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GEOLOGIC NOTES

Geology of the Rebak Islands, Langkawi, West Malaysia

D.J. Gobbett, Sedgwick Museum, Cambridge, England

I am prompted by recent papers in this Newsletter (Sartono 1972, Ahmad Jantan, 1972), to record observations I made during a complete shore traverse of the Rebak Islands in May 1963, and to discuss some of the problems involved.

The shore of Pulau Rebak Besar is dominated by a massive, medium to coarse-grained white sandstone which forms small promontories all around the island. These are connected by sandy beaches in places littered with sandstone boulders. The sandstone is extensively reddened by veins and stockworks of iron oxide, particularly in the southwest of the island and at one point lying northwest of Pulau Selat Senari (the outcrop 'opposite Selat Senari' of Sartono, 1972). Similar 'haematised' sandstone forms much of the north shore of Pulau Rebak Kechil. Interbedded with the massive white sandstone is fine-grained laminated sandstone and siltstone, often red, pink or yellow in colour but in places green. This is generally less well exposed but forms the islet off southeast Rebak Besar and Pulau Selat Senari, and is important along the southern shore of Rebak Kechil. None of these sandstones appeared current bedded.

On the northwest coast of Rebak Besar massive grey, green, yellow and red mudstone and siltstone form cliffs behind the beach. These rocks are veined with stringers of iron oxide forming a stockwork. Fine-grained sandstone beds overlying these show a gentle synclinal structure.

As shown on Figure 1, the general strike of the beds is to the northeast. However there is a considerable amount of folding, locally tight but generally open and gentle. In the southeast, dips are generally towards the southeast and in the northwest towards the north. It is difficult to derive a sequence for these rocks: because of the folding and probably undetected faulting and because the nature of the lithology makes it likely that rapid lateral changes in facies occur. The massive white sandstone may be mainly older than the finer-grained sediments but the rocks cannot be divided into more than one formation.

I cannot agree with Sartono (1972, p.3), that the rocks of Rebak Kechil and Selat Senari, and the southeast of Rebak Besar belong to a different formation to the ferruginous sandstone outcropping 'opposite Selat Senari'. All the rocks forming the Rebak Islands should be regarded as belonging to a single formation.

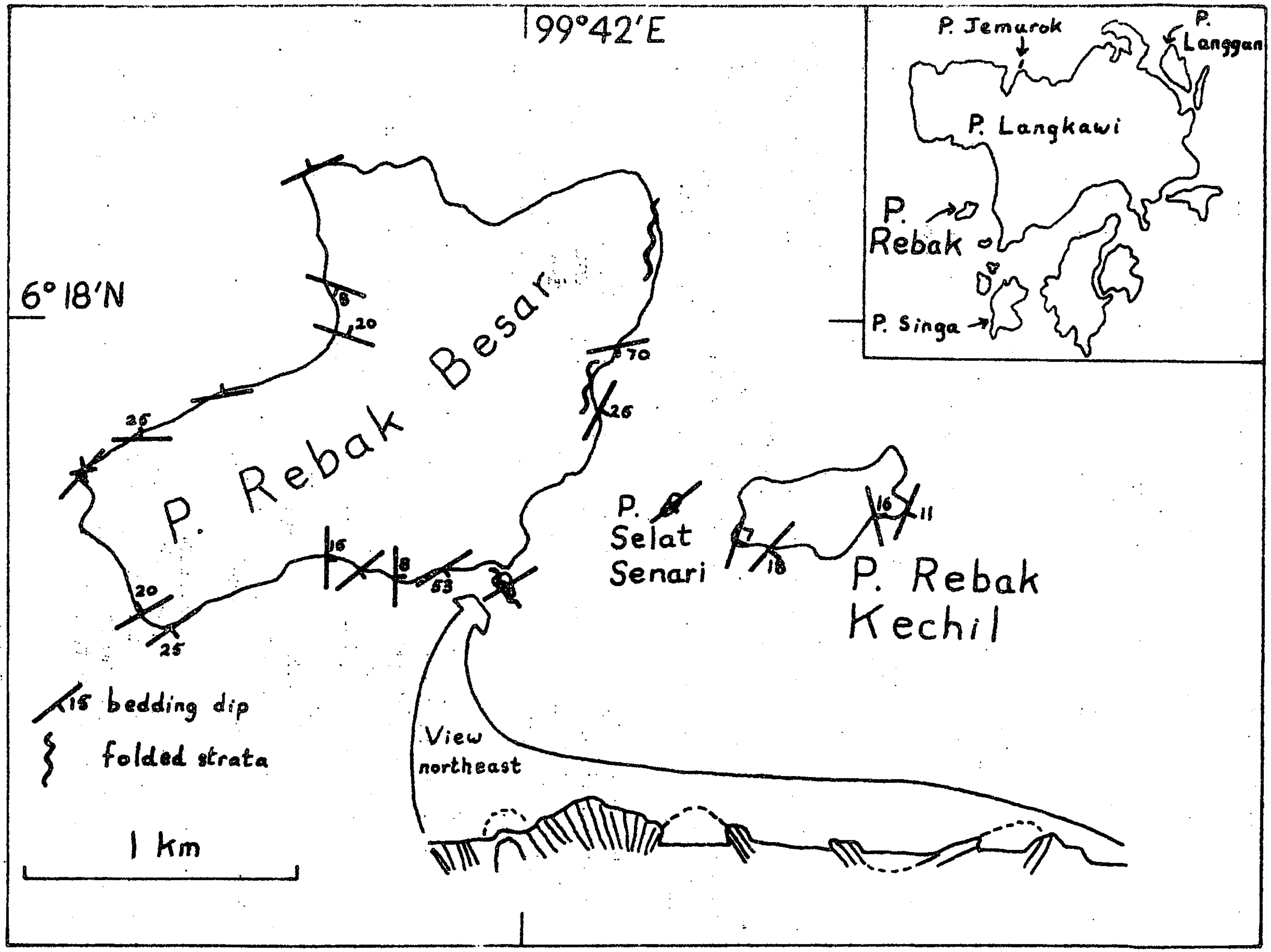

Fig 1 Geological ·ketch map of the Rebak Islands, Langkawi.

