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The terrane of the Patani Metamorphics

T.T. KHOO
Jabatan Geologi, Universiti Malaya, Kuala Lumpur

Abstract: A regional metamorphic terrane has been mapped in west Kedah covering an area not less than 650 sq. km. The metamorphics in this terrane are called the Patani Metamorphics. The terrane trends NW-SE and is about or more than 30 km wide. At the southeast side the regional metamorphic effects appear to peter out at Lunas—Padang Serai but the northwestern end is truncated by the coast. It is possible that similar metamorphics in southeastern Langkawi group of islands and at Gunung Utan Aji, Perlis may be extensions of the mapped terrane in west Kedah.

The terrane is mostly underlain by slates and phyllites with assemblages such as muscovite + quartz + chlorite ± paragonite ± pyrophyllite ± chloritoid. Higher grade rocks centre around the Jerai granite area developing biotite in pelitic schists and quartzites rocks and calc-silicate minerals such as hornblende, diopside, garnet and epidote in calcareous and amphibolitic rocks. The Jerai granite is believed to superimpose contact metamorphism on the regional metamorphics.

The regional metamorphism is believed to come to an end by Middle Carboniferous followed by the late or post-tectonic emplacement of the Jerai granite in the late or late Middle Carboniferous. The onset of regional metamorphism is believed to be early Devonian or earlier with a probable deformation phase in the Middle or late Devonian.

INTRODUCTION

The purpose of this article is to report on the occurrence of a regional metamorphic terrane covering no less than 650 sq. km. in west Kedah, Peninsular Malaysia. The area covered by the terrane is shown in figure 1. The regional metamorphic rocks in this terrane will be called the Patani Metamorphics after the town of Sungai Patani which is in the terrane.

In this article, the extent of the terrane in west Kedah will be delineated and the timing of the metamorphism and oher implications will be discussed. Detailed petrological studies of the metamorphics are in progress and here only brief descriptions of the metamorphics will be given.

GENERAL GEOLOGY

Much of the area underlain by the Patani Metamorphics in west Kedah has been surveyed by Bradford (1972). The eastern and northwestern margins of the terrane, however, lie outside Bradford's (1972) area of mapping.

Stratigraphy

The layered rocks of the west Kedah area have been divided by Bradford (1972, p.28) into two formations—Jerai and Sungai Patani Formations. The Jerai Formation is made up of an underlying schist sequence and an overlying quartzite sequence with minor calcareous horizons. The Jerai Formation is succeeded comformably by the

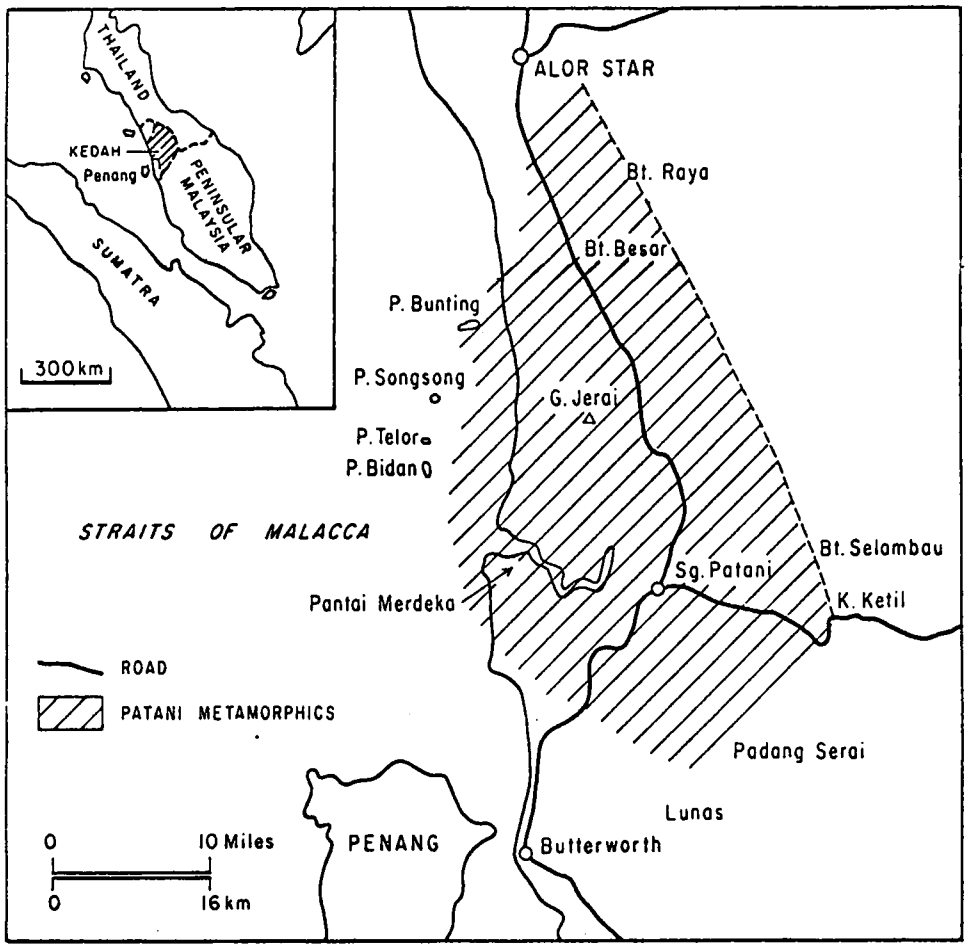

Fig. 1. Area underlain by the Patani Metamorphics in west Kedah.

