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Evidence of polymetamorphism in the Rebak Islands, Langkawi, Kedah

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Abstract: The clastic rocks of the islands of Rebak Besar and Rebak Kecil in west Langkawi are found to have undergone low grade regional metamorphism followed by contact metamorphism and metasomatism from a granitic source believed to occur under the Rebak rocks at no great depth and possibly underlying the adjacent seafloor. The regional metamorphism gave rise to the formation of slates, phyllitic slates and phyllites with low angle cleavages or schistosities and quartzites with strained quartz grains. The contact metamorphism was responsible for new growths of randomly orientated muscovite which also occurs as rosettes. Widespread tourmalinization and pyritization are evidence of metasomatism.

It is suggested that the Rebak rocks resemble some lithologies of the Upper Detrital Band and that the sea between the Rebak islands and the Machinchang hills is probably floored by extensions of the Raya granite. This may explain the absence of the Setul limestone in west Langkawi which may not be due to the presence of an unconformable contact between the Upper Devonian Rebak rocks and the Cambrian Machinchang Formation.

INTRODUCTION

The purpose of this paper is to bring attention to the occurrence of polymetamorphism in Pulau Rebak Besar and Pulau Rebak Kecil (Fig. 1), two rather small islands off the west coast of Langkawi, and to discuss the implications. Another reason for describing the occurrence of polymetamorphism in the islands is that previous workers either have failed to recognize its occurrence or have not appreciated its significance sufficiently to merit any mention in their publications (to be mentioned later). In this respect it is interesting to note that previous workers have made use of lithologies to compare and correlate the stratigraphy of the Langkawi area without considering the effects of metamorphic imprints.

GEOLOGY OF THE REBAK ISLANDS

The earliest, and still one of the most significant, detailed study of the Rebak islands which form part of a larger area of Langkawi and Perlis studied, is that of Jones (1981) whose manuscripts were available since the 1960s. Map of the area was published earlier (Jones, 1966). A much simplified geological map and the stratigraphy of the Langkawi area after Jones (1966) are shown in figure 2. A more detailed geological map of the Rebak Islands is shown in figure 3 which is from Jones (1981, p. 31). He showed the islands to be underlain by argillaceous and arenaceous rocks such as shale, mudstone and quartzite believed to belong to the upper Cambrian Machinchang Formation. In Jones (1981, p. 28) it was stated that the rocks were 'interpreted as Cambrian on dispositional and partly on lithological grounds only as no fossils have been found' and in p. 78 he pointed out the Rebak rocks 'could equally belong to the Singa Formation' as they are of similar lithology to the basal strata of the

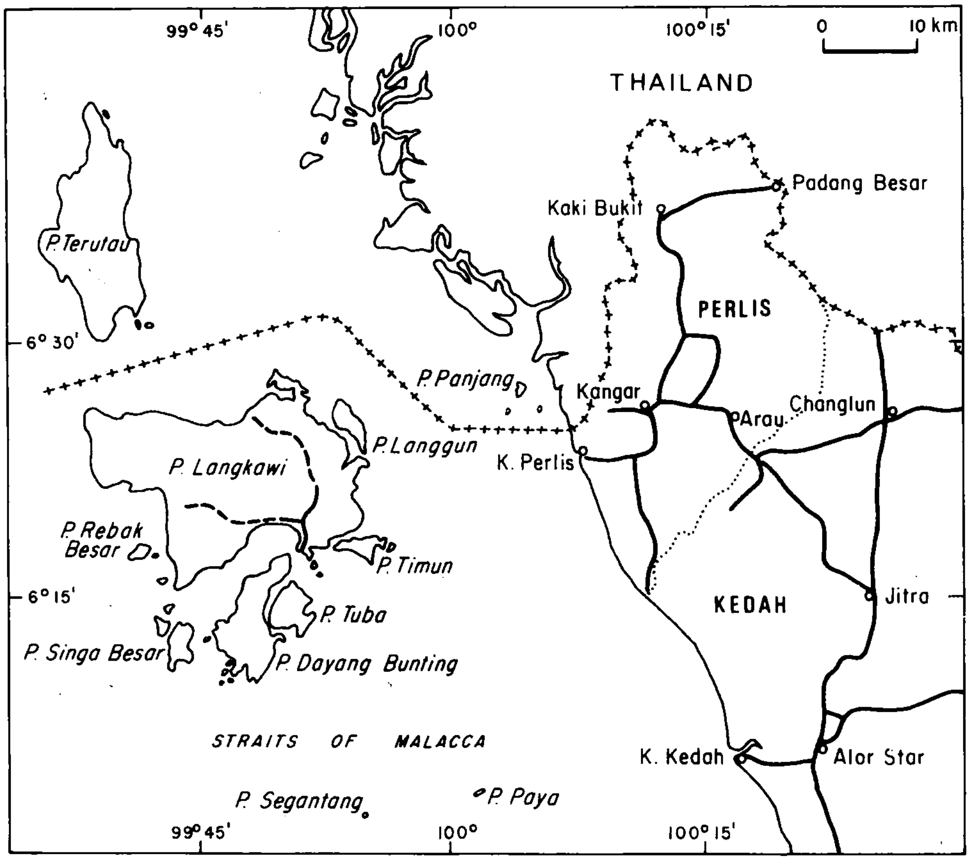

Fig. 1. Locality map of the Langkawi area.

Singa Formation in Pulau Langgun which consist of 'red and grey argillites, conglomeratic gritty and shaly in part.'

In the early 1970s there was renewed interest on the geology of the Rebak islands with the appearance of several papers. Sartono (1972) reported that on 'Rebak Kecil and Selat Senari the rocks consist of sandstones and siltstones which have a conspicuous red as well as yellow colour' which also occur on the southeastern coast of Rebak Besar. In this island he reported the occurrence of whitish-grey to light-grey claystones. Sandstones in Rebak Besar showing cracks filled by veins of quartz and iron-oxides are also reported by him. Comparing these lithologies mentioned with rocks of the Machinchang and Singa Formations he contended that the rocks of the Rebak islands are not entirely built of Machinchang Formation but rocks of the Singa Formation occur as well.

Ahmad Jantan (1972) gave further information on the geology of the Rebak islands and pointed out that mudstones are more common than previously believed in

