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KESATUAN KAJIBUMI MALAYSIA

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GEOLOGIC NOTES

Siderite spherulites from Ayer Hitam, Selangor

K.F.G. Hosking, Department of Geology, University of Malaya

Recently Mr Wong Yoke Fah gave the writer a sample of the coarse fraction obtained by sieving material obtained during Banka drilling on the Ayer Hitam dredging site, Selangor. The nature and genesis of some of the components of this sample form the basis of this note.

A cursory examination of the sample by the naked eye and then under a binocular microscope indicated that it consisted essentially of sub-angular grains of quartz, varying in size from c. 100 microns to c. 1.5 mm, and yellowish, crudely spherical bodies, which were provisionally identified as siderite and subsequently this identification was shown to be essentially correct. These spherulites represented about 5 per cent of the sample and varied in size, but were, for the most part, c. 1 mm in diameter.

The sample under review, and similar ones, were obtained from grey sandy clays and clayey sands, in all 23 feet thick, overlying limestone. A bed of grey, peaty, sandy clay immediately overlies the siderite-bearing beds. The complete sequence of sediments, as reported in the bore log, is given in Table 1.

TABLE 1

(By permission of Mr Wong Yoke Fah)

Depth from surface in feet		
0 - 15	Decomposed vegetation with some brown clay	
15 - 25	Brown clay with some fine sand	
25 - 30	Brown clayey sand	
30 - 35	Brown, mainly coarse sand	
35 - 45	Brown clayey sand	
45 - 50	Grey sandy clay	
50 - 55	Grey peaty sandy clay	
55 - 60	Grey sandy clay	) siderite
60 - 65	Grey clayey sand	) spherulites
65 - 75	Grey clay with some fine sand)	present
78	Limestone bedrock	

Thin sections revealed the following characters of the spherulites:

i. Their sections are crudely spherical and they possess serrated peripheries due to the fact that the latter consist of projecting crystal terminations.

ii. Most of the spherulites are isolated bodies, but a few 'doublets' with a common 'straight' boundary occur, and one 'triplet' has been seen.

iii. The spherulites lack nuclei, and all consist of radiating crystals. They are further characterised by a mosaic of largely cleavage-dependent fractures.

iv. If the inclusions, noted below, are ignored, most of the spherulites consist of pale yellow siderite throughout. Occasionally, however, a spherulite may have a core composed of dark powdery material embedded in siderite. This material, which has also been examined in polished section is non-metallic, and probably carbonaceous or argillaceous. Occasionally a spherulite may show one or two narrow concentric arcs of reddish-brown iron oxide, and rather more frequently diffuse rays of red, orange, and brown iron oxide are to be seen. Some of these latter can be traced from the periphery towards the centre, but on other occasions they are confined to the core and intermediate zone. Rarely, a few opaque veinlets are to be seen extending a little in from the periphery, and these commonly follow cleavage planes in the carbonate. These, and certain other small and rare opaque inclusions are seen, in polished section, to consist of pyrite, and are discussed further below.

v. Whilst some spherulites are free from inclusions, others may contain from a few to many. These inclusions are almost solely quartz. A few muscovite inclusions occur and also the occasional one consisting of pyrite. Usually the quartz inclusions are appreciably smaller than the majority of the free quartz fragments of the sample. They are randomly disposed and orientated, and not infrequently they display a pull-apart texture, having been first fractured by the stresses imposed on them by the growing carbonate crystals and then cemented by the siderite. It is possible that some slight replacement of the quartz by the siderite has occurred locally, as, on occasion is seen in ooliths from the iron ore of Lorraine (Bubenicek, 1964). All the muscovite inclusions are fan-shaped due to the splaying out of the mica flakes by the crystallising siderite.

In one instance a quartz fragment was seen to 'sit' across the join of two spherulites. Occasionally, also, a quartz fragment projects from the spherulite host.

Polished sections of briquetted spherulites, and of the whole sample, confirmed many of the observations made above, and, in addition, provided the following data:

i. A few of the spherulites contain small inclusions of pyrite. These consist of framboids in various stages of disarray, and are possibly part-replaced by siderite, and provide textures reminiscent of squashed raspberries. Individual pyrite crystals are only a micron or so across.

ii. As noted earlier, small veinlets of pyrite are seen very occasionally extending locally a little way in from the periphery of a given spherulite. Their disposition has been largely determined by the cleavage directions of the siderite, but under high power they are, clearly, somewhat sinuous, and may have been formed, in part, by replacement of the carbonate.

iii. In briquetted polished whole samples, in addition to quartz fragments and siderite spherulites, there are a few fragments of ilmenite and pyrite framboids, some of the latter show a high degree of ordering of their crystal components, and not infrequently 'colonies' of framboids, which in section occupy a circle, are in evidence. These 'colonies' may well have developed with plant tissue, as, for example, in the hollow 'centres' of fragments, stems and roots of some aquatic plants, and may then have been liberated and washed into the deposit from which the sample under review was obtained.

