Earth Sciences, State University of New York, Brockport, 14420. Phone: 716/395-2635; 716/637-2324. Fax: 716/395-2416)

◆◆◆ **June 21–25**

ROCK ENGINEERING (Meeting and Workshop), Lisbon, Portugal. Sponsored by the International Society for Rock Mechanics. (Luis Ribeiro e Sousa, Portuguese Society for Geotechnique, Laboratório Nacional de Engenharia Civil, Av. do Brasil, 101, 1799 Lisboa Codex Portugal. Phone: 848 2131; telefax: 89 76 60)

◆◆◆ **June 28–July 2**

INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS: HYDROGEOLOGY

OF HARD ROCKS (24th IAH Congress), Oslo, Norway. (Geological Survey of Norway, P.O. Box 3813, Ullevål Hageby, N-0805 Oslo, Norway. Phone: 47–2–950895)

▶ **July 1993**◆◆◆ **July**

ENVIRONMENTAL CONTEXT OF HUMAN EVOLUTION (International Scientific Congress and Exhibition), The Netherlands and Indonesia. (Dr. Hans Beijer, Geological Survey of The Netherlands, P.O. Box 157, NL-2000 AD Haarlem, The Netherlands. Telefax: 31 23 351614)

◆◆◆ **July 5–8**

ROCK FRAGMENTATION BY BLASTING (4th International Symposium), Vienna, Austria. (Dr. H.P. Rossmannith, Institute of Mechanics, Technical University Vienna, Wiedner Hauptstraße 8–10/325, A-1040 Vienna, Austria. Phone: (222) 588 01 5514 or 5519; telefax: (222) 587 5863)

◆◆◆ **July 5–9**

FLUVIAL SEDIMENTOLOGY (5th International Conference), Brisbane, Australia. (Continuing Professional Education, The University of Queensland, Queensland 4072, Australia. Phone: 61 7 365 7100; telefax: 61 7 365 7099; telex: UNIVQLD AA40315)

◆◆◆ **July 5–16**

VERY LOW GRADE METAMORPHISM: MECHANISMS AND GEOLOGICAL APPLICATIONS (IGCP Project 294 Thematic Meeting and Field Excursions), Xi'an, People's Republic of China. (Dr. Wu Hanquan, Xi'an Institute of Geology and Mineral Resources, 116 Easy Youyi Road, Xi'an 710054, People's Republic of China)

◆◆◆ **July 17–24**

GEOLOGICAL AND LANDSCAPE CONSERVATION, int'l. mtg., Great Malvern, U.K. (Margaret Phillips, The Company, St. John's Innovation Centre, Cowley Road, Cambridge CB4 4WS. Phone: (0223) 421124. Fax: (0223) 421158)

◆◆◆ **July 18–23**

CLAY CONFERENCE (10th International Conference in conjunction with Commission VII of the International Soil Science Society), Adelaide, South Australia. (Dr. Tony Eggleton, Geology Department, ANU, GPO Box 4, Canberra, ACT 2601, Australia)

◆◆◆ July 25-30

ORIGIN OF PARENTAL ANORTHOSITE MAGMAS, TECTONIC AND METAMORPHIC PROCESSES IN THE EVOLUTION OF ANORTHOSSITES (Conference), Kadalaksha, Kola Peninsula, Russia. Sponsored by International Geological Correlation Programme Project 290. (Michael Higgins, Sciences de la Terre, Université du Québec à Chicoutimi, Chicoutimi, Québec G7H 2B1, Canada. Phone: (418) 545-5012)

▶ August 1993

◆◆◆ August

INTRAPLATE VOLCANISM: THE POLYNESIAN PLUME PROVINCE (International Workshop), Tahiti, French Polynesia. (Workshop Tahiti 1993, C. Dupuy, Centre Géologique et Géophysique, Case 060, Université de Montpellier II, place E. Bataillon, 34095 Montpellier Cedex 5, France. Phone: (33) 67-634-983; telefax: (33) 67-523-908)

◆◆◆ August 1-6

GEOCHEMISTRY OF THE EARTH SURFACE (3rd International Symposium), University Park, Pennsylvania, USA. (Lee Kump, Department of Geosciences, Pennsylvania State University, 210 Deike Bldg., University Park, PA 16802, USA. Phone: (814) 863-1274; telefax: (814) 865-3191)