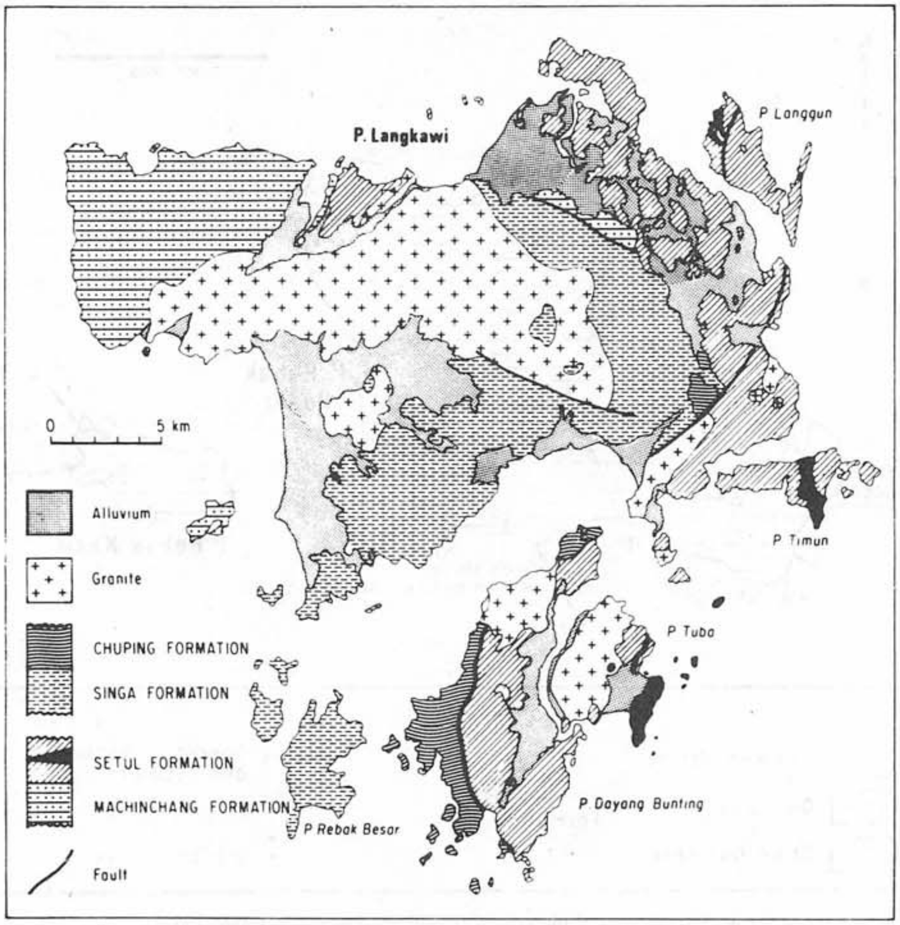

Fig. 2. Geological map of the Langkawi area (after Jones, 1966).

the islands and that mudstones in the northwest of Rebak Besar lithologically resemble those in Pulau Langgun which have been found to contain fossils of the Upper Devonian. Also he pointed out that *Posidonia* has been found in Rebak Besar thereby proving the presence of post-Cambrian sediments. He rasied the problem of whether to classify the Rebak rocks as forming the basal part of the nearby Singa Formation or can they be grouped as a separate formation.

Gobbett (1972) prompted by the interest shown in the Rebak islands made known his studies made in 1963. In addition to the information on the lithologies mentioned above he said that Rebak Besar is dominated by white sandstone which has been 'extensively reddened by veins and stock-works of iron oxide' and similar 'haematised' sandstone forms much of the north shore of Rebak Kecil. He disagreed with Sartono (1972) that the sandstones belong to two different formations and suggested that the

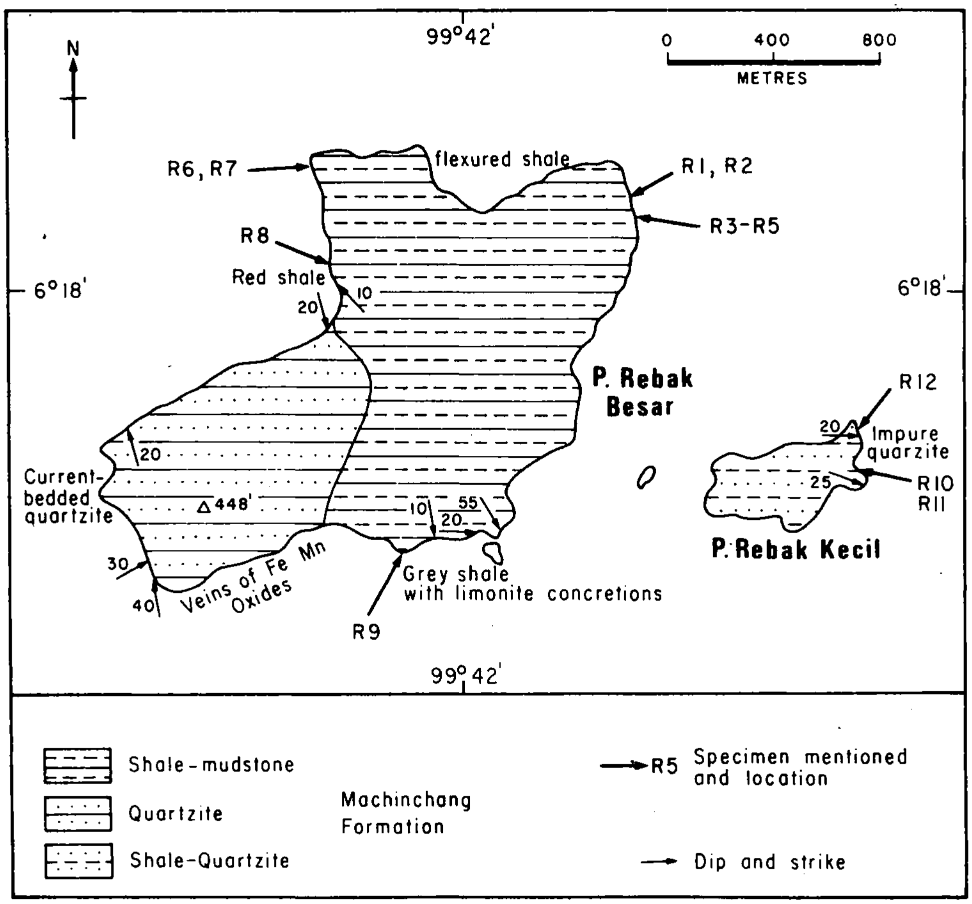

Fig. 3. Geological map of the Rebak islands (after Jones, 1981).

Rebak rocks together with the similar Langgun rocks be conveniently grouped as the 'Rebanggun Beds' since they are 'lithologically and structurally distinct from the type Singa Formation.' As regards the latter aspect he reasoned that the 'more intense minor folds on Pulau Rebak compare with the structure of rocks older than the type Singa Formation' as described by Koopmans (1965).

The fossil discoveries in Rebak Besar have been the subject of interesting papers by Sarkar (1972) and Yancey (1972) who assigned the age of the Rebak rocks to the Lower Carboniferous (tentative) and Upper Devonian respectively.

Recent studies by Khoo (1980) on mainland Kedah have delineated a belt of regional metamorphics called the Patani Metamorphics trending northwest and truncating at the west Kedah coast. In Khoo (1981) the belt was extended into the Langkawi islands and Terutao Areas. In the Langkawi islands the rocks adjacent to granitic intrusives, dated to be Upper Triassic by K-Ar and Rb-Sr methods (Bignell and Snelling, 1977), have suffered contact metamorphism as well. However, in the area of the Rebak islands, there is no evidence of granite nearby. But based on evidence and nature of contact metamorphism (including metasomatism) available elsewhere in the Langkawi area and also the petrography of the rocks it will be shown below that regional metamorphism has been followed by contact metamorphism in the Rebak islands.