Chemical Composition

As that fraction of the spherulites which is soluble in hot HCl consists essentially of siderite, the solution resulting from such an attack was analysed for Fe, Mn, Ca and Mg by means of the A.A.S. The results, calculated as carbonates, are as follows:

$FeCO_3$	-	99.6
$MnCO_3$	-	0.3
$CaCO_3$	-	0.5
$MgCO_3$	-	0.5
		100.9

(Analysis by Mr Lee Meng Chong)

Genesis of the spherulites

The quartz, clay and minor components, other than the pyrite, comprising the sediments in which the spherulites developed, were carried into the limestone basin via a drainage system which was deriving much of its solid load from a known, neighbouring, weathered granitic mass. The pyrite framboids, which were deposited simultaneously, must have come from a slightly earlier deposited and nearby peaty deposit through which the basin-feeding streams were cutting. The Eh/pH conditions in the accumulating basin sediments were such, that, whilst they allowed pyrite to survive, they provided optimum conditions for the deposition of siderite. (Stability fields for the iron species mentioned in this paper have been established by Krumbein and Garrels (1952) and need not be discussed here.) Although still a subject of debate, it seems likely that the iron of the siderite was largely or entirely carried to the site of deposition from the peaty deposits noted above as 'ferric oxide hydrosol stabilised by organic colloids' (Pettijohn, 1957, p.460) and there the chemical environment dictated that it should be deposited as siderite.

What determined the precise siderite points of deposition is unknown: perhaps comparatively dense centres of clay behaved as nuclei, nuclei which the developing radiating crystals subsequently and generally, completely eliminated. As noted earlier, the force of crystallisation of the siderite pulled apart some of the entrapped quartz grains and partially disrupted pyrite framboids and mica books. Occasional temporary lowering of the watertable permitted certain framboids to become superficially oxidised in the manner noted earlier.

Finally, transgression of the siderite-bearing sediments by organic-rich ones, within which the chemical environment was favourable for the generation of biogenic H_2S, and iron sulphides, locally permitted

siderite near the base of the peaty zone to acquire within fractures, possibly generated by sediment loading, a deposit of what is now pyrite. It is uncertain whether this sulphide developed by direct action between H_2S-charged water and the siderite or whether a deposit of colloidal iron sulphide was carried into the fractures where it was subsequently converted to pyrite.

Conclusion

As far as the writer is aware this is the first record of such spherulites from West Malaysia.

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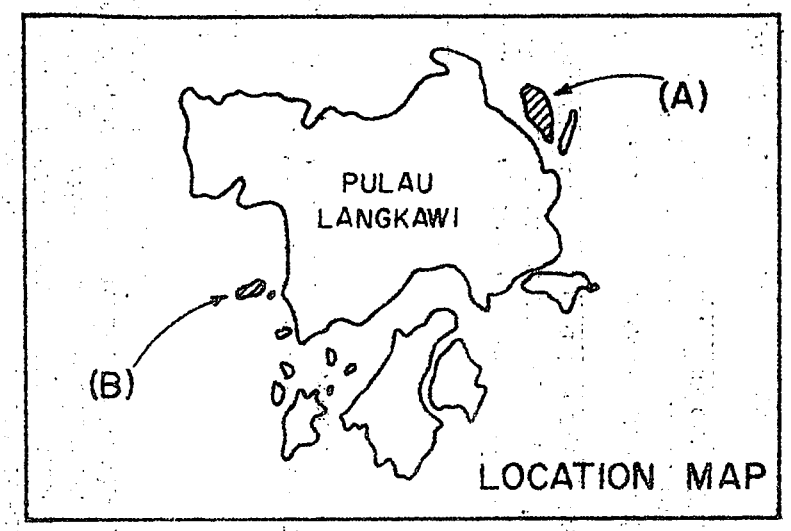
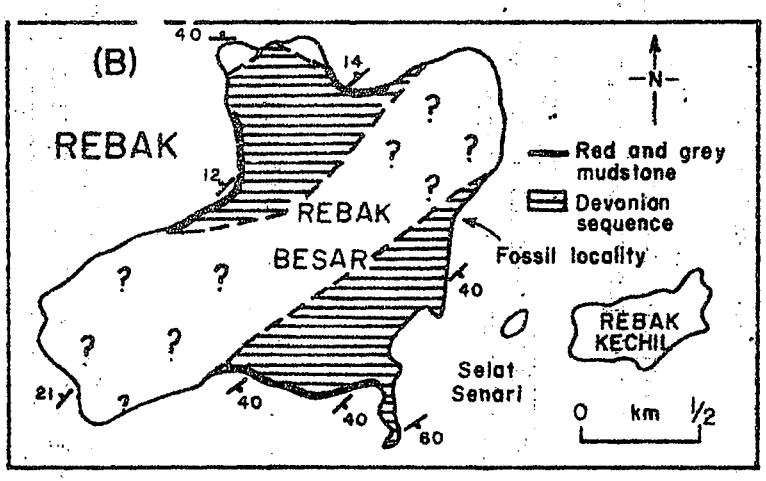
Note on the geology of the Rebak Islands (Langkawi) Kedah, West Malaysia