◆◆◆ August 4-7

PALEOZOIC MICROVERTEBRATES (IGCP Project-328) (2nd International Symposium), Berlin, Germany. In conjunction with the birthday anniversary of Professor Walter Gross. (Dr. S. Turner, Queensland Museum, P.O. Box 3300, South Brisbane, Qld 4101, Australia. Telefax: 617 846 1918. Or Prof. H. Jaeger, Museum für Naturkunde, Invalidenstr. 43, 00-104 Berlin, Germany)

◆◆◆ August 8-12

STRATIGRAPHIC RECORD OF GLOBAL CHANGES: CLIMATE, SEA LEVEL, AND LIFE (SEPM Meeting), University Park, Pennsylvania, USA. (Mike Arthur, Department of Geosciences, Pennsylvania State University, University Park, PA, 16802, USA. Phone: (814) 865-6711)

◆◆◆ August 11-15

GEOSCIENCE IN URBAN DEVELOPMENT (International Conference), Beijing, China. (Professor Wang Sijing, Chairman LANDPLAN IV, Institute of Geology, Academia Sinica, P.O.

Box 634, Beijing 100029, China. Phone: 86-1-2027766; telefax: 86-1-4919140; telefax: 22474 ASCHI CN c/o Institute of Geology)

◆◆◆ August 15-19

CARBONIFEROUS TO JURASSIC PANGAEA: A GLOBAL VIEW OF ENVIRONMENTS AND RESOURCES (International Symposium), Calgary, Alberta, Canada. (Dr. Benoit Beauchamp or Dr. Ashton Embry, Geological Survey of Canada, 3303 33rd St. NW, Calgary, Alberta T2L 2A7, Canada. Phone: (403) 292-7190; telefax: (403) 292-4961)

◆◆◆ August 23-29

GEOMORPHOLOGY (3rd International Conference), Hamilton, Ontario, Canada. (3rd International Geomorphology Conference, Department of Geography, McMaster University, Hamilton, Ontario L8S 4K1, Canada. Phone: (416) 525-9140, ext. 4535; telefax: (416) 546-0463; E-mail: GEOMORPH)

◆◆◆ August 23-29

COASTAL SEDIMENTOLOGY (Meeting), Hamilton, Ontario, Canada. (William F. Tanner, Dept. of Geology B-160, Florida State University, Tallahassee, FL 32306, USA) Phone: 904/644-3208)

◆◆◆ August 28-September 15

LANDSLIDES (International Meeting and Workshop), Czech and Slovak Federal Republic. (ICFL-C.S. Landslides '93, c/o NOVOSAD IG/EG, I. Sekaniny 1801, CS-70800 Ostrava 4, Czechoslovakia. Phone: (42-69) 473028; telefax: (42-2) 381848)

▶ September 1993

◆◆◆ September 5-11

NUCLEAR-WASTE MANAGEMENT, int'l mtg., Prague, Czech and Slovak Federal Republic, by American Society of Mechanical Engineers, Czech and Slovak Mechanical Engineering Society, and the Czech and Slovak Nuclear Society. (Radovan Kohout, Ontario Hydro (H11 A2), 700 University Ave., Toronto, Ontario M5G 1X6. Phone: 416/592-5384. Fax: 416/592-4485)

◆◆◆ September 6-8

STRUCTURES AND TECTONICS AT DIFFERENT LITHOSPHERIC LEVELS (International Conference), Graz, Austria. (Wolfgang Unzog, Department of Geology, University of Graz, Heinrichstrasse 26, A-8010 Graz, Austria. Phone: 43 316 380 5584; telefax: 43 316 38 28 85)

◆◆◆ September 8-13

JURASSIC GEOLOGY (Arkell International Symposium), London, UK. (Dr. Stewart Brown, Conference Secretary, Petroleum Science and Technology Institute, 25 Ravelston Terrace, Edinburgh EH4 3EX, UK. Phone: 031 451 5231; telefax: 031 451 5232)

◆◆◆ September 8-17

LAYERING IN IGNEOUS COMPLEXES - WAGER AND BROWN 25th ANNIVERSARY COMMEMORATIVE MEETING (Symposium), Johannesburg, South Africa. (Professor R. Grant Cawthorn, Department of Geology, University of the Witwatersrand, P.O. Wits 2050, Republic of South Africa. Phone: 11 716 2711 or 2608; telefax: 11 339 1697 or 430 1926)