Sungai Patani Formation (Bradford, 1972, p.28). The Sungai Patani Formation is described by Bradford (1972, p.30) to consist predominantly of a fissile red shale and other sediments of colours such as black, green etc. Some calcareous, arenaceous and phyllitic rocks also occur in the Formation according to Bradford (1972, p.31).

Burton (1967) contended that the red shales of the Sungai Patani Formation are weathered black argillaceous rocks such as shales of the Mahang Formation, the type area of which outcrops further to the southeast (Figure 2). This interpretation is accepted by Jones (1973, p.31). But Courtier (1974, p.16), whose area of study included the type area of the Mahang Formation, persisted with the usage of the Sungai Patani Formation and said that the most characteristic and widespread rock type of the Sungai Patani Formation is a reddish shale and the red colouration is a result of deposition in an oxidizing environment.

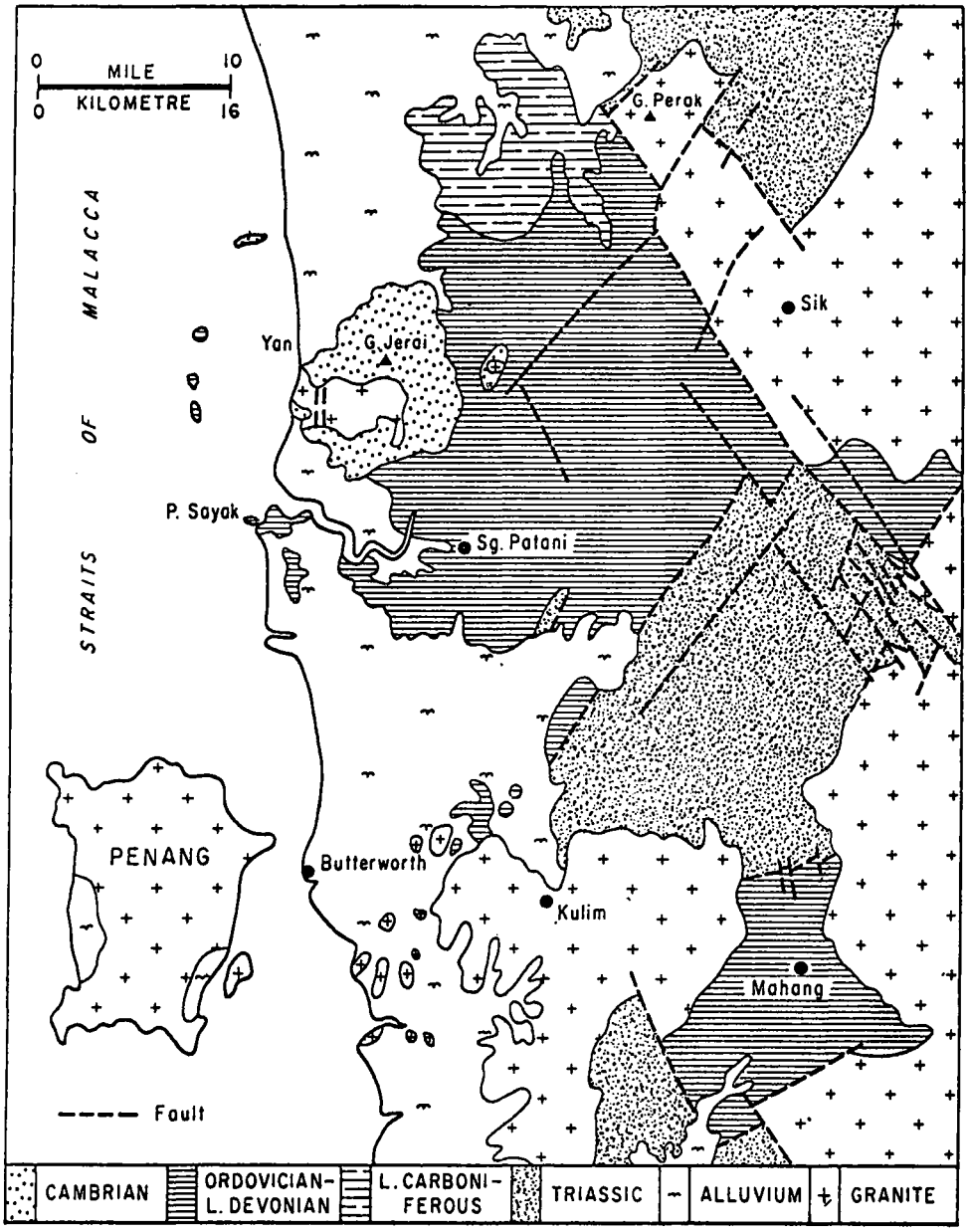

Fig. 2. Geological sketch map of the west and south Kedah area (after Yin and Shu, 1973)