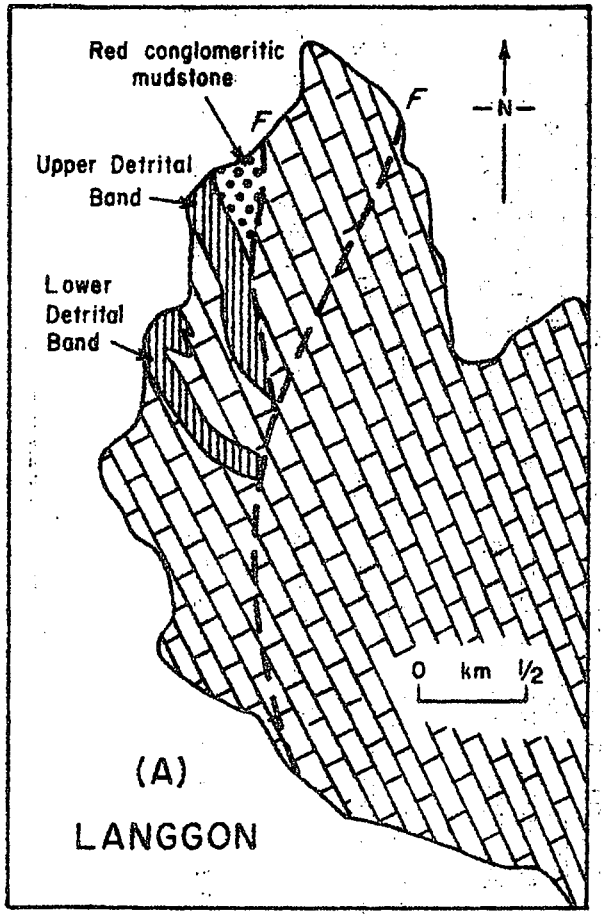
Ahmad Jantan, Jabatan Geologi, Universiti Malaya

The object of this note is to add further information to the observations made on the problems of the stratigraphy of the Rebak Islands.

Sartono (1972) is of the opinion that the rocks of the Rebak Islands are not entirely built of the Machinchang Formation, and that the rocks at the southeastern part of P. Rebak Besar, P. Selat Senari and P. Rebak Kechil (see Fig. 1B) resemble more closely to the description of the rocks of the Singa Formation. If this assumption is correct then one should have a stratigraphical contact between the Machinchang Formation and the Singa Formation in the area. This







Geology after C. R. Jones, (1966)

Figure 1

stratigraphical contact could then be found on P. Rebak Besar.

The writer, who is presently working in the area on the stratigraphy of the Singa Formation for an M.Sc. thesis project, considers that P. Rebak is more problematical than just whether it consists wholly of the Machinchang Formation or that part of it is of the Singa Formation.

The base of the Singa Formation: Jones (MS) located the base of the Singa Formation only at the northwestern coast of P. Langgun (see Fig. 1A). Here it consists of soft red mudstone of Uppermost Devonian age, supposedly unconformably overlying the Upper Detrital Member (Lower Devonian) of the Setul Formation. The contact was interpreted as an erosional unconformity.

Jones (MS) did not designate the base of the Singa Formation in the western part of the Langkawi Island Group, where the rocks of the formation are best exposed. He considered the rocks on the Rebak Islands to be wholly of the Machinchang Formation (Upper Cambrian), and the black shale on P. Tekon Baba, an island to the south of the Rebak Islands to be the lowest exposed rocks of the Singa Formation. The Setul Formation is absent here, and the Singa Formation oversteps the Setul Formation to lie directly on the Machinchang Formation. The contact is postulated to be probably under the sea.