EVIDENCE OF REGIONAL METAMORPHISM

Regional metamorphism of sedimentary rocks in the Langkawi area in general is of low grade, mainly equivalent to the chlorite zone. Pelitic and other micaceous rocks developed cleavages, usually at low angles to beddings caused by the development of preferred orientation of layered silicates such as fine muscovite and chlorite which may be interlayered with the white mica. Rocks ranging from the Upper Cambrian Machinchang Formation to the Carboniferous Singa Formation show the mentioned features. Calcareous and arenaceous rocks affected by the regional metamorphism are either recrystallized, dynamically deformed (mortared) or show aligned, ribboned, elongated mineral grain fabric.

In the Rebak islands the pelitic and psammitic rocks occurring there show some of the features of regional metamorphism mentioned. Examples are given below.

Pelitic Rocks

Pelitic rocks in Rebak Besar and Rebak Kecil are slates (R11), phyllitic slates (R6)

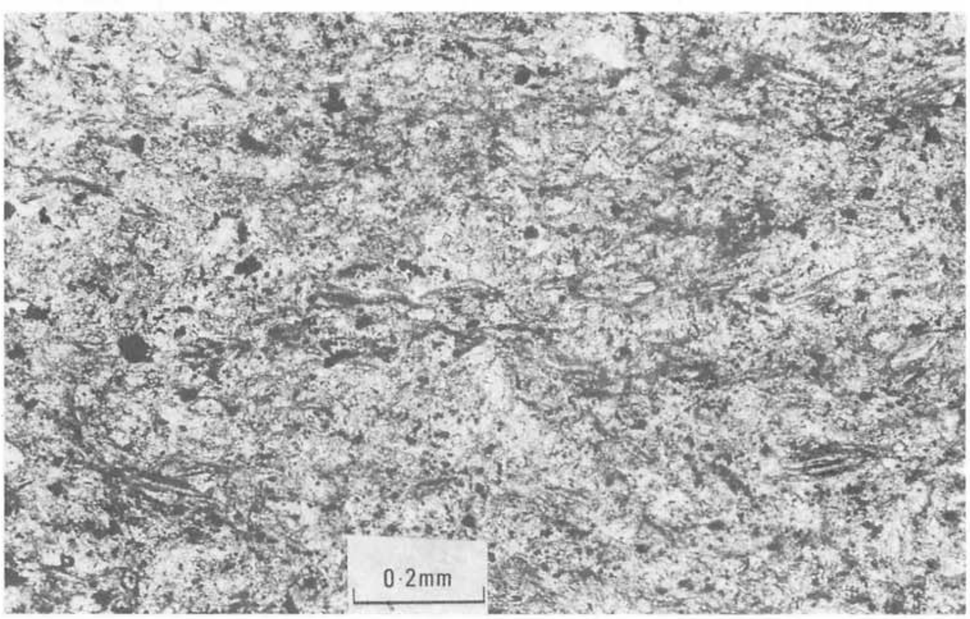

Fig. 4. Photomicrograph of phyllitic slate. Specimen R8. Plane polarized light.

and phyllites (R8). Localities of the specimens mentioned are shown in figure 3. These rocks on weathering are transformed to shales and mudstones and they were reported as such by previous workers. It is well known that in Peninsular Malaysia low grade metamorphosed pelitic rocks are easily transformed to become shales and mudstones on tropical weathering.

The rocks show cleavages or schistosites defined by preferred orientation of fine muscovite, 14Å chlorite and also sometimes platy hematite (e.g. R8). The chlorite may also be porphyroblastic and it is likely that it developed during regional metamorphism. However, it is also possible that it developed during the subsequent contact metamorphism. Figure 4 shows an example of the texture developed by the pelites and figure 5 is a diffractogram showing the mineralogical composition.

Psammitic Rocks

Psammitic rocks in the islands have been metamorphosed to various types of quartzites. Those originating from quartzarenite become quartzite with hardly any matrix, usually micaceous (e.g. R3217, Universiti Malaya collection, exact locality unknown). Those which are semi-psammitic become micaceous quartzite with matrix consisting of muscovite and also chlorite (Fig. 6) like the pelitic rocks (R9, R1-R5 and R2929 from Universiti Malaya collection of unknown exact location).

The effect of regional metamorphism on the psammitic rocks give rise to quartzite with common occurrence of strained quartz grains showing strongly undulatory extinction, development of Boehm lamellae, occasional small biaxiality of interference figures, and other features of deformation (Fig. 6 & 7). The low grade of the regional metamorphism and the relatively low temperatures attained evidently failed to recrystallize these deformation features. This is also evident from the common

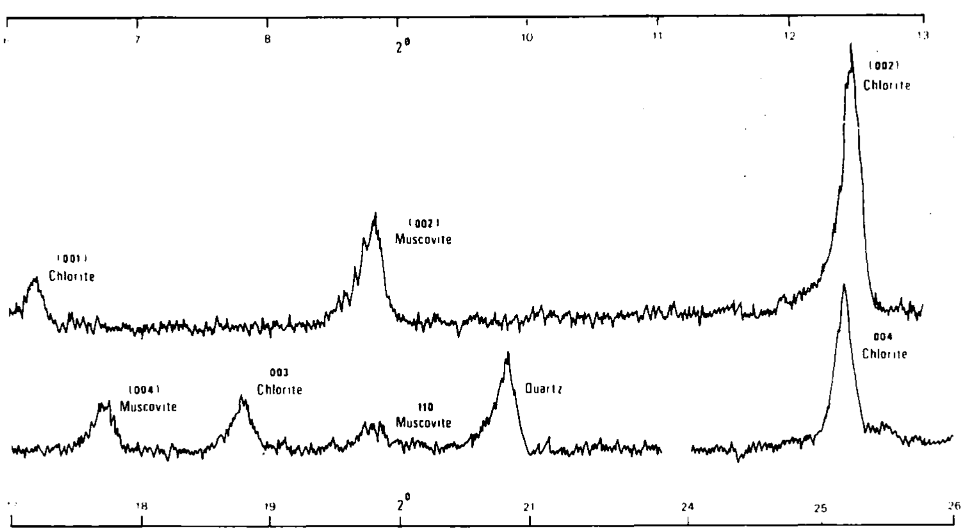

Fig. 5. X-ray diffractogram of specimen R8. (CuK_α radiation).

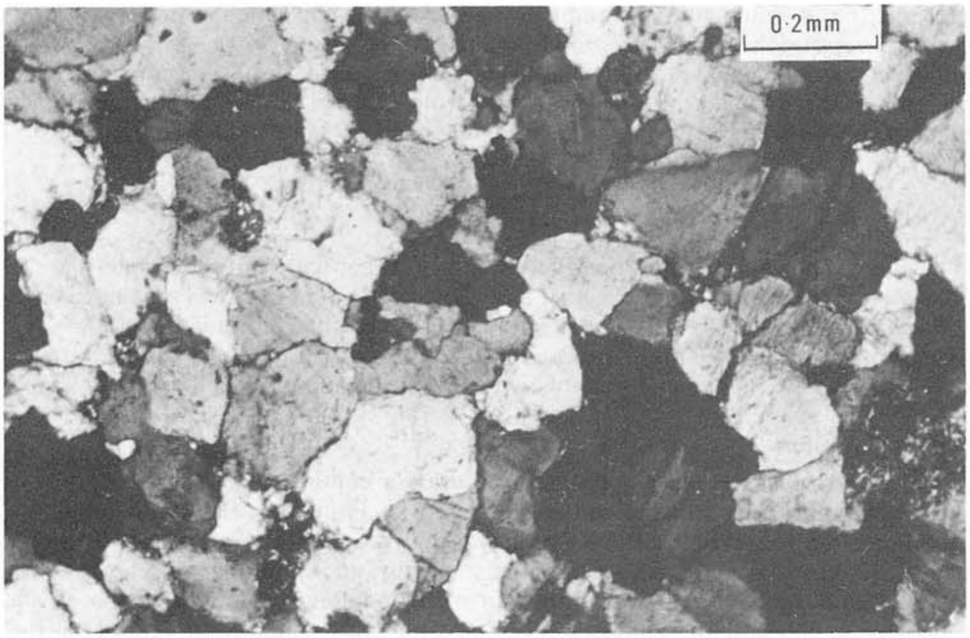

Fig. 6. Photomicrograph of quartzite. Specimen R3. Crossed-polars.