Dr T.E. Yancey has kindly informed me about the fossil find mentioned by Ahmad Jantan (1972). The collection includes Posidonia, brachiopods and ostracods. The brachiopods include small productoids of Upper Devonian type. According to Dr Yancey this fauna and the mudstone in which it occurs bears a close resemblance to the fossiliferous red mudstone of Pulau Langgun (Hamada, 1969), and thus also to the fossiliferous red mudstone of Hutan Haji in Perlis. The Langgun mudstone forms part of a sequence which has been regarded as the lowest part of the Singa Formation (Jones, 1966). This implies that the rocks of the Rebak Islands should also be included within the Singa Formation. However, this is the question raised by Ahmad Jantan (1972, p.8), and which I would like to discuss further.

For convenience we may refer to the rocks of the Rebak Islands and of the so-called basal Singa Formation on Pulau Langgun as the 'Rebanggun Beds', and the Singa Formation of the southwest Langkawi Islands as the type Singa Formation. Nowhere is the junction of these two sets of beds observed. Lithologically the 'Rebanggun Beds' are quite distinct from the overlying type Singa Formation, the lower part of which is characterised by dark coloured flaggy siltstones and black mudstones, locally with scattered pebbles. The coarser beds in the middle part of the formation are poorly cemented yellow sandstones quite unlike the resistant white sandstone of Pulau Rebak.

Although the rocks of the type Singa Formation were originally confused with the Machinchang Formation (Jones 1961, p.294), this was not through a comparison of the 'Rebanggun Beds' with the type Singa Formation. The erroneous correlation was based on a comparison of fossiliferous beds occurring in the upper part of the type Singa Formation on Pulau Singa Besar with similar beds, also fossiliferous, on Pulau Jemurok. Indeed, the upper part of the Machinchang Formation exposed on the west shore of Pulau Jemurok, is lithologically very similar to the typical Singa Formation.

The general southeasterly dip of the Pulau Rebak rocks, which averages about 20° inclination, corresponds to the dip of the type Singa Formation. However the folding (Fig. 1) on Rebak Besar has no counterpart in the Singa Formation of southwest Langkawi which has a broad, simple structure conforming to the intrusion of the Langkawi granite. The more intense minor folds on Pulau Rebak compare with the structure of rocks older than the type Singa Formation (Koopmans 1965, p.512-3).

The 'Rebanggun Beds' appear lithologically and structurally distinct from the type Singa Formation. Including them within a Singa Formation obscures the gap in the sequence below the type Singa Formation, the lowest exposed part of which may be no older than Upper Carboniferous. Also, they are separated from the Machingchang formation by several hundred metres of Setul Formation on Pulau Langgun, and by an unconformity

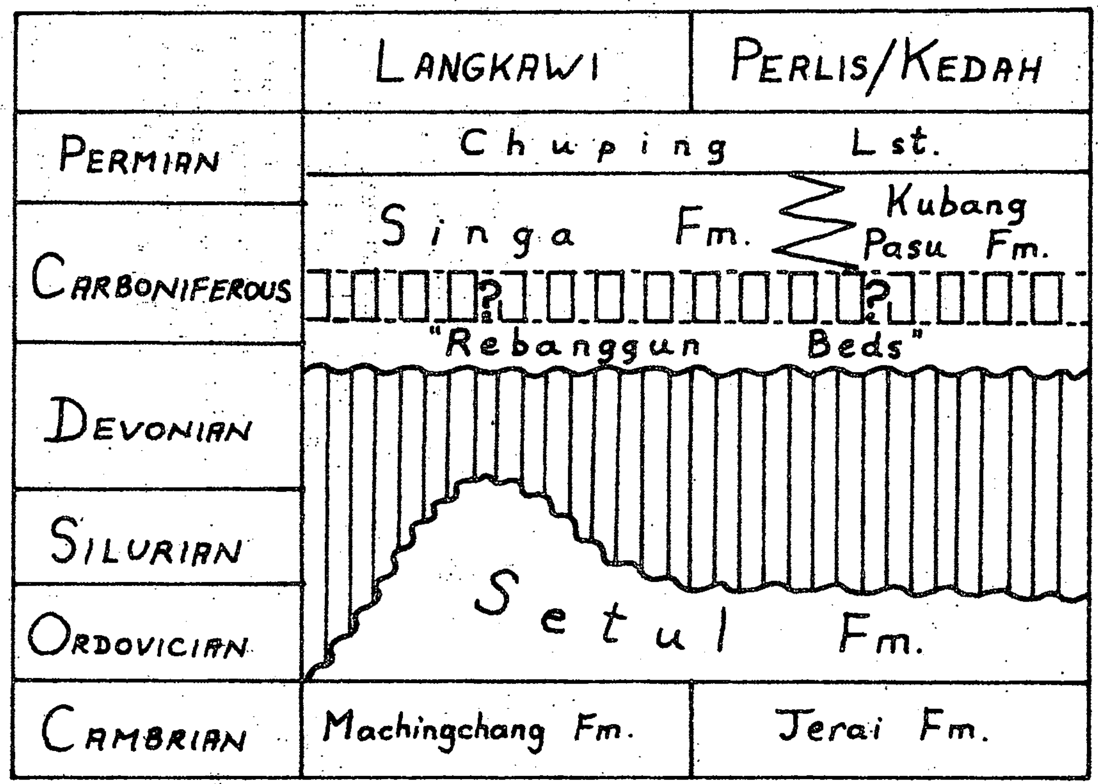

Fig. 2. Stratigraphic relations of the 'Rebanggun Beds'.

in west Langkawi. Therefore, I think it is best to consider them as a distinct formation which can be traced from Pulau Rebak to Gunong Hutan Haji in Perlis (Fig. 2).