The Rebak Islands: If one took a boat around Rebak Besar, one would get the impression that the island is underlain predominantly by hard quartzitic sandstone, except for the southeastern cape and the northwestern bay. This is because sandstone blocks and boulders mar the underlying bedrock, and appear as though they make up the underlying bedrock. The southeastern cape consists of soft yellow-brown mudstone, siltstone and fine sandstone, similar to the rocks at P. Selat Senari and P. Rebak Kechil. The northwestern bay, which Sartono did not visit, consists of soft red and grey mudstone very much resembling the red mudstone at P. Langgun. From such an examination one may be led to form an opinion that the soft, yellow mudstone and siltstone on one hand, and the hard sandstone on the other belong to separate sedimentary formations.

One need only walk along the coast, preferably at low tide around P. Rebak Besar, to realise that the island is in fact to a large extent underlain by soft mudstone, both red and grey. Sandstone occurs as interbeds, which in only a few cases are more than 5 m thick, but which form the more resistant and prominant beds, deluding one's observation. The mudstones are mainly clay. The contact between the mudstone and sandstone is always sharp. No unconformity is so far met, and there could possibly be no unconformity at all.

Nik Mohamed, S. S. Sarkar and T.E. Yancey (personal communication) on a field trip during early March 1972, found fossil brachiopods and bivalves (Posidonia sp.) in the mudstone from P. Rebak Besar (fossil locality shown in Fig. 1). This proved beyond doubt the presence of post-Cambrian clastic sedimentary sequence in P. Rebak Besar. At the present stage of work, the rocks of P. Rebak Besar, except that at the southeastern cape, appear to belong to one sedimentary sequence.

Implications and problems: The fossil finds at P. Rebak Besar point out Jones' mistake in classifying the rocks of the Rebak Islands as wholly of Cambrian sequence, the Machinchang Formation, Devonian sequence is also present at the Rebak Islands. Known Upper Paleozoic clastic sedimentary formation in the Langkawi Island Group is the Singa Formation, which is Uppermost (or probably Middle) Devonian to Lower Permian.

The question arises as to which sedimentary formation the Devonian sequence in the Rebak Islands belongs. Does it represent the basal sequence of the Singa Formation which Jones was not able to recognise in the western part of the Langkawi Island Group, or is it a formation by itself?

The writer is still working in this area.

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CONFERENCES

Regional Conference on the Geology of Southeast Asia - March 1972

Report on Meeting

The largest and most ambitious meeting which the Society has ever attempted to organise was held in Kuala Lumpur in late March. With a final total of 260 registered participants, the meeting was rather larger than had been expected. Many of these participants were from overseas, and especially gratifying was the large number of geologists from other Southeast Asian countries who were able to attend. For many of us in Malaysia it provided our first chance to meet and discuss regional geology with colleagues from Burma, Vietnam, the Philippines, India, as well as Thailand and Indonesia.

The meeting was formally opened on 20 March by the Deputy Prime Minister and Minister of Home Affairs, Y.B. Tun Dr Ismail bin Dato Haji Abdul Rahman, who made special mention in his remarks of the role that indigenous geologists have to play in the development of the region.

About forty-five papers were presented in the technical sessions spread over six days. The variety of topics dealt with - many aspects of the geology of a vast and only partly known region - can be seen from the abstracts volume. Despite this diversity, there was a fabric of relatedness, and a definite theme emerged in the Conference. This theme was appropriately first stated in Warren Hamilton's keynote address: "Plate tectonics of Southeast Asia and Indonesia". Hamilton lucidly explained the plate tectonics hypothesis and the now almost overwhelming evidence in favour of it, thus setting up a model for others to apply. Much of the discussion during the meeting was in fact concerned with attempts to apply and test these ideas against the geology of this region.

At first, however, the plate tectonics model seemed to produce only divisiveness. There seemed to be no common language between those participants who had accepted the model and used its terminology habitually, and those who spoke in classical terms of geosynclines and orogenes. The wide differences in mental frames of reference was spotlighted by the presentation of the various national tectonic maps (mostly in draft form). The degree to which plate tectonics ideas are incorporated in these maps ranges from zero to one hundred percent, and those maps which do not incorporate plate tectonics themselves follow different sets of ideas. But as the discussions went on, concepts were clarified, barriers of terminology broken down, and differences narrowed, so that

by the end the participants all seemed engaged in a common endeavour of testing plate tectonics against the real world of Southeast Asian geology. It was not concensus but it was effective communication, and the endeavour will surely be continued by many of the participants in their own areas. The meeting thus had a degree of unity, and plate tectonics was the thread that tied it together.