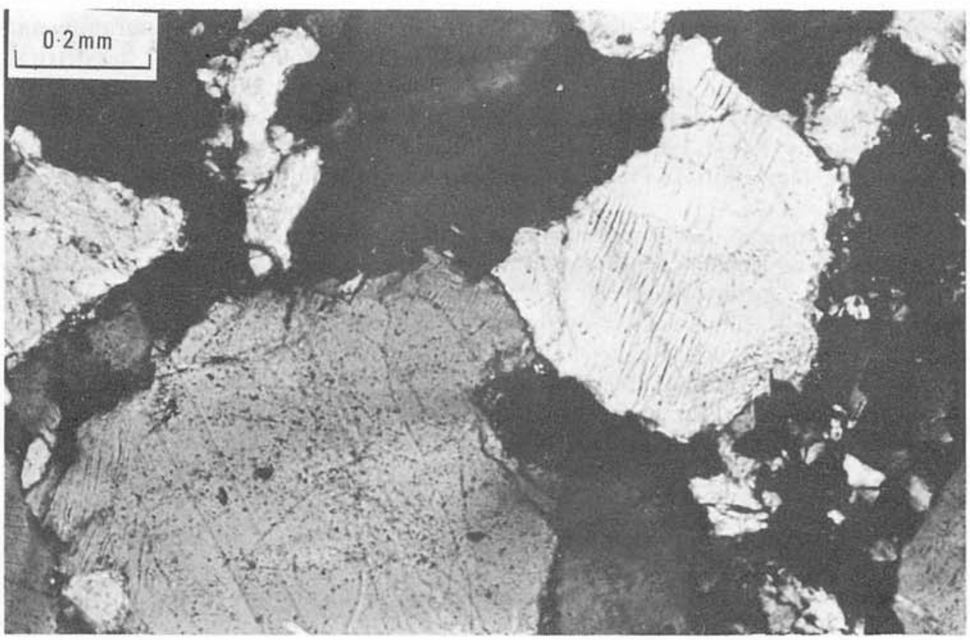

Fig. 7. Photomicrograph of quartzite showing strained quartz grains with wavy extinction and development of Boehm lamellae. Specimen R2. Crossed-polars.

preservation of sedimentary textures in the rocks, in particular, the preservation of quartz overgrowths which surround original more dusty clastic grains (Fig. 8). However, occasionally, metamorphic texture with quartz grains meeting in triple junctions occur. Whether this feature results from regional or the subsequent contact metamorphism is uncertain.

EVIDENCE OF CONTACT METAMORPHISM AND METASOMATISM

There is no exposed plutonic igneous bodies in the vicinity of the Rebak islands. However, features of contact effects found elsewhere in the Langkawi area have been found in the Rebak islands. It is therefore interpreted that plutonic rocks, possibly extensions of the Raya granite exposed in Pulau Langkawi, occur at no great depth under the Rebak islands and possibly exposed on the adjacent seafloor as well.

Tourmalinization

One of the best evidence of proximity to granitic contacts in the Langkawi area is the development of tourmaline in the country rocks. Granitic rocks in the Langkawi area are often tourmalinized and not surprisingly country rocks adjacent to them developed borosilicates such as tourmaline in pelitic and psammitic rocks and axinite in calcareous rocks. The Raya granite in mainland Pulau Langkawi show much tourmalinization near the Langkawi Country Club Hotel and also at Telok U at the north coast. The Tuba granite, which the author believes is a much larger concealed pluton trending southwest from Pulau Timun to the south islands of Pulau Batang and Pulau Balar, is also tourmalinized e.g. in Pulau Tuba. Pelitic and psammitic rocks of the Machinchang Formation developed tourmaline adjacent to the Raya granite and schorl rock occurs near Telaga Tujuh (UM1450, GR179869). Rocks of the detrital band exposed at the northern coast of Pulau Timun show all degrees of tourmalinization up to development of schorl rock. Schorl rocks within the aureole of the Tuba granite (Khoo, 1981) also occur in Pulau Tiloi and tourmaline replaces biotite in contact metamorphosed Detrital Member rocks in Pulau Nyior Setali.

In the Rebak islands, rocks particularly those occurring on the eastern part of Rebak Besar and Rebak Kecil show various degrees of conspicuous tourmalinization. The tourmaline grains developed are usually fine and randomly orientated. They developed in micaceous matrix of the rocks and occasionally isolated patches of micaceous matrix (and also detrital micaceous clasts) may develop nests of fine tourmaline. Fine tourmaline grains also form networks of slim interconnecting 'strands' enclosing quartz grains evidently representing replaced micaceous matrix. Figures 9 and 10 show the textures of tourmalinized rocks from the Rebak islands.

Pyritization

One of the most unique features of the Rebak islands not found elsewhere in the Langkawi area to the best of my knowledge, is the development of pyritization in the rocks of both pelitic and psammitic compositions. Pyritization is widespread in both Rebak Besar and Rebak Kecil.

Due to weathering, the pyrite is usually not preserved in the rocks. However, in

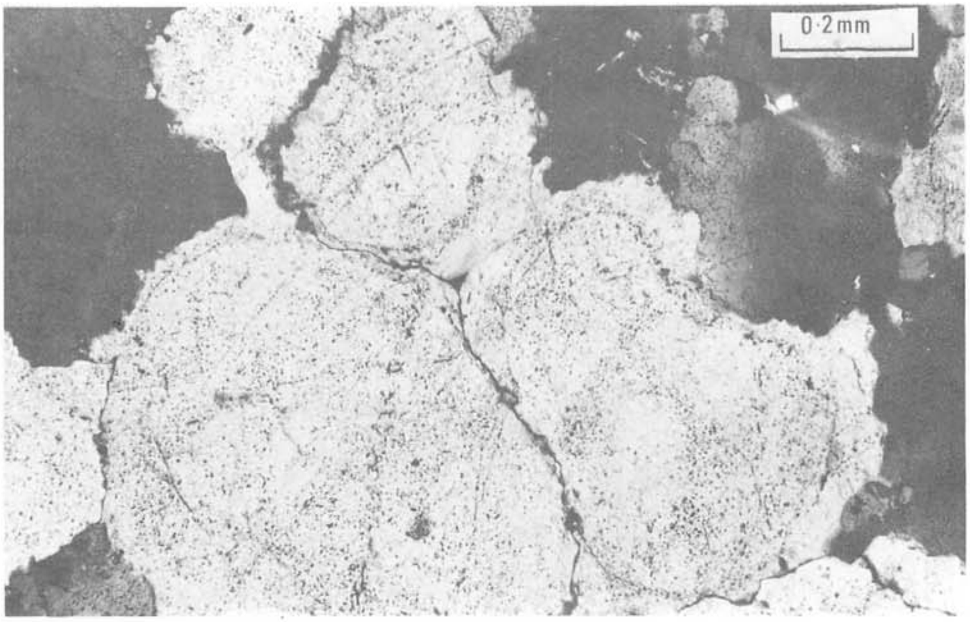

Fig. 8. Photomicrograph of quartzite showing quartz grains with overgrowths, strained quartz and some recrystallization. Specimen R3217. Crossed-polars.