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On the Posidonia from Rebak Islands Langkawi, West Malaysia

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While reading a paper entitled: "On the Carboniferous and Permian biostratigraphical correlation of Malaya" in the Geol. Soc. Mal. Regional Conference on the geology of Southeast Asia, Kuala Lumpur, held in March 20-25, 1972, I announced the discovery of Posidonia by me from the Pulau Rebak of Langkawi islands with the second year Geology students and discussed on the biostratigraphical correlation of the Posidonia reported before from Malaysia. The present paper is the outcome of the materials examined and collected from Langkawi.

The following is the list of species of Posidonia described or reported from Malaya and Thailand, as could be gathered from the literatures available to me:

Jurassic : Posidonia sp. ex. gr. ornati Quenstedt from West Thailand

Triassic : Posidonia kedahensis Kobayashi 1963 from Malaysia
Posidonia cfr. japonica Kobayashi and Hukasawa from Malaysia
Posidonia malayensis (vide Kobayashi, 1963, p.121, no further details given)
Posidonia sp. indet. Kobayashi and Tamura, 1968 from Singapore

Permo-Carboniferous:

Posidonia sp. aff. P. siamensis (Reed) Kobayashi 1963, from Malaysia
Posidonimya becheri var. siamensis Reed 1920, from Thailand only details of this species obtained from p.117 of Kob. 1963.

(for other reports on Posidonia,Jones, et. al., 1966 may be seen).

It has been observed that the Carboniferous species: Posidonia aff. siamensis (Reed) from Paya Mak Isun resembles the Posidonia from strata of uppermost Devonian or lowest Carboniferous age at Gunong Hutan Haji in Perlis. (Jones et al 1966 p.323). As I have not examined this bivalve from Paya Mak Isun, it is not possible for me now to endorse the views, if between Devonian and Carboniferous the Posidonia of Malaya and Thailand did undergo any specific change. Jefferies and Minton (1965) in their study of the mode of life of Jurassic "Posidonia"has shown the ontogeny of P. becheri Bronn in eight stages where the umbo has shifted the position at each stage and the shell outline has also changed in form at each stage until the adult form had been reached. As it is not always possible to determine an adult shell precisely there might be risk in depending upon the position of the umbo or the shell outline for specific determination.

A good deal of specific resemblance has been observed between the Posidonia collected from Langkawi and the Posidonia collected before from Gunong Hutan Haji of the Lower Carboniferous by the Geology Department of the University of Malaya. The specimens are well preserved but the umbos and umbonal regions are not mostly present. Although greatly handicapped by relevant literatures it is high time that these varied forms be grouped specifically and made known to other workers in these countries to facilitate their work, instead of waiting indefinitely for all the literatures. So far the figures and the collection referred to about the forms presented in this paper have not been reported before from these countries.

Posidonia elongata sp. nov. (text fig. 1 (x119)

Based on two well preserved shells, one from Langkawi and the other from Gunong Hutan Haji. The height of the shell is exceptionally long that is 11.90 cm and the maximum breadth of the shell is 4.90 cm. About 32 concentric ribs on the shell from Gunong Hutan Haji. The costation is fine with interspaces. The ribs on the specimen from Gunong Hutan Haji have mostly been broken leaving the sharp outlines while that from Langkawi do not show any such erosion and they number 27 countable ribs. The prosocline is present but not prominent. The umbo is subterminal and the outline of the shell is elongated oval. The umbonal region of the shell impression from Langkawi is not present. The hinge line truncates the outline in the specimen from Gunong Hutan Haji where the umbonal region resembles to Posidonomya alpina Gras. (Fig. 67 in Piveteau).

Posidonia dilatata sp. nov. (text fig. 2 (x2.4)