◆◆◆ September 14-16

AFRICAN GEOLOGY (16th International Colloquium), Ezulwini, Swaziland. (The Chairman or Secretary, Organizing Committee, 16th Colloquium of African Geology, P.O. Box 9, Mbabane, Swaziland. Phone: 42411; telefax: 45215; telex: 2301 WD; telegram: GSM)

◆◆◆ September 21-23

ANDEAN GEODYNAMICS (2nd International Symposium), Oxford, UK. Sponsored by University of Oxford and Institut Francais de Recherche Scientifique pour le Développement en Coopération (Orstom). (Pierre Soler, ISAG 93, Orstom, CS1, 213 rue Lafayette, 75480 Paris Cedex 10, France. Telefax: 33 1 48 03 08 28)

◆◆◆ September 25-October 1

INTERNATIONAL ASSOCIATION OF VOLCANOLOGY AND CHEMISTRY OF THE EARTH'S INTERIOR (Meeting), Canberra, Australia. (IAVCEI ACTS, GPO Box 2200, Canberra ACT 2601, Australia. Phone: 61 6 257-3299. Fax: 61 6 257-3256)

◆◆◆ September 27-30

ENVIRONMENTAL BIOGEOCHEMISTRY (11th International Symposium), Salamanca, Spain. (Dr. J.F. Gallardo Lancho, I.E.T./CSIC, Aptdo. 257, Salamanca 37071, Espana, Spain. Phone: (923) 219606; telefax: (923) 219609)

◆◆◆ September 27-29

GLOBAL BOUNDARY EVENTS (Interdisciplinary Conference of IGCP Project 293, Geochemical Marker Events in the Phanerozoic), Kielce, Poland. (Barbara Studencka, Muzeum Ziemi PAN, Al. Na Skarpie

20/26, 00-488 Warszawa, Poland. Phone: (4822) 217-391; telefax: (4822) 297-497. Or Helmut H.J. Geldsetzer, Geological Survey of Canada, 3303-33rd St. NW, Calgary, Alberta T2L 2A7, Canada. Phone: (403) 292-7155; telefax: (403) 292-5377)

◆◆◆ September 28-October 1

ENVIRONMENTAL POLLUTION (International Conference), Barcelona, Spain. (ICEP Conference Office, ICTR Secretariat, 11-12 Pall Mall, London SW1Y 5LU, UK. Phone: 44 71 930-6825; telefax: 44 71 976-1587; telex: 925312 REICO)

▶ October 1993

◆◆◆ October 4-9

BASIN INVERSION (International Conference), Oxford, UK. (James G. Buchanan, British Gas Exploration and Production Limited, 100 Thames Valley Park Drive, Reading, Berkshire RG6 IPT, UK. Phone: 0734-353222; telefax: 0734-353484; telex: 846231)

◆◆◆ October 10-15

INTERNATIONAL ASSOCIATION FOR MATHEMATICAL GEOLOGY (Silver Anniversary Meeting), Prague, Czechoslovakia. (John C. Davis, Kansas Geological Survey, University of Kansas, Lawrence, KS 66047, USA. Phone: (913) 864-3955; telefax: (913) 864-5317; E-mail: john_davis.moore_@msmail.kgs.ukans.edu. Europe, Africa, and Asia: Jan Harff, Institute for Baltic Sea Research, Seestr. 15, 0-2530 Warnemuende, Germany. Phone: 49 381 58 261; telefax: 49 381 58.336; E-mail: harff@geologie.io-warnemuende.dbp.de)

◆◆◆ October 11-24

INTERGEMS '93 (2nd International Symposium on Precious and Decorative Stones), Prague, Czechoslovakia. Sponsored by Czech and Slovak Geological Services and Museums. (Secretariat INTERGEMS, Malostranske nam. 19, CS-11821 Praha 1, Czechoslovakia. Phone: 535 357; telefax: 533 564)

◆◆◆ October 17-20

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS (International Meeting), The Hague, The Netherlands. (AAPG, Box 979, Tulsa, OK 74101, USA. Phone: (918) 584-2555; telefax: (918) 584-0469)

◆◆◆ **October 18-23**

NEW DEVELOPMENTS IN GEOTHERMAL MEASUREMENTS IN BOREHOLES (Meeting), Klein Koris, Germany. (Prof. E. Hurtig, GFZ Potsdam, Telegrafenberg A45, 0-1561 Potsdam, Germany. Phone: 49 331 310 347; telefax: 49 331 310 610; E-mail: gth@gfz-postsdam.dbp.de)