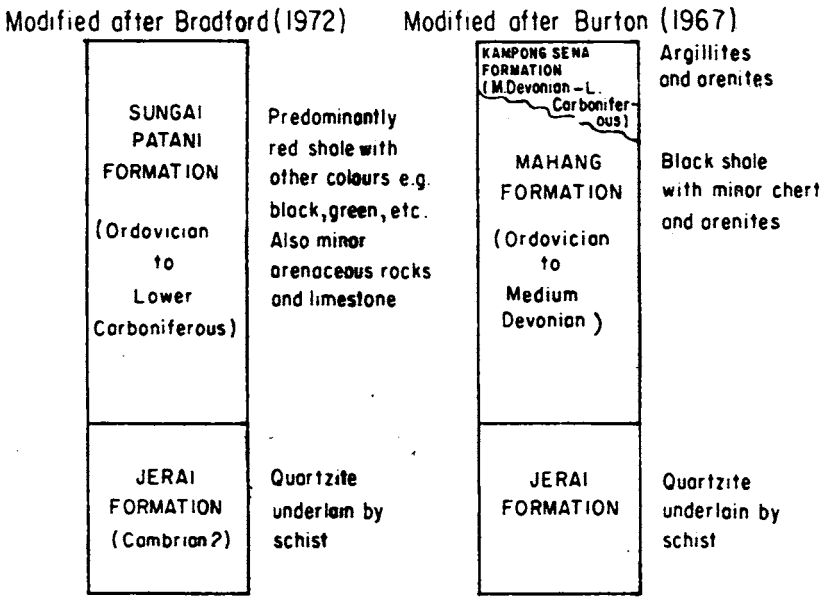

Fig. 3. Summary of the stratigraphy of the west Kedah area.

The Sungai Patani Formation in west Kedah is subdivided into a lower Mahang Formation and an upper Kampung Sena Formation by Burton (1967). The Kampung Sena Formation rocks outcrop at the northern parts of Bradford's (1972) map area and according to Burton (1967) the Kampung Sena Formation consists of argillites and arenites. This split is accepted by Yin and Shu (1973).

A summary of the stratigraphy of the west Kedah area is shown in figure 3.

Igneous activities

Rocks of the Jerai Formation at the Gunung Jerai area have been intruded by small bodies of earlier quartz porphyry and a stock of later granite called the Jerai granite (Figure 2). The quartz porphyry bodies occur at the northern flank of the Gunung Jerai massif and also form much of Pulau Bunting. The quartz porphyry bodies in the Gunung Jerai area have been conclusively shown to be intrusive with contacts cutting the beddings of the Jerai quartzite by Lim (1979). Suggestions by Bradford (1972, p.39) that the quartz prophyry is metasomatized arenaceous rocks and Almashoor (1974) that it is bedded tuff are therefore unacceptable.

The Jerai granite is a biotite-bearing granite intruded into the Jerai Formation. Bignell and Snelling (1977, p.45) dated the granite by radiometric methods and interpreted that granite emplacement occurred at about 300 Ma (ie. late Carboniferous).

The age of the quartz porphyry is uncertain. It intruded into the supposedly late Cambrian Jerai quartzite. There is no evidence that it may not intrude into overlying

Ordovician and younger rocks above the Jerai quartzite which by now have been eroded and removed. However, the presence of acid tuff in the Machinchang Formation in Langkawi and Tarutao (Lee, 1981) which may be lateral equivalents of the Jerai quartzite may indicate that the quartz porphyry may be of late Cambrian age.

Metamorphism

Bradford (1972, p.58) stated that *all the rocks of the Jerai Formation and a few of those of the Sungai Patani Formation have been affected by some degree of metamorphism* and in p.59 he mentioned that *the occurrence of chlorite is limited to a few exposures of the Sungai Patani Formation in the neighbourhood of Bedong and it is noteworthy that in general chlorite is absent from rocks of the Jerai Formation.* In p.60 he further wrote

> *In contrast the rocks of the Sungai Patani Formation, with rare exceptions, are practically unmetamorphosed, although most of its shale exhibits some degree of schistosity. Scattered local evidence of induration can be seen, and phyllite is present in a few localities, but nowhere have metamorphic rocks of a grade higher than chlorite schist been recorded in the formation.*

From the foregoing it is clear that Bradford (1972) considered that regional metamorphism affected rocks of the Jerai Formation and some rocks of the Sungai Patani Formation in the vicinity of the Gunung Jerai massif. However, it is not really clear as regards the statements in p.60.

It was shown by Bradford (1972, p.202) that generally higher grades of metamorphism (greenschist to amphibolite facies) occure near the Jerai granite. Hutchison (1973, p.285) interpreted the increase in grades to be due to the granite intrusion and further wrote

> *It is deduced that the Gunung Jerai granite represents a deep-seated synkinematic stock intrusion into the Cambrian sediments while they were undergoing dynamothermal metamorphism, generally to greenschist facies. The granite stock locally elevated the temperatures in a thermal aureole to raise the metamorphic temperature to that of amphibolite facies.*

This is one explanation for the distribution of higher grade minerals adjacent to the granite.

PATANI METAMORPHICS

Introduction

From the brief account of the general geology of the west Kedah area it is evident that there is much contention as regards the nature of the rocks of the Sungai Patani Formation away from the Gunung Jerai massif and Bradford (1972, p.60) seems to be exceedingly vague or even contradictory as regards the occurrence of metamorphic rocks and texture in the Formation. This confusing state of knowledge in my opinion largely stems from a lack of understanding of the role of tropical weathering on the metamorphics.