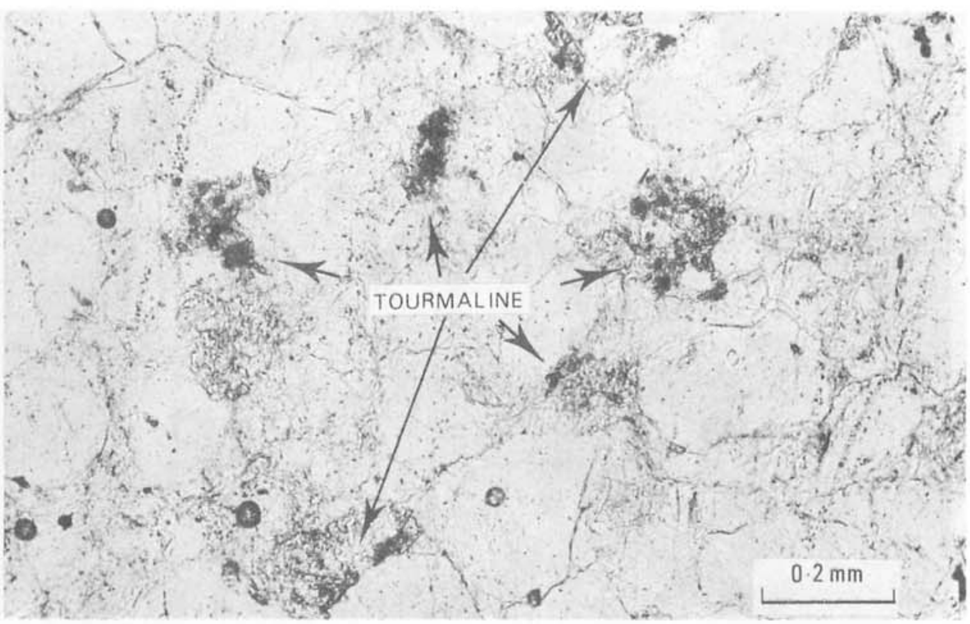

Fig. 9. Photomicrograph of quartzite showing nests of fine tourmaline developed from fine micaceous groundmass. Specimen R1. Plane polarized light.

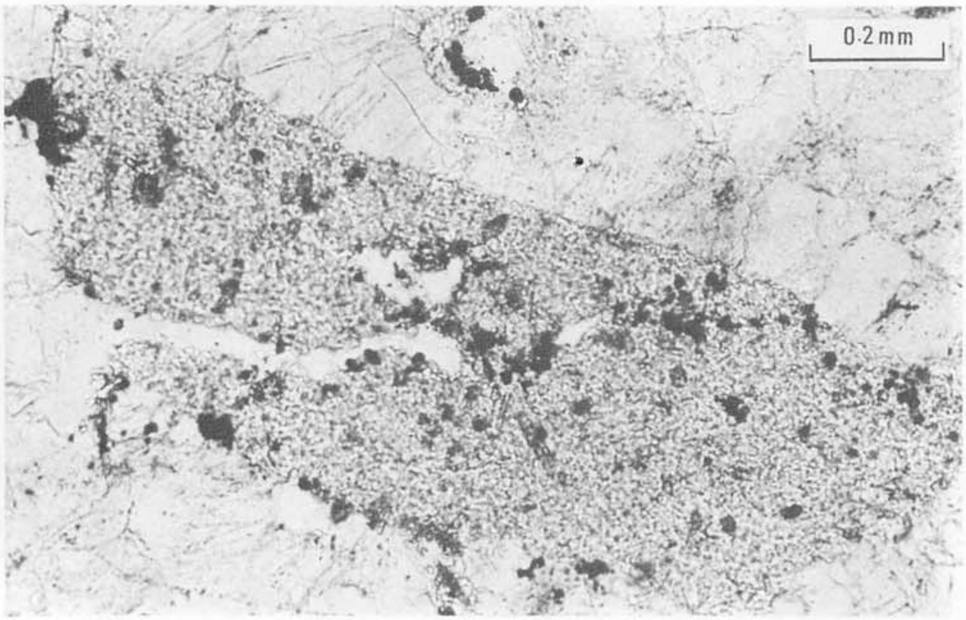

Fig. 10. Photomicrograph of quartzite showing fine tourmaline developed in pelitic clast. Specimen R1. Plane polarized light.

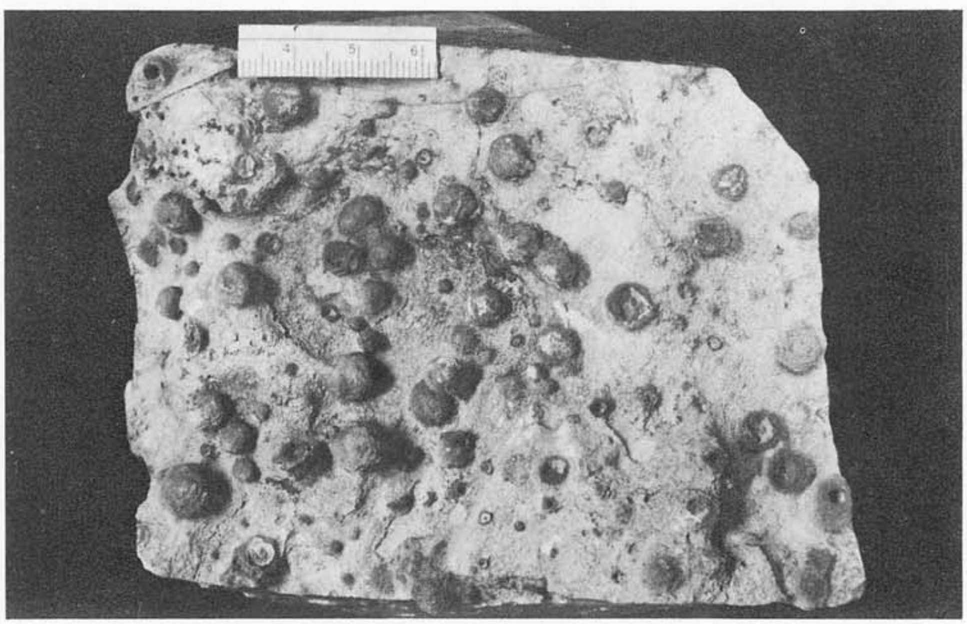

Fig. 11. Iron oxide alterations after pyrite porphyroblasts in quartzite. Note cubic molds left by pyrite enveloped by spherical 'concretions' of iron oxides. Specimen R10.