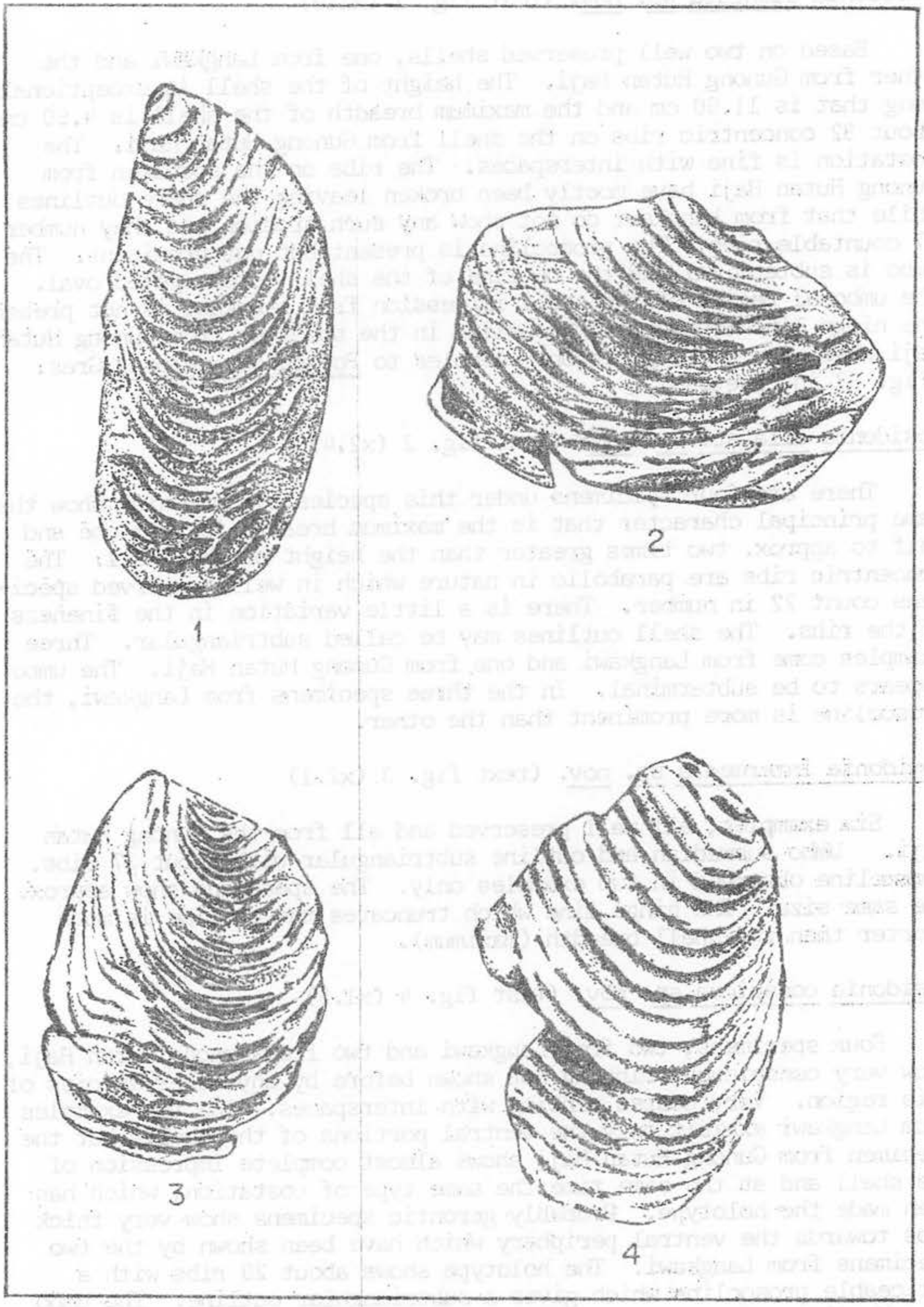
There are four specimens under this species all of which show the same principal character that is the maximum breadth is from one and half to approx. two times greater than the height of the shell. The concentric ribs are parabolic in nature which in well preserved specimens count 22 in number. There is a little variation in the fineness of the ribs. The shell outlines may be called subtriangular. Three examples come from Langkawi and one from Gunong Hutan Haji. The umbo appears to be subterminal. In the three specimens from Langkawi, the prosocline is more prominent than the other.

Posidonia intermedia sp. nov. (text fig. 3 (x2.1)

Six examples, all well preserved and all from the Gunong Hutan Haji. Umbo submedian and outline subtriangular with about 37 ribs. Prosocline observed in two examples only. The specimens show approx. the same size. The hinge line which truncates the outline is much shorter than the shell breadth (maximum).

Posidonia conspicua sp. nov. (test fig. 4 (x1.5)

Four specimens, two from Langkawi and two from Gunong Hutan Haji, show very conspicuous ribbing not shown before by any other species of this region. Very coarse ribbing with interspaces. The two examples from Langkawi exhibit only the ventral portions of the shells but the specimen from Gunong Hutan Haji shows almost complete impression of the shell and at the same time the same type of costation, which has been made the holotype. Probably gerontic specimens show very thick ribs towards the ventral periphery which have been shown by the two specimens from Langkawi. The holotype shows about 20 ribs with a noticeable prosocline which gives a subtriangular outline. The umbo is submedian.



TEXT FIGURES

A more detailed description of these forms with respective dimensions and photographs will be published soon. According to the University of Malaya, Geology Department museum record all the fossils from Gunong Hutan Haji which have been discussed here come from the Lower Carboniferous. Opinions vary on the age of the Pulau Rebak of Langkawi and since fossils have been discovered now, basing on the Posidonia reported from the Lower Carboniferous of Gunong Hutan Haji, Pulau Rebak is now provisionally assigned to Lower Carboniferous also.

As I am far away from type collections and type literatures of Posidonia, I shall appreciate any observation on the new forms presented here. Any valid observation will also be duly acknowledged in the final paper.

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Devonian fossils from Pulau Rebak Besar, Langkawi Island, West Malaysia.

T.E. Yancey, Department of Geology, University of Malaya

The age of the sedimentary rocks on Pulau Rebak Besar on the western edge of the Langkawi Island group has been the subject of two notes in the GSM Newsletter (Sartono, 1972; Jantan, 1972). Jones (1966) originally mapped both Pulau Rebak Besar and Pulau Rebak Kechil as consisting of rocks of the Machinchang Formation (Cambrian age). Later geologic mapping by Ahmad Jantan for thesis work brought the assignment by Jones into considerable doubt, and placed Pulau Rebak Kechil and at least parts of Pulau Rebak Besar in the Singa Formation (Carboniferous age).

The importance of this problem is greater than just the question of the age of rocks on one or two islands. With the strata of Pulau Rebak assigned to the Machinchang Formation and the strata of close neighboring islands assigned to Singa Formation, a structural or stratigraphic discordance is required between the two locations. In no place are any of the resistant Ordovician and Silurian limestones of the Setul Formation present, which are found elsewhere in undisturbed stratigraphic sequences. This has been taken to suggest an unconformity between the upper Paleozoic and lower Paleozoic in northern Malaya. The discovery of Devonian fossils on Pulau Rebak Besar negates these supposed items of evidence and indicates a greater thickness and extent of middle Paleozoic rocks than had been suspected previously.

In early March of this year (1972) a class field trip visited the eastern end of Pulau Rebak Besar and discovered many fossils in a mudstone horizon. John Kuna Raj and Goh Sing Thu, both students in the Department of Geology, University of Malaya, first discovered the fossils. The fossil locality is in mudstones in the intertidal zone on the beach just south of the easternmost tip of the island. The easternmost point of the island consists of a large sandbar north and south of which are exposed varying amounts of bedrock along the beach. The first outcrops south of the sandbar are, firstly, a thin sandstone unit, then a wide space of poor exposure which is floored by mudstones, and another thin sandstone unit. The fossils come from the mudstones, especially from gray mudstones near the southern sandstone outcrop and from red mudstones in the center of the mudstone outcrop. The first is locality UM A-56 and the second is locality UM A-57.