In spite of the unexpectedly large size of the meeting, and the Society's inexperience in hosting such gatherings, the Regional Conference must be considered a great success. A large debt of gratitude is owed by the Society to all who helped make it so, especially the generous commercial companies who gave money, the University of Malaya and its Geology Department for offering fine facilities, and of course the Organizing Committee of the Conference, under the chairmanship of Dennis Taylor, last year's President of the Society.

P.H. Stauffer

Report on post-conference field excursions

A. East Coast, Monday, 27 March to Sunday, 2 April, 1972:

This post Congress field excursion was highly successful and well worth the effort put into its organization. There was a total of 19, made up as follows:

Leaders: Dr C.S. Hutchison of the University of Malaya, and
Mr Gan Ah Sai of the Malaysian Geological Survey

Participants:

Mr Asril Stahbuddin, Djakarta, Indonesia
Mr Wibisono, Djakarta, Indonesia
Mr Rab Sukamto, Bandung, Indonesia
Mr V.V. Sastri, Dehra Dun, India
Mr Andre Cournut, Bandar Masin, Kal. Sel., Indonesia
Mr C. Desreumaux, Pnom Pehn, Cambodia
Mr E.H. Bon, Billiton N.V., the Hague, Holland
Mr C.A. Laughton, West Australia
Mr M.M. Shouls, Chiengmai University, Thailand
Mr and Mrs E.P. Utting, West Australia
Mr D.R. Muerdter, Geological Survey of Malaysia
Mr Don Walcott, U.S. Geological Survey in Celebes, Indonesia

Mr R.E. Sweet, Mobil Oil, Princeton, USA
Dr D.J. Gobbett, Sedgwick Museum, Cambridge, U.K.
Mr Frank Hooper, Gulf Oil, Singapore
Bus driver: Ahmad Kamal Badarudin, University of Malaya

The purpose was to study an almost complete sequence of rocks in the Malayan geosyncline ("eugeosyncline").

Accommodation was at the Government Rest Houses, except in Singapore when the Hotel merlin was used.

Transport included a University bus and landrover.

Day One : Route: Kuala Lumpur to Raub. Lower Palaeozoic to Devonian Schist Series, ophiolites, Genting Highlands ignimbrite, Foothills Bentong Group. Limestone near Raub.

Day Two: Route: Raub-Benta-Temerloh-Kuantan
Benta. Migmatite of the Malayan catazone, Triassic formations near Kerdau and Temerloh. Unconformity at Jenka Pass. Kampong Awah Permian andesitic agglomerate. Tembeling Formation. Upper Palaeozoic metasediments near Gambang.

Day Three: Route: Kuantan to Sungei Lembing
Underground tours of P.C.C.L. tin mine in morning. Tour of mill in afternoon. Return route to Bukit Bangkong magnetite skarn mine, then to basalt near Beserah, north of Kuantan.

Day Four: Route: Kuantan to Mersing. Rhyolitic agglomerate at Nenasi, Panti-Lesong Cretaceous sandstone and shale at Bukit Bangkong on road to Ulu Rompin. Coastal section at Kampong Penyabong, southeast of Endau of rhyolite tuff sequence and basalt sill.

Day Five: Route : Mersing to Johore Bahru
Mersing coastal section of isoclinally folded Permo-Carboniferous metasediments. Granite quarry near Jemaluang. Pelapah Kanan iron-tin mine near Lombong. Waterfall outcrops of granite-metasediment contact.

Day Six: Route: Johore Bahru to Singapore
Gabbro-granite contact on Bukit Panjang and Bukit Gombak. Swee quarry in gabbro and norite; Poh Hin quarry in hornblende gabbro, Jurong quarry where numerous granite dykes and veins cut and assimilate the gabbro. Afternoon free for sightseeing in Singapore at the request of participants.

Day Seven: Excursion broke up after breakfast in Hotel Merlin.

A complete field guide has been prepared for the excursion. The Society may publish this field guide in the near future.

One of the features of the excursion was that a continual comparison of Malayan geology was possible with Cambodia to the north and the Indonesian islands to the south. Many rock formations were found to be closely similar.