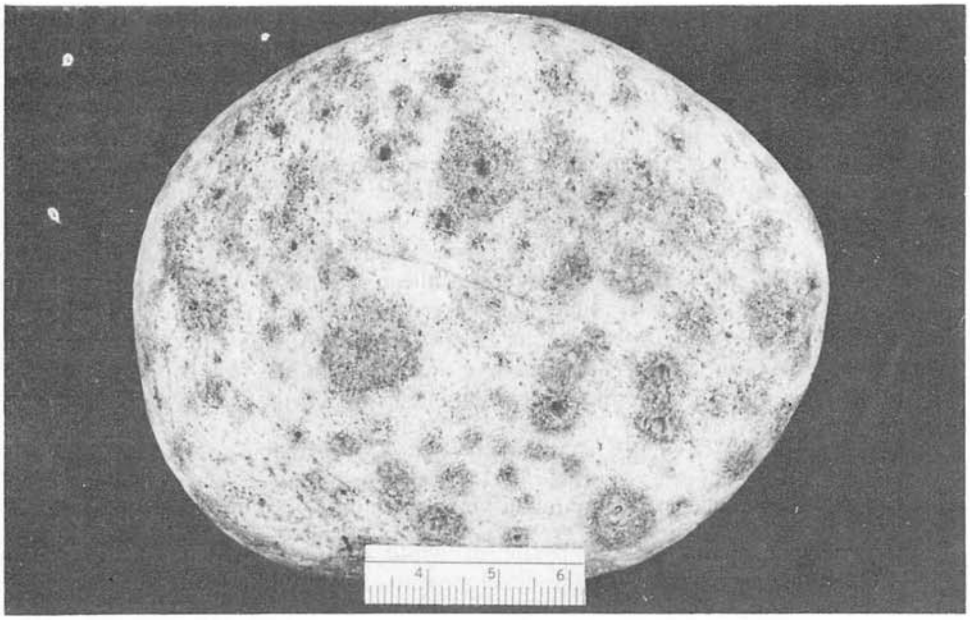

Fig. 12. Reddish diffused spots of iron oxide alterations after pyrite in white quartzite. Note occurrence of cubic molds left by pyrite. Locality-Pulau Rebak Besar.

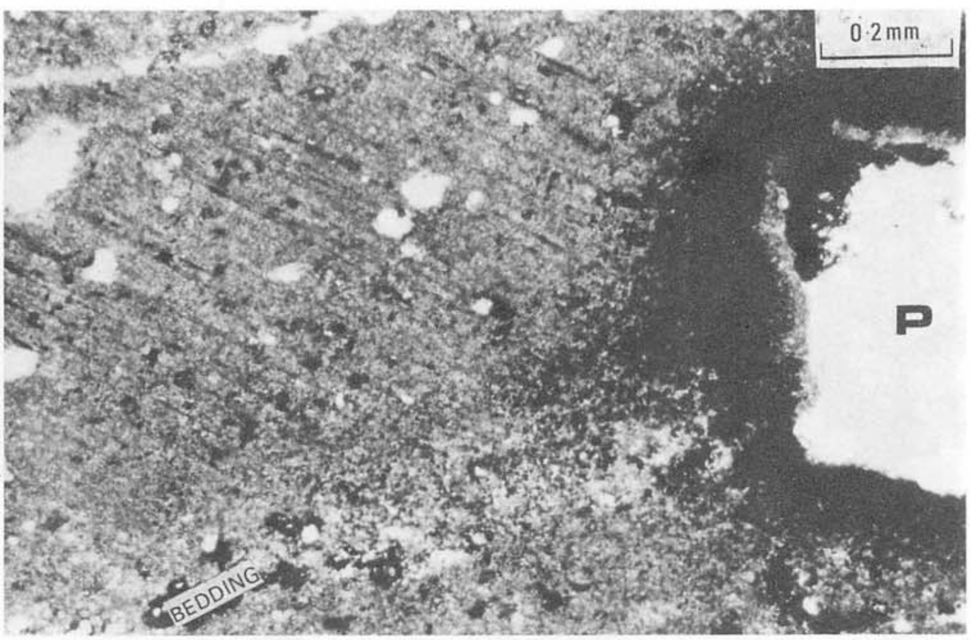

Fig. 13. Photomicrograph of slate showing slaty cleavage at an angle to bedding and overprinting pyrite (p) porphyroblast (only cavity left) surrounded by spherical shell of iron oxide alterations. Specimen R11. Plane polarized light.

fresh rocks and in those where the pyrite occurs as larger porphyroblasts (e.g. up to 2 cm across) remnants of the pyrite can still be seen surrounded by a rim of reddish iron oxides which forms a rather spherical aureole around the pyrite of cubic and irregular shapes. This aureole of iron oxides, which is larger than the original size of the pyrite it encloses, sometimes appear to 'harden' the rock in the aureole on weathering and thereby is preserved as protuberance or spherical grain in the rock (Fig. 11). This feature somewhat resembles a concretion. (cf. Jones, 1981, p. 31). Usually the pyrite is no longer evident in the rock and its former presence is represented by specks or patches of reddish, yellowish or orange iron oxides sometimes surrounding empty cubic cavities (Fig. 12). In many exposures, these alteration products of pyrite are particularly abundant and strangely they have not been reported. The 'reddening' of the dominant white sandstone in Rebak Besar said to be due to veins and stockworks of iron oxide in Gobbett (1972) is I believe more dominantly due to the presence of alteration products of pyrite like the specimen shown in figure 12.

What is the origin of the pyrite porphyroblasts? Considering

(a) the occurrence of tourmalinization indicating proximity to granite,

(b) the occurrence of the pyrite in white quartzite which is an unlikely sedimentary parent for the development of pyrite like black clastics,

(c) the widespread occurrence of pyritization throughout the succession and

(d) the common occurrence of veins of iron and manganese oxides traversing the Rebak rocks in exposures and also thin-sections (Fig. 14)

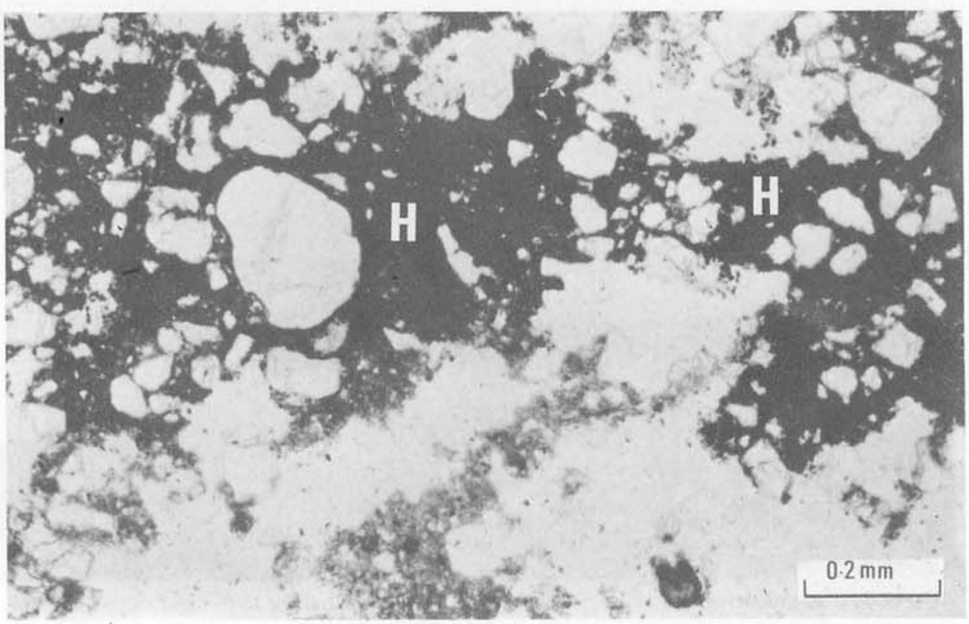

Fig. 14. Photomicrograph of quartzite veined by hematite(H). Specimen R7. Plane polarized light.