Stratigraphically the fossils were collected from about the youngest strata exposed on Pulau Rebak Besar. A regional dip is discernable for strata on the island which is a very low dip about due east. Complicating this in part are a series of small folds with E-W axes which also plunge to the east. The eastward dip is similar to the attitudes of strata on neighboring islands, and appears to be conformable with the Singa Formation exposed in these places. The strata on Pulau Rebak Besar are older than strata on neighboring islands.

The fauna recovered from these rocks is limited to five species, two of which are common. Further collecting will probably find more species but these are enough to date the strata.

Brachiopoda:

chonetid brachiopod - there is one specimen of a small chonetid with strong spines along the hinge line in the collections. This is too poorly preserved to permit critical determination, but it resembles a chonetid that Reed (1920) called _Chonetes cf. rectispina_ for fossils in Thailand.

productid brachiopod - this is a common species. The species is generically indeterminate, but is recognizable as a productid by its shape and size and presence of spines along both the hinge line and projecting laterally. The shell is small and deeply convex on the brachial valve. Based on the small size and simple form, the shells are most similar to Devonian productids. Devonian productids are restricted to the middle and upper parts of the Devonian. The primitive character of the brachiopods argues against an early Carboniferous age.

brachiopod indeterminate - there is one specimen of a non-productid, non-chonetid brachiopod in the collection.

Mollusca:

Posidonia sp. - this species is large, with strong concentric growth lines and lacking in other ornament, with a long hinge-line. It is similar to _P. siamensis_ as described by Reed (1920) although some details of hinge and ornament are not the same.

Arthropoda: A few indeterminate ostracods.

The age of the assemblage appears to be middle or upper Devonian, and is definitely post-early Devonian and pre-late Carboniferous, based on the productid brachiopods. The productids are of a type indicative of the Devonian, and appear to be too primitive to be early Carboniferous. _Posidonia siamensis_ of Reed (1920) was described as a Carboniferous fossil, and Jones and others (1966) considered the _Posidonia_ collected at Pulau Langgun and in Perlis to be of uppermost Devonian or lowermost Carboniferous age. The Posidonia from Pulau Rebak Besar appears to be identical to Posidonia collected in these other localities. Hamada (1968) described some brachiopods from Posidonia-bearing beds in Perlis, and suggested an upper Devonian age for these strata.

I would like to thank Nik Mohamed and S.S. Sarkar for their parts in leading the field trip which visited Pulau Rebak Besar and discovering the fossil locality, and to thank S.S. Sarkar for reading the manuscript and offering constructive comments.

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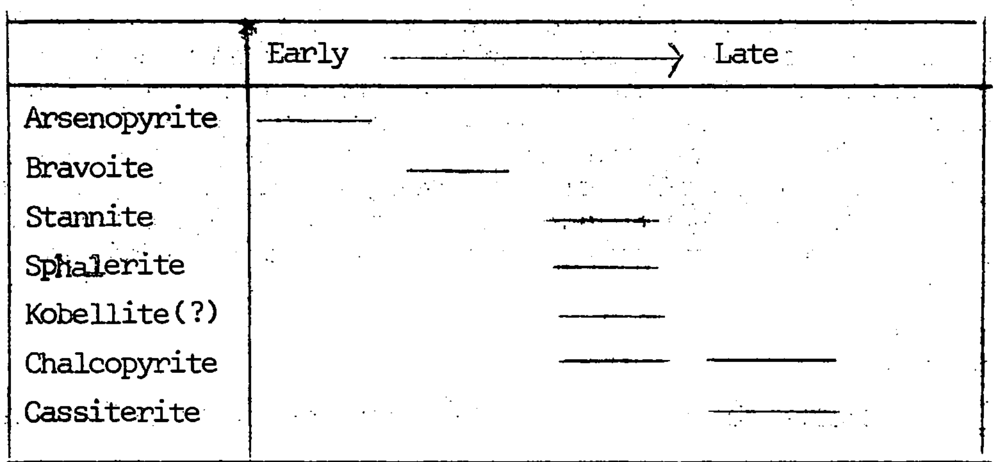
Stannite, kobellite(?), bravoite, etc., from Tanjong Tualang, Perak W. Malaysia

K.F.G. Hosking and J.H. Leow, Department of Geology, University of Malaya and McPhar Asia, 51 Kallang Place, Singapore 12

Some time ago Mr Roy McDonald of Anglo-Oriental (Malaya) Sdn. Bhd., kindly presented one of us (K.H.) with a pebble, c. 1 inch in diameter, composed of minerals with metallic lustre, which had been recovered by the No. 5 S.M.T.D. dredge in the Tanjong Tualang district of Perak.

The specimen has, clearly, been derived from a lode.

The minerals observed in a polished section of the specimen are as indicated in the following paragenesis table:



There is no doubt that the arsenopyrite and the bravoite, (Ni, Fe)S_{21}, (which in polished section is pinkish-brown and very faintly anisotropic) are the earliest members of the sequence. In one instance these two minerals were seen in contact and the impression gained was that the bravoite was deposited on the arsenopyrite.

Following the movement along the embryonic lode, which led to the fracture of the early components, the system was invaded by mineralising agents which permitted the deposition of stannite. The tetra-stannite was in part laid down around fragments of the earlier species and in part it developed by replacing arsenopyrite.

This stannite contains numerous exsolution bodies of chalcopyrite and sphalerite and a few which yield microhardness and reflectivity values consistent with them being kobellite ($5PbS. 4(Bi,Sb)_2S_3$) and which display other properties under the reflecting microscope which support this tentative identification. (On account of the invariably small size of these bodies it has not been possible to further check the their identity by micro-chemical or x-ray methods).