◆◆◆ **October 25-28**

GEOLOGICAL SOCIETY OF AMERICA (Annual Meeting), Boston, Massachusetts, USA. (Vanessa George, GSA, P.O. Box 9140, Boulder, CO 80301, USA. Phone: (303) 447-2020)

▶ **November 1993**◆◆◆ **November 15-30**

LOW TEMPERATURE METAMORPHISM: PROCESSES, PRODUCTS AND ECONOMIC SIGNIFICANCE (IGCP Project 294 Thematic Meeting), Santiago, Chile. (Professor M. Vergara, Universidad de Chile, Departamento de geologia y Geofisica, Casilla 13518-Correo 21 Santiago, Chile. Telefax: 56 2-6963050)

1994

◆◆◆ **June 6-10**

EUROPEAN ASSOCIATION OF EXPLORATION GEOPHYSICISTS (56th Annual Meeting and Exhibition), Austria Center, Vienna, Austria. (Evert Van der Gaag, Business Manager, European Association of Exploration Geophysicists, Utrechtseweg 62, NL-3704 HE Zeist, the Netherlands. Phone: (03404) 56997; telefax (03404) 62640; telex:33480)

1995

◆◆◆ **May 29-June 2**

EUROPEAN ASSOCIATION OF EXPLORATION GEOPHYSICISTS (57th Annual Meeting and Exhibition), Glasgow, UK. (Evert van der Gaag, European Association of Exploration Geophysicists, Utrechtseweg 62, NL-3704 HE Zeist, The Netherlands. Phone: (03404) 56997; telefax: (03404) 62640; telex: 33480)