In particular the similarity of the Permo carboniferous, the Triassic, the Tembeling Formation, and the Panti Sandstone to formation in neighbouring countries became apparent during discussions on the outcrops.

This was a most memorable and happy field excursion. The participants expressed a wish that the Society could organize similar activities more frequently, and that the Society would from now on concern itself with the larger region rather than solely with Malaysia.

C.S. Hutchison

B. North-west Malaya, Monday 27 March to Sunday 2 April 1972

Leaders : Dr T.E. Yancey, Department of Geology, University of Malaya, Kuala Lumpur

Mr Yap Fook Loi, Geological Survey of Malaysia

Participants:

Miss Suzanne Hill - New South Wales, Australia
Mr and Mrs F. Fletcher - Perth, West Australia
Mr and Mrs K. Summers - - do -

Mr and Mrs W. Jones	- Perth, West Australia
Mr and Mrs D.K. Malcolm	- - do -
Mr H.F. Doutch	- Bureau Min. Res., Australia
Dr Fritz Baum	- Geol. Survey, Germany
Mr Hideo Kido	- Japex Co., Japan
Mr Toshio Tanabe	- Petr. Dev. Corp., Japan
Mr I.P.H. Silitonga	- Geoloical Survey, Indonesia
Mr C. Burk	- Mobil Oil, Princeton, New Jersey,USA
Miss L. Burk	- New Jersey, USA

Driver : Enche Harun bin Salleh, University of Malaya

This trip was attended by 16 participants from many areas with some coming from the United States, Germany, Japan and Indonesia, but the bulk of the participants were Australians. They brought with them the Australian love of beer at any occasion, and this helped greatly to smooth out the rough edges of a trip carried out in crowded land rovers or crowded boats. There was a great group spirit among the participants and everybody enjoyed the trip very much despite certain discomforts inevitable in such travels. Although the group was international in origin, many of the participants had worked or are working in Malaya, Sumatra, or Thailand.

The trip covered the distance from Kuala Lumpur, the site of the Conference, to the Langkawi Islands in the northwest corner of the country, and ended on Penang Island. Throughout the trip the emphasis was placed on seeing the stratigraphy of the Paleozoic and Lower Mesozoic (Triassic), and on determining the geologic history of the region. After passing several exposures of sedimentary rocks or metasediments and being asked what are these rocks and not being able to answer the question, it became obvious that much remains to be learned of the detailed geologic history. Thereafter the trip assumed more the character of a task force trying to determine as much as possible of the geologic history of the region.

The trip started at Kuala Lumpur and made its first stop at Rawang, to examine a stratigraphic sequence related to the stratigraphy of the Kuala Lumpur area. The next series of stops were in the Kinta Valley where the stratigraphy of the limestone units was examined. The next day was spent in the Kuala Kangsar area and Taiping area, where stops were made to examine the Quaternary volcanic ash, granites of Main Range, and several stops to examine the Triassic Semanggol Formation which is so well exposed there. This segment covered the youngest geology encountered on the trip.

The following day was spent in Perlis examining the Devonian to Permian stratigraphy. Following this were two days spent in the Langkawi Islands spent examining the Ordovician to Devonian stratigraphy on Pulau Langgun, and the Carboniferous to Permian stratigraphy of the south portion of the Langkawi Islands.

The variability and great thickness of the Semanggol Formation were features that impressed many people; also the abundance of rhythmic bedding and characters of basinal infilling, interbedded with sediments typical of normal shallow water environments. This same confusion was encountered when examining the Carboniferous Singa Formation on the Langkawi Islands. The Singa Formation is unique in that it contains abundant slump structures and large clasts scattered in fine grained matrix (diamictrite), but it also contains sedimentary features traditionally interpreted as deep water and shallow water origin. Maybe another field trip will place this in better perspective.

A very significant gain in understanding was made when examining the Devonian section at Gunong Hutan Haji in Perlis and on Pulau Langgun. We spent one day in N.W. Pulau Langgun examining the Ordovician to Devonian section, and the consensus of opinion (which I support) is that the section is continuous and complete (although condensed) from Ordovician to Upper Devonian, without unconformity. The Devonian strata at Gunong Hutan Haji does not require an unconformity to explain its position in regards to the Ordovician rocks (they are separated by one mile's distance, and the existence of an unconformity in the Devonian in northern Malaya is cast into extreme doubt. The Devonian section appears to be quite thick, but composed mostly of fine mudstones and shales, and consequently poorly exposed.