The concentration and character of the exsolution bodies in the stannite vary markedly from one part of the polished section to another. In certain areas only small chalcopyrite blebs occur, whilst in others comparatively large amoeba-like bodies of sphalerite, commonly fringed by chalcopyrite, are much in evidence: only occasionally is kobellite seen and although it may report as small isolated bodies it is more commonly accompanied by chalcopyrite.

Finally, and possibly following incipient fracturing, chalcopyrite replacement veins developed in the stannite. The larger of these commonly contain aggregates of minute cassiterite crystals, a feature which has often been observed in similar material elsewhere and which has given rise to the thought that both the cassiterite and the chalcopyrite may have been derived from the breakdown of the stannite (see, for example, Singh and Bean, 1967). Locally associated with the major chalcopyrite veins are swarms of small anastomasing ones of variable width, surrounding relicts of stannite and producing a beautiful mottled texture.

CONCLUSIONS

This specimen is of particular interest for the following reasons:

i. It provides yet another stannite-bearing locality in West Malaysia.

ii. It contains the first bravoite to be recorded from W. Malaysia.

iii. It contains what is believed to be kobellite, a species which has hitherto only been described from one locality (Tekka, Perak) in W. Malaysia. (See Leow, et al. 1969).

Finally it is of interest to note that during the present study certain exsolution bodies of a species not yet identified which occurs in the stannite of Wheal Rock (Cornwall, England) possess properties very similar to the Malaysian 'kobellites': this discovery is in part responsible for the present writers' endeavours to have the Malaysian and British material further examined by means of the electron probe.

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REPORT ON MEETINGS

Discussion meeting, 26 May 1972: "Petrographic, mineralogical and geochemical criteria for interpreting the geological age and tectonic level of emplacement of granites in Malaysia".

This meeting, the first of a new series of meetings on selected topics of a fundamental nature in understanding the geology of the region, was held at 8.00 p.m. on the evening of Friday, 26 May 1972 in the Department of Geology, University of Malaya. The topic was introduced by Dr C.S. Hutchison with Dr K.R. Chakraborty and Mr Ng Chak Ngoon as the other speakers.

One of the main problems encountered by petrologists in Malaysia is the difficulty of identifying the various granite bodies according to their level of emplacement and their age. Radiometric dating has so far proved to be expensive and wasteful of effort. An ideal solution would be to find a petrographic means which could be applied to this problem.

High level granites should have got there by virtue of their being hot and mobile and should cool rapidly compared to lower level granite. This difference in the rate of cooling should leave some petrographic difference in the different types of granite. If we look at the phase diagrams of feldspars, it is apparent that if a granite cooled slowly, we would get microcline. A higher temperature phase would develop depending on the temperature at which rapid cooling started. The presence of orthoclase and sanidine indicate rapid cooling from a fairly high temperature.

One of the criteria for distinguishing different granites would be to determine whether orthoclase or microcline is present in the rock. Twinning does not provide a reliable method. Universal stage work involving 2V determinations of K-feldspar is critical as the optic axial angle could distinguish between the very rapid cooling obsidian (low 2V), the high level granite (intermediate values of 2V) and the mesozonal granite (high 2V). The plagioclase fledspar from a high temperature granite would also have a lower 2V than the lower temperature granite.

Another way of attacking the problem is by studying the symmetry of feldspar by x-ray diffraction. Microcline is tricline while sanidine is monoclinic. Orthoclase is monoclinic but grades to microcline continuously. The x-ray pattern can however determine the range of triclinicity, or position in the microcline-orthoclase series.

Textural features would also be useful. The textures to look for are (i) hypersolvus texture made up of perthitic K-feldspar with no discrete plagioclase crystals - these are yet to be found in Malaysia and (ii) mature texture consisting of large separate plagioclase crystals and K-feldspar.

During the discussion following Dr Hutchison's introduction, Dr A. Mitchell pointed out that it is possible for the central part of a high level granite to have feldspars similar to lower level granite. Dr Hutchison agreed that some overlap is possible and Dr Stauffer stressed the importance of knowing exactly from which part of the granite body the specimen came from.

Mr Ng Chak Ngoon, who is currently working on the Mt. Ophir granite for his M.Sc. then presented the data he had been able to gather so far. The feldspar in different specimens were found to have different structural state. This phenomenon may sometime be found even in the same thin section.

Data on 2V values from granites from Tampin, G. Pulai and Mt. Ophir indicate that a wide range of 2V values is present. The G. Pulai and Mt. Ophir granites which have both been regarded as high level granites gave 2 modes of 2V values which show some fit with the expected 2V values of high level granites. The data from the granite from Tampin, which is part of the main range granite, with probably a lower emplacement level and from which a higher 2V is expected, does not however fit the theory.

During discussion, Professor Hosking brought out the problem of late stage potash metamorphism. Dr Hutchison said that this may explain the higher 2V values and explain the spread in 2V.

Dr Chakraborty presented some theoritical consideration regarding the problem. High level emplacement of granite melt may ordinarily be explained in two ways:

(i) melt generated at great depth and subsequently ascended to high level.

(ii) melt generated at the high level itself.

For a melt to rise from a great depth, it should

(i) be dry
(ii) be granodioritic in composition
(iii) contains xenolith, if present, should show effect of high temperature
(iv) should be impoverished in hydrous phases like biotite or hornblende due to its dryness, and
(v) have a high Rb/Str ratio.

The Gunong Pulai granite does not fit into this scheme for a high level granite. The Gunong Pulai granite is granitic and not granodioritic. The xenolith do not show any high temperature effect and neither is a contact aureole present. Biotite and hornblende are both significantly present indicating that the granite is not dry. However, these minerals may be due to late contamination while the melt was rising to the surface but as yet, no signs have been found that these minerals are later than the others. All these features contradict the hypothesis that the granite is a high level granite from a melt which originated at great depth.