The Patani Metamorphics away from the Gunung Jerai massif undergo dramatic transformations as a result of tropical weathering. Phyllites and slates undergo lithological transformation to shales and mudstones. In less lithologically transformed rocks the metamorphic fabric is preserved. More lithologically transformed rocks lose the metamorphic fabric and they are no different from sedimentary rocks. This explains the peculiar statements of Bradford (1972, p.60) quoted above. Besides the lithological transformations, the metamorphics also undergo colour transformations, mainly to red, as a result of oxidation during weathering. This explains the predominance of red shales in the Sungai Patani Formation observed by Bradford (1972, p.30). Further details of the effects of weathering on the phyllites and slates of the Patani Metamorphics are given in Khoo (in manuscript, a).

Lithology

The lithologies of the Patani Metamorphics vary with the composition of the original rock types and the grade of metamorphism. It will be convenient here to describe the rocks occurring in each of the Formations proposed by Bradford (1972, p.28).

Jerai Formation

LOWER UNIT

The lower unit consists of various types of schists such as biotite-muscovite schist, quartz schist and biotite-hornblende schist. The schists show tourmalinization especially those occurring adjacent to granite contacts. Some of the schists are not truly pelitic as evidenced by the occurrence of calciferous minerals in significant amounts such as hornblende and epidote. Glaucophane has been reported in the schist unit by Bradford (1972, p.16) but its occurrence is doubted in Khoo (1980).

At the southern part of the Gunung Jerai massif a body of white marble occurs within the schists. This marble is known as the Jerai marble in Khoo (in manuscript, b) and is possibly the oldest known marble occurrence in Peninsular Malaysia.

UPPER UNIT

The upper arenaceous unit consists of various types of quartzite such as pure white quartzite, pale grey micaceous quartzite, dark or dark greenish grey quartzite which is calcaceous and micaceous and others. The micaceous quartzites developed both biotite and muscovite and the darker varieties contain epidote minerals and sometimes also amphibole. Magnetite is common in the grey quartzites. The quartzites are feldspathic (Chow, 1980).

Some mica schist and calc-silicate rocks also occur interbedded with the quartzites. The schists contains muscovite and biotite. The calc-silicate rocks contain garnet, hornblende, diopside, epidote and other minerals. More details of the mineralogy of the calc-silicate rocks can be found in Bradford (1972, p.58–62) and Hutchison (1973, p283–286).

The quartz prophyry bodies in the Jerai Formation occurring at the Malaysia waterfall behind the abandoned JKR quarry near Gurun, at the Rest House area near

the top of the peak and at Pulau Bunting, off Gunung Jerai have all been regionally metamorphosed. In these rocks the fabric is gneissic. Biotite, muscovite and reorientated relict feldspars show preferred orientation in a quartzo-feldspathic groundmass. Relict quartz phenocrysts are crushed and mortared. The rocks are also sometime tourmalinized and veined by magnetite. However, the larger body of quartz-porphyry at Pulau Bunting has less tectonized rocks where the igneous characters are more preserved (Foo, 1979, p.42).

Sungai Patani Formation

The metamorphics in this Formation consist of rocks of varied compositions. It is made up predominantly of pelitics such as slates and phyllites with minor quartzites, cherts and marble.

PELITIC ROCKS

The pelitic metamorphics consist of 3 main types-black phyllite (and also slate), green slate (and also phyllite) and red slate (and also phyllite). It should be noted here that the red slate is not red-weathered but intrinsically red. Both the black phyllite and green slate can become red-weathered. Evidence, which will be given later that the red slate is intrinsically red and not red-weathered lies in its mineralogical composition which is entirely metamorphic and the mineral assemblage is the same as rocks of similar grade metamorphism eslewhere.

The black phyllite is widespread in the terrane. It is well exposed in the Teluk Nipah—Pulau Sayak area, Pulau Bidan, Pulau Telor, Tikam Batu and in the plantations east of Gunung Jerai such as Gordon Estate, Patani Para Estate, Guthrie KMS Estate and Sungkap Para Estate. These localities occur in the southern, western and eastern parts of the terrane. The only known locality in the northern part is at Bukit Raya.

The green slate occurs at several places notably at Pantai Merdeka, Bukit Raya, Pulau Songsong and Su Poh Estate.

Intrinsically red slates are known at Bukit Raya and Bukit Besar. However, throughout the whole terrane red slaty rocks or even red mudstones are known. It has yet to be confirmed whether some of these may well be intrinsically red and not red weathered. So at present it is uncertain as to the extent of occurrence of the intrinsically red slates. Many localities of the red coloured rocks (red for what ever reasons) in the terrane are shown in Khoo (in manuscript, a).

The black phyllite is carbonaceous and contains quartz, white mica, chlorite, Fe-Ti oxides and pyrite. Some varieties are more quartzitic and less micaceous. The green slates are generally similar to the black phyllities in mineral content except for the lack of carbonaceous materials. The red slate is often quartz-rich with subordinate amounts of white mica, chlorite and hematite. These three rock types occurring in the Bukit Raya area have been found to contain pyrophyllite and 14 A chlorite by Zainol Abidin (1980, p.23). At Pulau Telor and the Pantai Merdeka area the green pelite has been found to contain chloritiod porphyroblasts together with chlorite and reflections in X-ray

diffractograms suggesting the presence of pyrophyllite and paragonite (Foo, 1979, p.34). Muscovite is present in all the pelitic rocks. At Pulau Songsong red slates containing biotite also occur (Foo, 1979, p.37a). The schistose fabric of the rocks is defined by the preferred alignment of the fine white micas and chlorite.