the author is led to interpret that the pyrite is likely to be metasomatically introduced by the unexposed pluton below.

Muscovite New Growths

This feature is interpreted by the author to be a result of reheating of the rocks due to contact metamorphism. In many of the quartzites new growth of coarser muscovite can be seen in the matrix. Usually these muscovite plates form randomly orientated aggregates which are different from the preferentially orientated aggregates resulting from the earlier regional metamorphism. Sometimes these muscovite new growths form rosettes adjacent to quartz grains (Fig. 15) and also appearing to have involved reaction with the quartz as the contact shows the quartz having been 'eaten'.

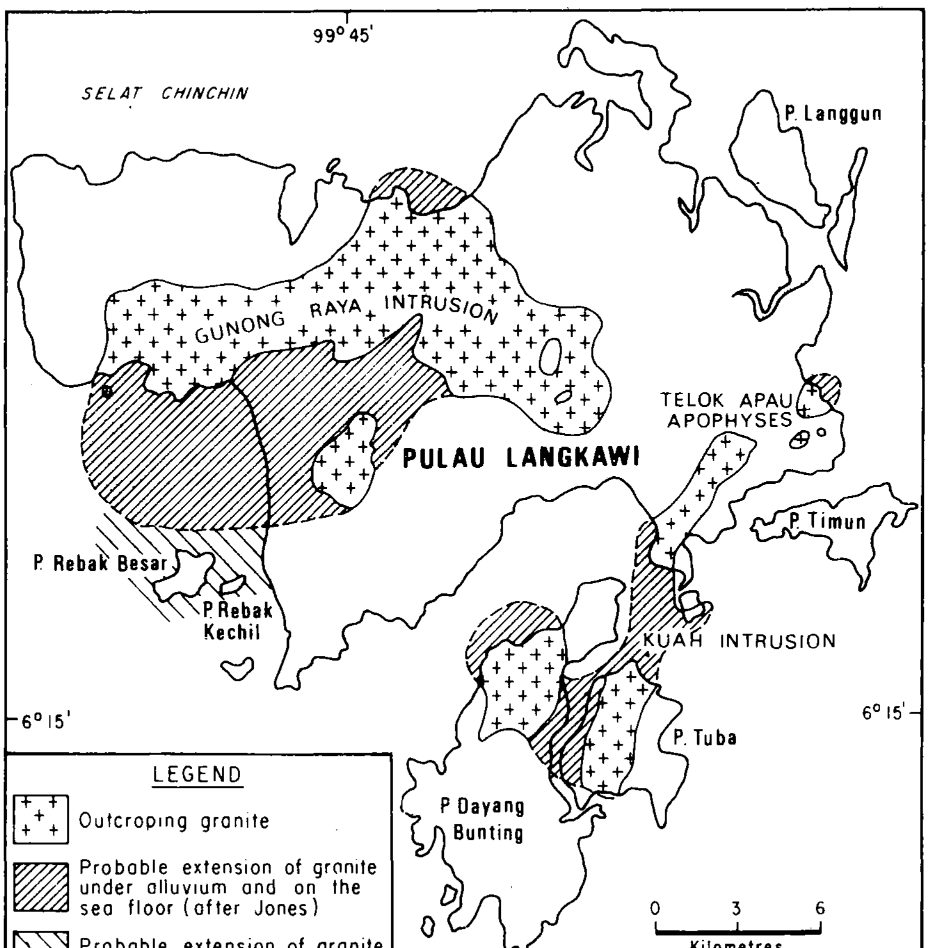

Fig. 15. Suggested extension of the outcrop of the Raya granite.

The evidence given above favours an interpretation that the Rebak islands have suffered contact metamorphism and associated metasomatism after an earlier regional metamorphism of low grade.

IMPLICATIONS

The evidence of polymetamorphism in the Rebak islands has given rise to some implications which are discussed below.

Lithological Comparisons

In the Langkawi area, Jones (1981) has masterfully unravelled the stratigraphy using palaeontological evidence and lithological comparison. However, the use of lithological comparison can sometimes be misleading and the classification of the Rebak rocks as belonging to the Machinchang Formation is a case in point. Jones (1981, p. 78) has, however, pointed out that the Rebak rocks also have similarities to the Pulau Langgun rocks above the Upper Detrital Member. Later, discovery of Upper Palaeozoic fossils in the Rebak rocks which has been mentioned earlier, proved that Jones' (1966) geological map has picked the wrong choice. The lithological similarities of the Rebak rocks to the Machinchang and Singa Formations as claimed by Sartono (1972) and the lithological similarities of the Machinchang Formation with part of the Singa Formation as pointed out by Gobbett (1972) point to the difficulties of making lithological correlation of clastic rocks in the Langkawi area. The lack of a proper understanding of the transformed nature of the rocks, both metamorphic and weathering, compounded the difficulties.

As they are at present, the Rebak rocks petrographically have little resemblance to the rocks of the Machinchang and Singa Formations and the clastic rocks in Pulau Langgun. However, if we ignore the effects of tourmalinization, pyritization and development of muscovite new growths in the Rebak rocks which are almost certainly due to contact metamorphism and metasomatism, then the Rebak rocks may bear some resemblance to some of the rocks of the Upper Detrital Member below the so-called basal Singa Formation in Pulau Langgun. Below the famous red mudstone of the basal Singa in Langgun are tough white quartzite with pebbles in places. Further down the sequence, intensely cleaved grey to green pelitic rocks occur. The psammitic and pelitic rocks of the top part of the Upper Detrital Member appear to resemble the quartzite and low grade pelites in the Rebak islands.

The author has not made a study of the rocks of the basal Singa in Langgun and how far the Rebak rocks resemble the basal Singa lithologies is uncertain. However, Gobbett (1972) and Yancey (1972, 1975) would like to group these rocks as a separate unit distinct from the Singa Formation. Gobbett's (1972) Rebanggun Beds do not include the Upper Detrital Member but Yancey's (1975) unnamed Devonian formation includes the so-called basal Singa and the Upper Detrital Member. Much obviously depends on whether the famous pebbly red mudstone in Langgun above the Upper Detrital Member is unconformably overlying the rocks below. The contact is not exposed. However, if it is true that the Rebak rocks are the lateral equivalent of the upper part of the Upper Detrital Member, there is still enough space in the seafloor between the Rebak islands and the nearest typical Singa Formation exposed in Pulau Tekon to accomodate the sequence above.