T.E. Yancey

NEWS OF THE SOCIETY

Schedule of meetings for 1972:

With the successful Regional Conference behind us, it is time to look ahead to the remainder of the Society's year. It is hoped that some of the interest and excitement stirred up during the Conference can be maintained through the other meetings planned. The Council of the Society has agreed on the following tentative schedule:

26 May	: Evening discussion session
21 July	: Evening discussion session
22 September	: Evening discussion session
November or December	: Ipoh discussion meeting
January 1973	: Annual General Meeting

The three planned evening discussion sessions represent a new type of meeting: organized by one or a few people, each will feature brief, provocative, and informal presentations, and emphasis will be on lively discussion. We hope to select topics sufficiently timely, important and controversial so that intense discussion will be stimulated.

The Director of the Geological Survey of Malaysia has kindly agreed to host once again an extended Discussion Meeting (probably two days) in Ipoh late in the year. The exact dates will be fixed later to immediately follow the Survey's Annual Conference.

Suggestions for topics, themes, and speakers for any of these discussion meetings are invited.

In addition, other meetings may be organised in order to hear speakers. Suggestions here are also welcome.

P.H. Stauffer

Field Meetings

In view of the good response received for both the week long excursions following the Regional Conference, the Council of the Society is contemplating planning more field excursions. Response to field meetings organized by the Society in previous years have not been encouraging. It is felt that members of the Society would be more likely to be interested in field excursions which would take them to places which they would not normally consider going by themselves. Perhaps what is needed is an "ambitious" field excursion planned and announced well ahead of time covering not only parts of Malaysia but also some aspects of the geology of the neighbouring areas, for example, southern Thailand or Sumatra. Such field excursions might stimulate interest and support from members, not only locally but also from outlying areas and even overseas.

Suggestions as to the possible locations for such a field excursion are invited.

New Publications

The 1 : 1,000,000 coloured geological map of West Malaysia and Singapore, compiled by Dr D.J. Gobbett, printed for inclusion with the Wiley-Interscience "Geology of the Malay Peninsula" is now available for sale through the Society. The price is $3.00 a copy plus postage.

Abstracts of papers, Regional Conference on the Geology of Southeast Asia, edited by N.S. Haile has been published by the Society for the Conference. Members of the Society who did not attend the Conference will receive their free copy together with this newsletter. Members wishing extra copies may purchased them through the Society. The price is $3.00 a copy plus postage.

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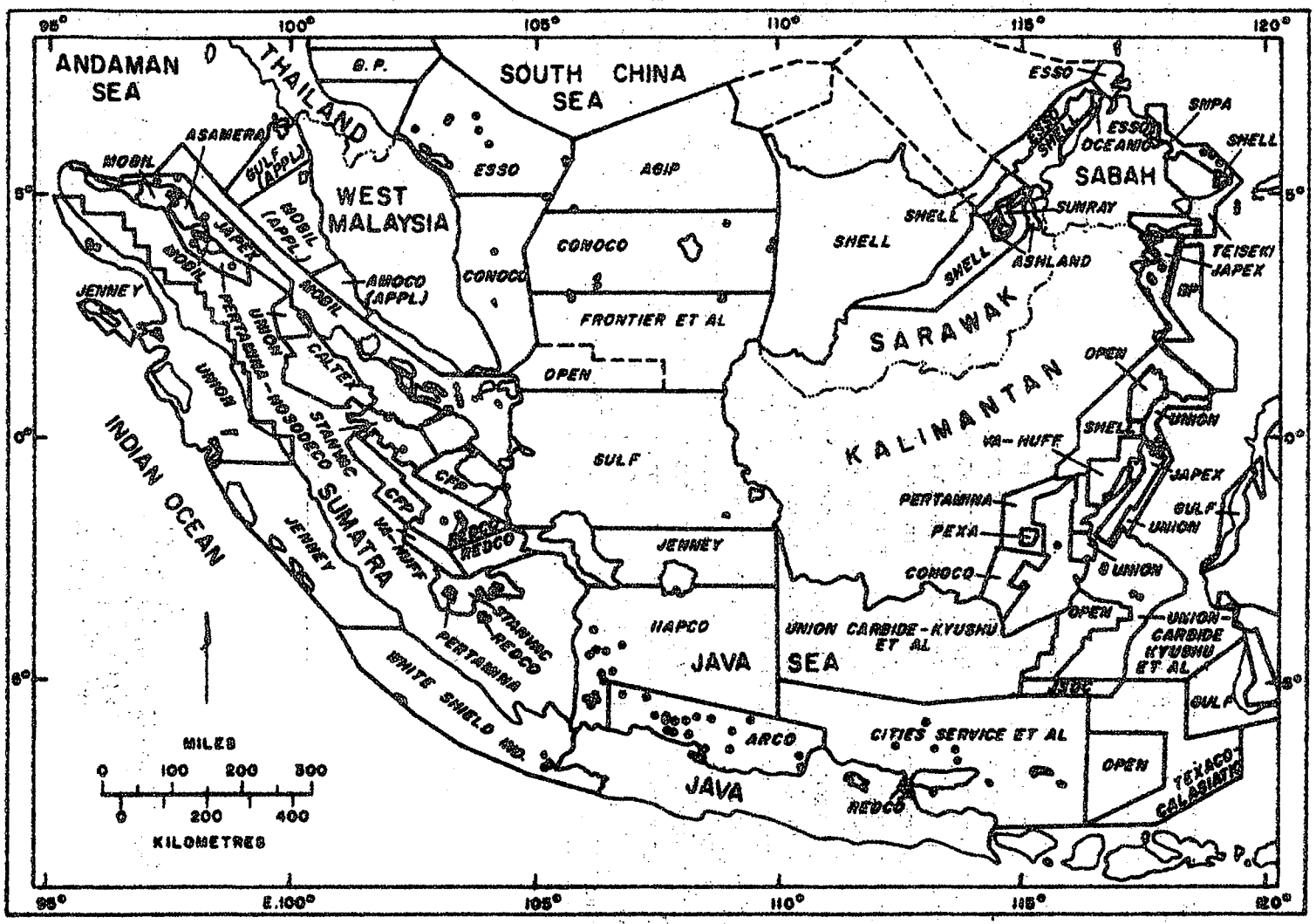
PETROLEUM DEVELOPMENTS IN FAR EAST