The pelitic rocks usually show one set of cleavage which is parallel to axial planes in places where folds can be seen. The prominant strike of the cleavage is NE-SW with variable angle of dip. In some areas more than one set of cleavages is rather common.

OTHER ROCKS

With increasing amounts of quartz, the pelitic rocks mentioned above may become quartzitic. In addition there are whitish quartzites interbedded with the pelitics especially in areas near Kampung Mak Insun, Sungai Jagong and Junun.

Cherts sometimes with radiolarian remains occur as lenses in the red slates (eg. Bukit Besar) and also as interbeds with black phyllites (eg. Tikam Batu). They often do not show signs of much recrystallization probably due to their competency and the low grade of metamorphism.

Dark grey marble occurs at Pulau Bidan. A *limestone* called the Sungai Patani limestone was reported by Jones (1968) to occur in the Sungai Patani Formation.

Distribution

The distribution of the Patani Metamorphics is shown in figure 1. It can be seen that they form an elongate belt trending north-west. They stretch from Pinang Tunggal at the southeastern part of the belt to the west Kedah coast where they are covered by alluvium and from their occurrence on the island off Gunung Jerai it is highly probable that they underlie the seafloor off the west Kedah coast.

The southwestern margin of the belt is not known. It probably is covered by the alluvium of north Seberang Prai and is mostly offshore. The northeastern margin of the belt appears to be defined by a line joining Tanah Merah—Bukit Selambau.

It is presently uncertain how the belt ends at the southeastern end. Although rocks of the Sungai Patani Formation are exposed at Lunas and Padang Serai, there is no evidence of metamorphism and in these cases field observations are made less conclusive by the occurrence of more intensive weathering of the rocks. It is possible that the belt continues under the Triassic Semanggol Formation (Figure 2). If so, it certainly does not appear to reappear at the Mahang area where there is no evidence that the black argillaceous rocks of the Mahang Formation has developed any schistosity.

In the field the domains of the metamorphics and non-metamorphics can be delineated quite easily by searching for schistosities or cleavages. Even in red-weathered metamorphics relict cleavages can still be seen in many cases. However, if the rocks have suffered more advanced weathering evidence of any metamorphic fabric is not preserved. Also it should be noted that non-metamorphics affected by local

faulting could sometimes develop more than one set of cleavages together with much disturbance and contortion of the strata e.g. near Kampung Begia, Jeniang. Further observations on the relation between fabric preservation and weathering are given in Khoo (in manuscript, a).

DISCUSSION

Timing of metamorphism

The whole of the Jerai Formation in west Kedah and part of the Sungai Patani Formation have undergone regional metamorphism. The Sungai Patani Formation in the west Kedah area has yielded few useful fossils for age determination. Crinoidal marble containing cephalopods occurs in Pulau Bidan which Bradford (1972, p.34) said indicate a Palaeozoic age but Jones (1973) suggested the presence of the cephalopods in the beds may correlate in with the Ordovician to early Devonian Setul Limestone Formation. At the Pantai Merdeka area, Bradford (1972, p.35) found coniconchids similar to those accompanying Lower Silurian graptolitic rocks in the Mahang Formation outside the west Kedah area. The Sungai Patani Formation at the Kampung Mak Insun area was found to contain *Posidonia* which is reported to be Permo-Carboniferous (Kobayashi, 1963). However, later revisions by Jones, Gobbett and Kobayashi (1966) placed the Mak Insun occurrence as uppermost Devonian or lowest Carboniferous.

Lithologically the rocks of the upper unit of the Jerai Formation resemble the arenaceous Machinchang Formation where upper Cambrian fossils have been found at Tarutao. Coupled by the fact that the Jerai Formation underlies the Sungai Patani Formation where lower Palaeozoic fossils have been found, it is popularly believed that the Jerai Formation is also upper Cambrian.

From the disposition of the Patani Metamorphics it can be seen that rocks from upper Cambrian up to uppermost Devonian or lowest Carboniferous have been affected by regional metamorphism. The Mak Insun locality lies at the northeast margin of the Patani Metamorphics area and strata there could be one of the youngest rocks of the terrane if the beds young from west to east as claimed by Bradford (1972, p.15). It is possible that the youngest rocks affected by the metamorphism in the terrane is lower Carboniferous as middle to upper Carboniferous rocks appear to be scarce and anyway have yet to be proven in northwest Peninsular Malaysia (Chung and Yin, 1980).

The only rocks in the terrane not affected by the metamorphism are the Jerai granite and its associated dyke rocks such as pegmatites. There is no evidence that the granite has developed any fabric due to metamorphism. There is no evidence in the granite as well to support the suggestion of Hutchison (1973, p.285) that the granite is synkinematic. Geochronological data of the granite have been interpreted by Bignell and Snelling (1977) to indicate granite emplacement at 300 Ma and more granite emplacement at 200 Ma. These ages correspond to late middle Carboniferous and late Triassic respectively.