Extension Of The Raya Granite

In Jones (1981, p. 114), it was suggested that the Raya granite which comes up to the coast in north west Langkawi extends into the sea-floor and he showed the postulated extension of the granitic outcrop in a figure reproduced in figure 15 here. The almost certain occurrence of granitic rocks adjacent to or at no great depth below the Rebak rocks would suggest that the granite could well be more extensive on the sea-floor. The author's suggested extension of the granitic outcrop is shown in figure 16.

Here, it may well be appropriate to mention that a sample of heavy beach sand (R12) in Rebak Kecil was found to contain sand-size grains of tourmaline, zircon and also quartz grains containing abundant needles of tourmaline (Fig. 17). Nowhere in the Rebak islands has such coarse tourmaline been seen in the rocks. A more probable source of the tourmaline and quartz charged with tourmaline, most probably a fragment of tourmaline-quartz vein, is tourmalinized granite exposed nearby on the seafloor.

Two heavy mineral concentrates from beaches on the north coast of Rebak Besar (GR218793) and east coast of Rebak Kecil (GR233782) have been found by Jones (1981, p. 175) to contain abundant tourmaline, common ilmenite and zircon. The

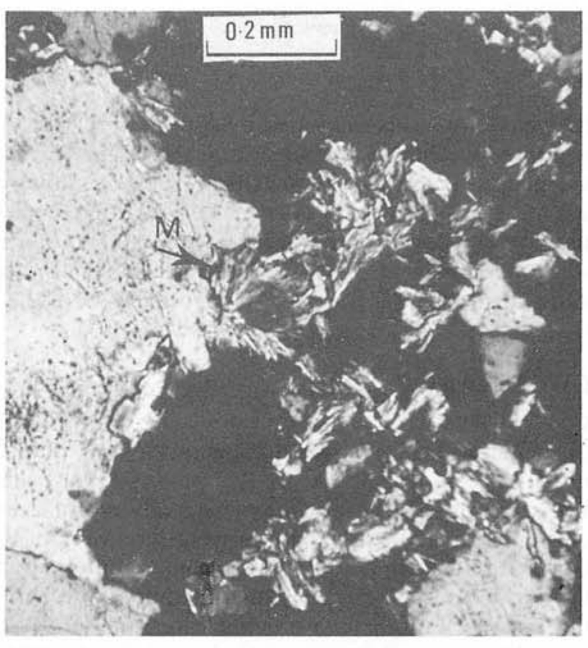

Fig. 16. Photomicrograph of quartzite showing muscovite new growth in clusters and a rosette (M) emanating from a quartz grain. Specimen R2929. Crossed-polars.

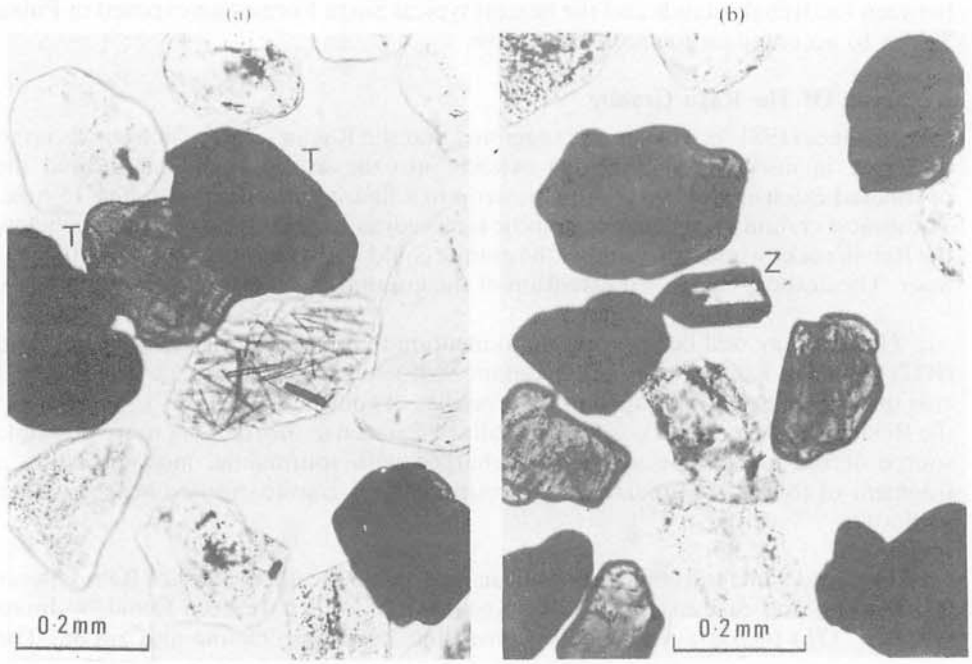

Fig. 17. (a) Heavy beach sand showing occurrence of tourmaline (T) and quartz charged with tourmaline needles. Specimen R12. Plane polarized light.
(b) Heavy beach sand showing occurrence of euhedral zircon (Z) and tourmaline. Specimen R12. Plane polarized light.

provenance of the heavy minerals suggested by Jones (1981, p. 175) is Machinchang Formation mixed for the Rebak Besar concentrate and Singa Formation mixed for the Rebak Kecil concentrate. These clastic formations are not known to be tourmaline-rich except metasomatized by adjacent granite. Usually only a few small tourmaline grains are present in the clastics of these two formations and such grains are likely to be of detrital and diagenetic origins. A nearby granite source for the heavy minerals appears to be more plausible and this source is suggested to be at the adjacent seafloor.

Stratigraphy Of West Langkawi

The absence of any exposed Setul limestone, in the west Langkawi area has resulted in various suggestions for a possible unconformity. Before the discovery of Upper Palaeozoic fossils in Rebak Besar, Koopmans (1965) interpreted that the 'mutual relation between outcrops of the Singa Formation on the west coast of Pulau Langkawi and of outcrops of Machinchang Formation on Pulau Rebak' suggests an unconformity. Gobbett (1972) suggested that the Rebanggun Beds are separated from the Machinchang Formation in west Langkawi by an unconformity and in Gobbett (1973) he said that in west Langkawi a much greater unconformity probably exists between the Upper Devonian Rebanggun Beds and the Cambrian Machinchang Formation.

The above suggestions not only assumed the absence of the Setul limestone between the Rebak islands and the Machinchang hills but also assumed the presence of a contact between the Machinchang Formation and the Rebak clastics on the seafloor in between the two areas. However, if the Setul limestone has not been telescoped or pinched out by complicated structures, there is no reason for the Setul limestone to be present between the Rebak islands and the Machinchang hills at present if the sea is floored by extensions of the Raya granite. The Setul limestone overlying the younger granite has been eroded away so that the granite is exposed, albeit on the seafloor. Unroofing of granite by removal of Setul limestone is in fact still going on in southeast Langkawi area where only the tops of the Tuba granite are exposed. In the west Langkawi area, unroofing of the Raya granite has been completed. There is no evidence for an unconformity between the Rebanggun Beds or Rebak rocks and the underlying succession in the west Langkawi area.

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