Humprey, Wilson, Esso Exploration Inc., Singapore

Abstract

The oil boom in Southeast Asia continued during 1970 with an increase in exploration activity, particularly drilling and seismic surveys. More than 190 exploratory wells were drilled and an increased number of seismic crews were active, as old operators evaluated their holdings and new operators began exploring. Five significant discoveries, 1 in Brunei and 4 in Indonesia, were reported. Indonesia was the area of the most activity and success as 15 operators were active on 101 exploratory tests, 20 companies conducted field activities, and 12 companies were awarded new contract areas for exploration. Boundary disputes, which could hamper exploration in the East China Sea and Korea Strait, arose during the year among Nationalist China, Japan, South Korea, and the Peoples' Republic of China. In Malaysia, an increase of 3 was noted in the number of companies drilling exploratory wells as 5 companies reported activities. The Oil and Gas Development Corporation, with operations in both wings of the country, continued to be Pakistan's most active explorer. A new cycle of exploration seems to have begun in the Philippines during 1970, 3 exploratory wells, the first since 1964, were drilled and more were planned for 1971.

Abstract and map, Brunei - Malaysia - Indonesia, Concessions and Exploratory wells 1970, reproduced by permission of American Association of Petroleum Geologist. Paper published in Bull. Amer. Assoc. Petrol. Geol., 55, p.1634-1656.



BRUNEI – MALAYSIA – INDONESIA CONCESSIONS AND EXPLORATORY WELLS 1970

LATE CENOZOIC VOLCANISM AND TECTONICS OF SUMATRA

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A potassium-argon age of 73,000 ± 12,000 years for the Toba ignimbrite sheds new light on the volcanic and tectonic history of Sumatra.

Since the Semangko fault (Great Sumatran fault) dextrally offsets the Toba ignimbrite and all older rocks about 25 km then the age of the fault must be 73,000 years old or less giving an average displacement of more than 30 cm/year.

The strato volcanoes of Sumatra are located on both sides of the Semangko fault. Those on the northeastern side have a higher potash to silica ratio than those to the southwest closer to the Java Sumatra trench. The caldera of the Toba ignimbrite lies on the northeastern edge of the fault and the ignimbrite has a similar potash to silica ratio as the strato volcanoes from the same side of the Semangko fault. The strato volcanoes and ignimbrites of Sumatra have a similar potash to silica ratio as the worldwide average of strato volcanoes that lie about 150 km above the Benioff zone. The earthquake foci under the Semangko fault range from 100 to 180 km deep.

Since the potash to silica ratio of the Toba ignimbrite is similar to the Sumatra strato volcanoes, we suggest that the potash to silica ratio in both is controlled by hydrothermal emanations from the Benioff zone.

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