From the above evidences it can be interpreted that the lowest Carboniferous

witnessed regional metamorphism but it came to an end by middle to late middle Carboniferous. The lack of middle-upper Carboniferous in the area may indicate a period of uplift and erosion which would terminate the metamorphism. The 300 Ma granitic emplacement episode is probably during the phase of uplift and so is late kinematic (or even post-kinematic) and not synkinematic.

At present, there is no good evidence as to when regional metamorphism first affected the rocks. However, the presence of metamorphosed intrinsically red, high alumina sediments possibly of continental origin in the Carboniferous exposures of Bukit Besar and Bukit Raya (Khoo, in manuscript, a) may indicate that the terrane may have undergone pre-Carboniferous uplift. In Burton's (1967) interpretation of the stratigraphy of the west Kedah area, much of the Sungai Patani Formation is classified as Mahang Formation and the rest is classified as the Kampung Sena Formation. The base of the Kampung Sena Formation is shown in Burton (1967) to be Middle Devonian and resting unconformably on the Mahang Formation. However, other authors (e.g. Gobbett, 1973) favour an uppermost Devonian—Lowest Carboniferous age for the base of the Kampung Sena Formation (= Kubang Pasu Formation). From these interpretations, it can be argued that the pre-Carboniferous uplift could be sometime in Middle to Late Devonian and this time marks an episode of deformation associated with regional metamorphism. The onset of metamorphism could be in the early Devonian or earlier.

The above interpretation is reinforced by observations that the rocks in the southwestern parts of the terrane such as the Pantai Merdeka area commonly have more than one set of cleavages and more highly metamorphosed and complexly deformed. On the other hand, the rocks on the northeast e.g. the Carboniferous are comparatively less deformed commonly with only one set of cleavage and show lower degree of metamorphism. If the rocks of the terrane show a younging towards the east (Bradford, 1972, p.15) then the interpretation will also be in agreement with the stratigraphy.

The metamorphosed quartz porphyry intrusions in the Jerai Formation are high level emplacements or even sub-volcanic from the relict textures of the rocks. It is therefore most Likely that they were emplaced in the late Cambrian where tuffaceous horizons occur in the lithologically similar Machinchang Formation in Langkawi or early Ordovician in order to satisfy the requirement for a thin cover. They have been regionally metamorphosed together with the enclosing Jerai Formation as the orientation of the foliations in the metamorphosed quartz porphyry bodies at the Rest House area and the nearby quartzites are concordant (330°/19° and 330°/50° for the former and 320°/7° and 310°/25° for the latter). As such they are not related to any of the deformation episodes mentioned.

Summarizing, the stratigraphic, metamorphic and structural development of the Patani Metamorphics discussed above as shown in figure 4. In the proposal, it is suggested that the regional metamorphic cum deformation episode spans at least 70 million years and that metamorphism was undergoing in the lower parts of the sedimentary pile while deposition was occurring at the top. During the early Carboniferous, the domain of metamorphism even extended to the younger rocks.