GEOLOGICAL SOCIETY OF MALAYSIA PUBLICATIONS

Back Issues Available

- Bulletin 1** (1968). 79 p. Studies in Malaysian Geology. Edited by P.H. Stauffer. A collection of papers presented at a meeting of the Geological Society on 31st January 1967. Price: M\$3.00. **Out of Stock.**
- Bulletin 2** (1968). 152 p. Bibliography and Index of the Geology of West Malaysia and Singapore by D.J. Gobbett. Price: M\$10.00 (US\$5.00) - Softcover, M\$15.00.
- Bulletin 3** (1970). 146 p. Papers in Geomorphology and Stratigraphy (with Bibliography supplement). Edited by P.H. Stauffer. Price: M\$10.00.
- Bulletin 4** (1971). 100 p. Papers in Petrology, Structure and Economic Geology. Edited by P.H. Stauffer. Price: M\$10.00.
- Bulletin 5** (1973). 70 p. The Search for Tungsten Deposits by K.F.G. Hosking. Price: M\$10.00.
- Bulletin 6** (1973). 334 p. Proceedings, Regional Conference on the Geology of Southeast Asia. A collection of papers, Kuala Lumpur, March, 1972. Edited by B.K. Tan. Price: M\$22.00 - hardcover only.
- Bulletin 7** (1974). 138 p. A collection of papers on geology. Edited by B.K. Tan. Price: M\$12.00.
- Bulletin 8** (1977). 158 p. A collection of papers on geology. Edited by T.T. Khoo. Price: M\$12.00.
- Bulletin 9** (1977). 277 p. The relations between granitoids and associated ore deposits of the Circum-Pacific region. A collection of papers presented at the IGCP Circum-Pacific Plutonism Project Fifth Meeting. 12-13 November 1975, Kuala Lumpur, Edited by J.A. Roddick & T.T. Khoo. Price: M\$25.00. **Out of stock.**
- Bulletin 10** (1978). 95 p. A collection of papers on the geology of Southeast Asia. Edited by C.H. Yeap. Price: M\$10.00.
- Bulletin 11** (1979). 393 p. Geology of Tin Deposits. A collection of papers presented at the International Symposium of 'Geology of Tin Deposits', 23-25 March 1978, Kuala Lumpur. Edited by C.H. Yeap. Price: M\$50.00.
- Bulletin 12** (1980). 86 p. A collection of papers on geology. Edited by G.H. Teh. Price: M\$20.00.
- Bulletin 13** (1980). 111 p. A collection of papers on geology of Malaysia and Thailand. Edited by G.H. Teh. Price: M\$20.00.
- Bulletin 14** (1981). 151 p. A collection of papers on geology of Southeast Asia. Edited by G.H. Teh. Price: M\$30.00.
- Bulletin 15** (1982). 151 p. A collection of papers on geology. Edited by G.H. Teh. Price: M\$30.00.
- Bulletin 16** (1983). 239 p. A collection of papers on geology. Edited by G.H. Teh. Price: M\$30.00.
- Bulletin 17** (1984). 371 p. A collection of papers on geology. Edited by G.H. Teh. Price: M\$35.00.
- Bulletin 18** (1985). 209 p. Special Issue on Petroleum Geology. Edited by G.H. Teh & S. Paramanathan. Price: M\$30.00.
- Bulletin 19 & 20** (1986). GEOSEA V Proceedings Vols. I & II, Fifth Regional Congress on Geology, Mineral and Energy Resources of Southeast Asia, Kuala Lumpur, 9-13 April 1984. Edited by G.H. Teh & S. Paramanathan. Price for both Bulletins 19 & 20: Members - M\$50.00, Non-Members - M\$125.00.
- Bulletin 21** (1987). 271 p. Special Issue on Petroleum Geology Vol. II. Edited by G.H. Teh. Price: M\$40.00.
- Bulletin 22** (1988). 272 p. Special Issue on Petroleum Geology Vol. III. Edited by G.H. Teh. Price: M\$40.00.
- Bulletin 23** (1989). 215 p. A collection of papers on the geology of Malaysia, Thailand and Burma. Edited by G.H. Teh. Price: M\$35.00.
- Bulletin 24** (1989). 199 p. A collection of papers presented at GSM Annual Geological Conference 1987 and 1988. Edited by G.H. Teh. Price: M\$35.00.
- Bulletin 25** (1989). 161 p. Special Issue on Petroleum Geology Vol. IV. Edited by G.H. Teh. Price: M\$40.00.
- Bulletin 26** (1990). 223 p. A collection of papers presented at GSM Annual Geological Conference 1989 and others. Edited by G.H. Teh. Price: M\$40.00.
- Bulletin 27** (1990). 292 p. Special Issue on Petroleum Geology Vol. V. Edited by G.H. Teh. Price: M\$40.00.
- Bulletin 28** (1990). 292 p. Special Issue on Petroleum Geology Vol. VI. Edited by G.H. Teh. Price: M\$40.00.
- Field Guide 1** (1973). A 7-day one thousand mile, geological excursion in Central and South Malaya (West Malaysia and Singapore). 40 p. by C.S. Hutchison. Price: M\$5.00.
- Abstracts of papers** (1972). Regional Conference on the Geology of Southeast Asia, Kuala Lumpur, 1972. 64 p. 8 figs, 3 tables, many extended abstracts. Edited by N.S. Haile. Price: M\$6.00.
- Proceedings of the Workshop on Stratigraphic Correlation of Thailand and Malaysia Vol. 1.** (1983). Technical Papers. 383 p. Price: M\$25.00 (Members: M\$12.00).
- WARTA GEOLOGI** (Newsletter of the Geological Society of Malaysia). Price: M\$5.00 per bimonthly issue from July 1966.
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BULETIN PERSATUAN GEOLOGI MALAYSIA

BULLETIN OF THE GEOLOGICAL SOCIETY OF MALAYSIA

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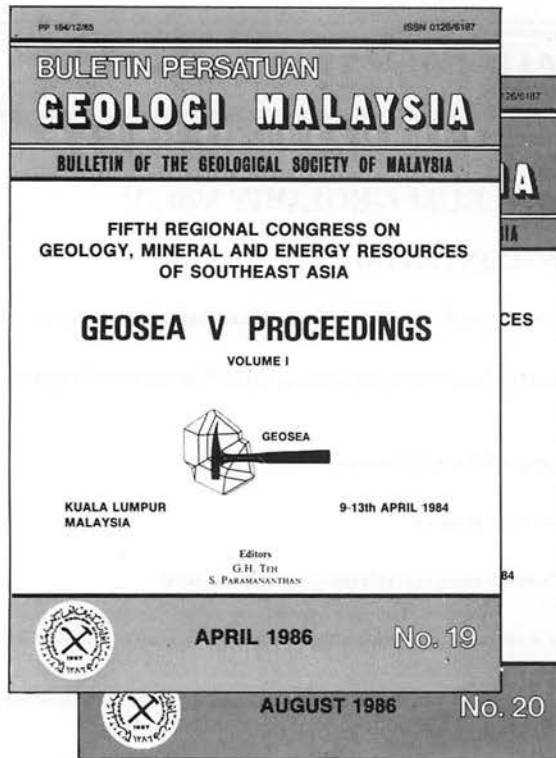
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Sep-Okt 1988

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