The alternative mechanism of a melt generated in situ at a high level will account for the absence of a contact aureole and the xenolith but it will not account for the triclinicity of the feldspar.

The only other mechanism is by a wet magma developed at great depth and rising to the surface. At a thermal gradient over 70°C/km it would be possible to generate a magma at about 8 km depth.

The triclinicity of feldspar is a doubtful criteria as it is dependent on

(i) vapour pressure and
(ii) shearing stress

Orogenic stresses may explain the presence of microcline in deep seated granite.

Professor Hosking raise the question of the space problem and likelihood of contamination of a dry melt moving upwards. If a dry melt on rising is contaminated with water, it would stop raising. Dr Mitchell asked if pegmatites are useful for telling the depth of emplacement. Dr Hutchison replied that the triclinicity of feldspar depend on vapour pressure and pegmatites, with their high vapour pressure, would not be useful.

Dr Hutchison also drew the meeting's attention to the recent finding of a good contact aureole around the Mt. Ophir granite by Mr Lim Yew Kuen, while carrying out geological investigation for his B.Sc. Honours thesis. Specimens of rocks from this area were on display together with specimens of granite from Gunong Pulai and considerable interest were shown on them by the audience after the meeting.

The meeting was attended by about 40 members and ended at approximately 9.45 p.m.

B.K.T.

Meeting of 7 July 1972: Charles Hughes

A meeting of the Society was held at 8.00 p.m. on the evening of 7 July 1972 in the Department of Geology, University of Malaya. The speaker for the evening was Dr Charles J. Hughes of the Memorial University of Newfoundland, Canada. Professor N.S. Haile of the University of Malaya, who knew the speaker when they were both graduate students at Oxford gave a brief introduction. Dr Hughes, a petrologist, previously worked for Anglo-American Mining Corporation in southern Africa. He gave a talk based on his African experience: "Petrology and economic aspects of the Bushveld igneous complex and the Great Dyke." A synopsis of the talk follows:

In southern Africa one finds the largest layered basic igneous intrusion in the world, and in fact also the largest body of ultra-basic rock in the world.

The Bushveld is a layered series of basic and ultrabasic rocks dated at about 2000 m.y., with in the center younger (1400 m.y.) granites and associated rocks, with a small even younger complex of alkaline igneous rocks - syenites, carbonatites, etc. Within the ring structure of the basic and ultrabasic rocks there also occur areas of the floor rocks underneath the intrusion, far higher structurally than would be expected if the whole mass had a simple basin structure. Recently it has been suggested that the Bushveld is in fact an astrobleme, and that these floor rock patches represent the central rebound.

This is an attractive idea, because it is hard to imagine any other process that could produce such an enormous amount of magma in such a short time (there is good evidence that most of the mass was liquid at the same time, but such a mass would take less than a million years to cool and crystallize, and hence must have been produced even more quickly). Nonetheless there is as yet no hard evidence supporting the astrobleme hypothesis.

The wall rocks around the intrusion have suffered thermal metamorphism of unusual extent. High grade hornfelses (pyroxene hornfels faaies) occur with thicknesses up to 6000 feet.

The sequence of layered rocks starts with basal layers of chromite and olivine rocks, in which the chromite is sometimes economic, succeeded by norites with cumulate plagioclase crystals, on top of which are gabbros and finally ferro-gabbros, in which magnetite is sometimes economic. The ultrabasic rocks and the lower portion of the norites are thought to constitute a separate intrusion, while the remainder constitute the main intrusion of the Bushveld. In this sequence there are various systematic vertical variations in composition, both mineralogical and cryptic (e.g. in the plagioclase, which systematically declines in An value upward, and in the Fe/Mg ratio of the pyroxenes). Plagioclase at the base of the norite portion starts at about An_{78} and in the uppermost gabbroic layers reaches about An_{30}.

There has been a long controversy over whether the thin and sharply demarcated chromite bands in the lower part of the Bushveld are separate thin sill-like intrusions or features produced by "igneous sedimentation" processes. The fact that they have such sharp boundaries and that they locally bifurcate have seemed to indicate intrusion. These features are beautifully seen at the famous outcrop at the Dwars River. But in other places it can be seen that the chromite bands often define trough-like features which appear to be current-produced, and the bifurcations may really represent erosion unconformities produced by magmatic currents.

There is evidence that the basin in which the Bushveld Complex was formed foundered during crystallization, for the normal sequence of the lower layers is in places broken into blocks (kilometers in size), between and around which are later layers whose layering wraps around the foundered fragments. In addition, there is some evidence that locally one had genuine small later intrusions of basic material. One such mass of magnetite-rich rock is being mined not only for iron but also for its 2% of vanadium pentoxide and for titanium. There is also a famour vertical replacement pipe of iron-rich olivine, on the order of 100 feet across, more or less circular, and thousands of feet deep (it was mined to a depth of 1100 feet, at which level its smaller size and lower grade made mining no longer economic). This is known to be a replacement feature, because where chromite bands are present in the layered rocks it crosses, these are still present within the pipe.

Some 800 miles to the north, in Rhodesia, is the Great Dyke. The first thing to note about the Great Dyke is that it intrudes a very old and virtually unique portion of the earth's crust. This is a region of greenstones, granites, and schists which occur in peculiar arcuate, swirled-looking patterns, quite different from the typically more linear Archean patterns in Canada. The Great Dyke itself cuts through this old crust, which has given ages up to 3500 m.y. (until the recent discovery of older rocks in western Greenland, this was the oldest known portion of the earth's crust). The Great Dyke has given ages of 2500-3000 m.y. (no good agreement yet) and hence is itself quite old, much older than the Bushveld, to which it is apparently not related.