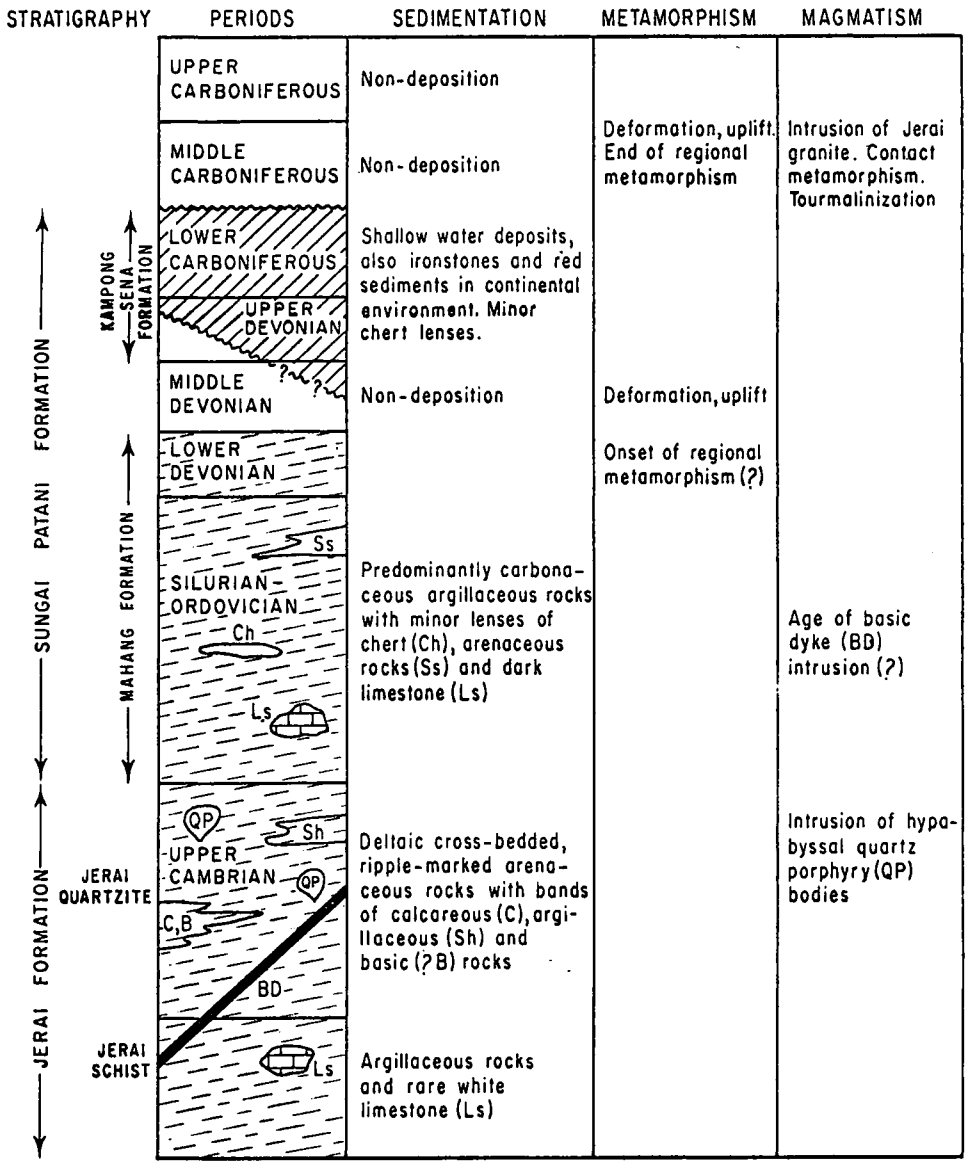

Fig. 4. Summary of the geological history of the terrane of the Patani Metamorphics.

Such characteristics are also suggested for the Caledonides (Read and Watson, 1978, p.47).

Conditions of metamorphism

This is a preliminary discussion as further work is in progress. At the present state of knowledge, the terrane can be divided into 2 zones.

a. an outer zone characterized by the presence of chlorite + pyrophyllite ± chloritoid in pelitic rocks and
b. an inner zone characterized by the presence of biotite in pelitic and psammitic rocks.

The disposition of these 2 zones is shown in figure 5.

From figure 5, it can be seen that the outer zone is more extensive than the inner zone which also includes the Jerai granite. The outer zone is essentially in the Sungai Patani Formation including elements of the Carboniferous. But the inner zone appears to encompass the whole of the Jerai Formation and parts of the Sungai Patani Formation.

OUTER ZONE

The outer zone which consists of slates and phyllites has rocks with mineral assemblages resembling those of the chlorite zone or the quartz albite-muscovite-chlorite subfacies of the greenschist facies (see Winkler, 1967, p.96). Minerals such as muscovite, chlorite, chloritoid, paragonite and pyrophyllite which are present in the outer zone occur in this subfacies. However, this mineral assemblage can also persist into the higher grade biotite zone or quartz-albite-biotite subfacies. Incidentally, chloritoid has so far been found only in areas nearer to the inner zone.

INNER ZONE

In the inner zone, rocks such as slates, phyllites, schists, marble, quartzites, gneisses, calc-silicate rocks and amphibolites can be found. The slates and phyllites petrographically are similar to those in the outer zone but sometimes biotite developed especially in quartzose parts. The quartzites are generally biotite-bearing.

There cannot be a clear understanding of the conditions of regional metamorphism of the Patani Metamorphics unless the effects of contact metamorphism by the Jerai granite are understood. From the limited data available it is still uncertain as regards the extent of contact metamorphism. Development of sillimanite in pelitic rocks adjacent to the granite at Sungai Bujang and the widespread development of tourmalinization of both the pelitic and psammitic rocks can safely be attributed to contact metamorphism and metasomatism by the granite. Also greisenization of country rocks near the granite contact e.g. at Tanjong Jaga is also a contact metasomatic effect.

In contact metamorphism of regionally metamorphosed rocks the regional preferential orientation fabric can still be preserved especially at lower grades. In