The Great Dyke is about 300 miles long and 3 to 5 miles in width. The walls are steep to vertical, but generally very poorly exposed and hence not well known. The layered rocks making up the dyke show a generally synclinal structure in their layering, with dips of 20-40° in towards the center from both margins, and the layers making rather smooth curves. In addition, the layers show plunge along the length of the dyke, and these plunges divide the dyke into four separate layered complexes. Each of these is evidently a lopolith which cooled independently, as each has a somewhat different sequence of rocks. Unlike the Bushveld, the Great Dyke has no remnants of its roof preserved, and hence the original thickness is not known.

The origin of the layered complexes of the Great Dyke presents the same problem as is posed by the Bushveld: how to produce such an enormous amount of magma in a short time. But in this case we surely cannot suppose a meteorite impact to have produced a linear opening 300 miles long. One suggestion is that it represents a rift in the crust produced in an early form of plate tectonics; perhaps at that stage of earth history the thermal gradient was so high that the relief of pressure associated with such a rifting movement would allow very large volumes of mantle to melt.

The synclinal structure, shown by the chromite bands and cumulate layers of olivine and orthopyroxene, has dips which are too steep to be original (there is little sign of slumping of the cumulates), and hence this structure must be a later feature produced by sag or subsidence (probably not by compressional tectonics). Some slip was taken up during the deformation by surfaces along the chromite seams.

Recent work on the probable cooling history of such large masses of magma seem to show that they would first crystallize at the bottom, not the top where cooling takes place. This is because the gradient of melting point with pressure is much steeper than the adiabatic gradient of temperature which a molten mass would strive to maintain by convection; hence during cooling, the melting point is first reached at the bottom of the mass, and crystals will form there.

At the edges of one of the individual lopoliths of the Great Dyke, detailed studies have shown that the sequence is not only thinner than in the center of the lopolith, but that there are also subtle lateral cryptic gradients, for instance in the pyroxenes, which are, level for level, more iron-rich at the edge than in the center. This presumably reflects the lower temperature produced by cooling in the thinner pile of magma here.

At the ends of the Dyke, the layered structure swings around in a smooth curve, giving a stubby termination. The layering here also seems quite conformable to the country rock, and there are one or two outliers beyond the end of the dyke. Hence at its ends, the Great Dyke seems to become a conformable sill. But in its center it is a genuine cross-cutting dyke, with near-vertical sides. A gravity traverse in this central part disclosed a very strong and sharply bounded positive anomaly, consistent with a vertical slab of ultrabasic rocks going right down through the crust - about 30 km thick here.

Professor K.F.G. Hosking, who has examined these African igneous complexes in the field, proposed a vote of thanks to the speaker for his most interesting presentation. About 25 members attended.

P.H.S.

NEWS OF THE SOCIETY

Constitutional amendments

Voting for the proposed amendments to the constitution was as follows:

Amendment A	For	80	Against	2
Amendment B	For	80	Against	2

The new constitution is therefore amended to be effective from the 26th May 1972. However, for administrative reasons Council decided that the new name of the Society will be officially used only after the next AGM.

Subscriptions

Could I remind members who have yet to pay their 1972 subscriptions that they are now long overdue. There are still some 1971 subscriptions outstanding. The Society's annual subscription rate if not paid before March in any year is M$17.00. Your cooperation in this matter will be much appreciated.

C.H.L.

Publications Received by the Society

1. From Geological Survey of Indonesia:

   (i) 1 set geological map of Southeast Kalimantan, Scale 1:500,000

   (ii) 1 copy geological map of Bali, scale 1:250,000

2. From Professor R. Toriyama, Association for Palaeontological Research in Southeast Asia

   (i) Geology and palaeontology of Southeast Asia (ed. by T. Kobayashi and R. Toriyama - vol. 10, pp.320 (with XLIV plates), 1972, Tokyo Univ. Press.

3. International Geological Congress, Montreal, 1970

   International subcommission on stratigraphic classification

   Report No. 3 - Preliminary report on lithostratigraphic units
   Report No. 4 - Preliminary report on stratotypes
   Report No. 5 - Preliminary report on biostratigraphic units
   Report No. 6 - Preliminary report on chronostratigraphic units

K.R.C.

Membership

New Members - Full Members

1. Mr A.G. Hatley
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2. Mr G.J.J. Aleva
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10. George Courtenay Riley
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Associate Member

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Student Member

1. Mr Chow Yue Cheong
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Resignations

1. Mr J.R. Fletcher
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2. Mr E. Vacirca
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3. Mr P. Maioli
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   Djakarta, Indonesia

EMPLOYMENT OPPORTUNITIES

Vacancies for the post of

a) Economic Geologist
b) Drilling Superintendent

a) Economic Geologist. Duration one year, with possibility of extension. Date required: July 1972. Duty stations: Rangoon, with extension periods in field areas.

Duties will include assuming responsibility for exploration/evaluation programmes to be carried out on tin/tungsten alluvial deposits in the Heinze Basin and Kazat/Yamon areas of the Tenasserim Division in Burma. The work will also involve programming and supervising Bangka drilling on both onshore and nearshore alluvial deposits, planning and executing scout-drilling programme, organization of geological laboratory, training of Burmese personnel and preparation of maps, plans and reports.

The expert must be a qualified geologist with broad background in the exploration and evaluation of alluvial tin deposits in the Southeast Asia environment, fully familiar with Bangka drilling and sampling techniques and experienced in nearshore or offshore drilling operation.

Interested candidates for the post can make further enquiries to Mr D.A. Harkin, Technical Advisor OTC, United Nations Headquarters, New York, N.Y. 10017, U.S.A.

b) Drilling Superintendent. The post is available in Indonesia (Banka) under a U.N. project. The period of employment is one year. Requirements to fill this post are experience in offshore alluvial drilling with normal flushing or counter flushing (not necessarily for tin), and being familiar with operation, maintenance and carrying out repairs on hydraulic pumps, motors and other parts of hydraulic system.

Interested candidates can write to Dr A.I. Scholtens, Deputy Project Manager, P.O. Box 20, Pangkalpinang, Bangka, Indonesia.