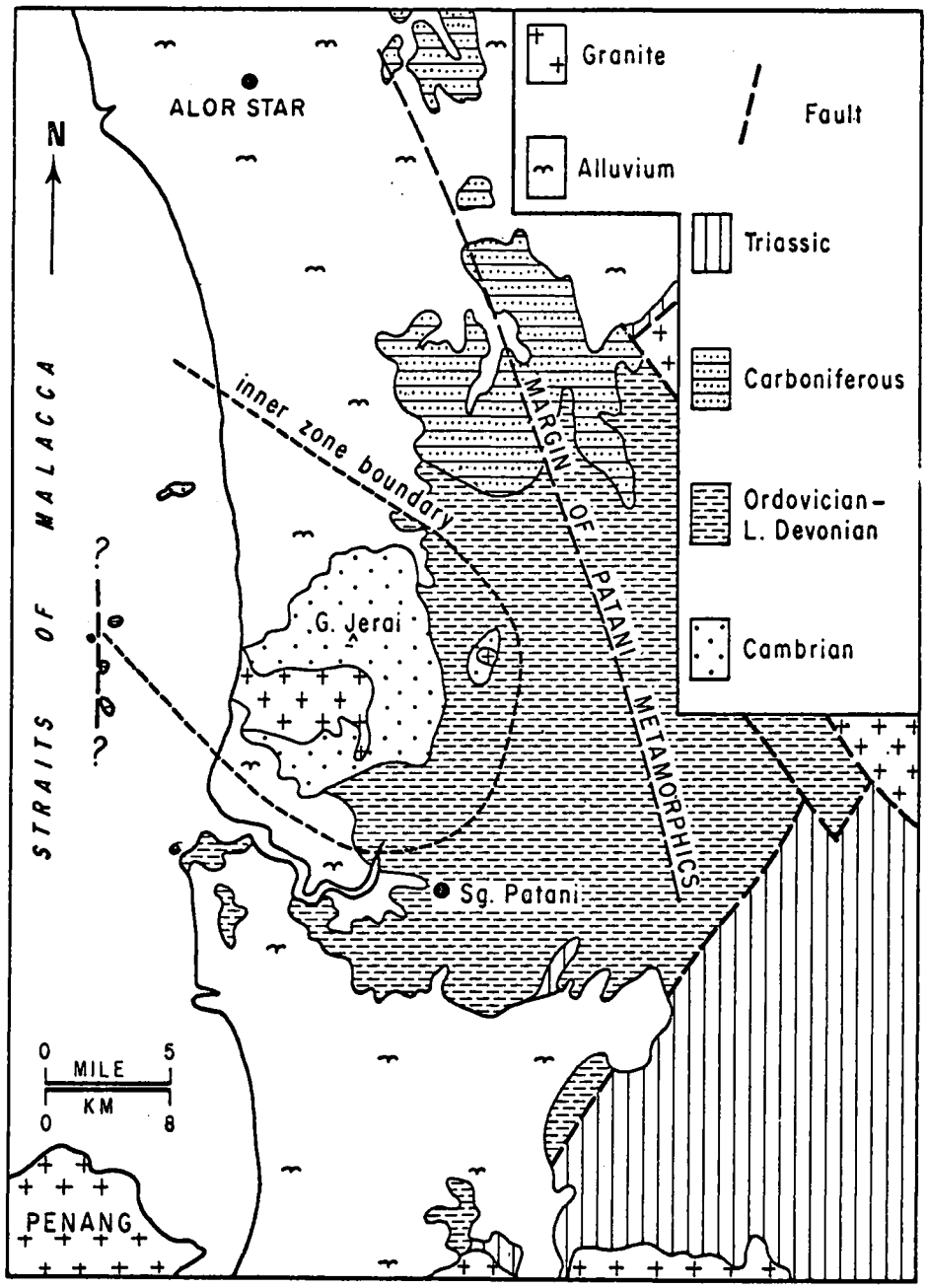

Fig. 5. The terrane of the Patani Metamorphics showing the inner and outer zones.

Donegal (Naggar and Altherton, 1970) and Shetland (Khoo, 1974), contact metamorphism of muscovite-chlorite schists and phyllites respectively gives rise to development of coarser biotite schists due to mimetic crystallization of biotite after other layered silicates. In the Jerai area, it is possible that the schists may be derived from lower grade rocks of the Patani Metamorphics such as phyllites and slates. Aligned biotite in the quartzite could have been developed from preferentially orientated muscovite and chlorite. Aligned hornblende in the calc-silicate rocks and amphibolites could have been derived from aligned actinolitic amphiboles of regional metamorphic origin. There is therefore a possibility that the inner zone may be contact metamorphic in origin.

Extension of the terrane

The regional metamorphic effects of the belt appear to peter out at the southeast in the Lunas—Padang Serai area. But towards the northwest the belt truncates at the west Kedah coast and it will be interesting to find the extension of this belt. West of Pulau Songsong is a solitary sea-stack called Tukun Terundak which is made up of dark pebbly mudstone. The pebbles are calcareous and quartzitic. The mudstone shows no sign of metamorphism. It is possible that a fault exist in the seafloor in between Pulau Songsong and Tukun Terundak. This fault may form the western boundary of the terrane.

Further northwest, the uppermost Devonian—lowest Carboniferous clastics of Gunung Utan Aji in Perlis also show the presence of cleavages like the Patani Metamorphics. It may be possible that these rocks are part of the terrane. The limestone of Gunung Keriang does not show evidence of regional metamorphism and yet this locality would lie within the extended terrane. However, it has been deduced earlier that the regional metamorphism came to a close by the middle Carboniferous but the limestone of Gunung Keriang is believed to be the Permian Chuping Formation (Gobbett, 1973). It is therefore possible that the limestone may be unconformable on the Patani Metamorphics.

Across the sea to Langkawi, Koopmans (1965) showed that the southeastern parts of the group of islands are made up of regional metamorphics such as slates and phyllites with low-angle cleavages (Fig. 6). The similarities between these rocks and the Patani Metamorphics such as the petrography and age of the rocks involved are most striking. There is a strong possibility that the metamorphics in Langkawi belong to the Patani Metamorphics. If so, this will open up new areas for discussion of Langkawi geology and will serve as a link between the geology of Langkawi and the west-south Kedah area which has hitherto been rather neglected in discussions of Langkawi geology.

CONCLUSIONS

The Patani Metamorphics terrane covers a rather large tract of the west Kedah area and there is a possibility that it may extend northwest into south Perlis and the Langkawi islands. The grade of metamorphism of the terrane is generally low and for areas adjacent to the Jerai granite higher temperature minerals developed. At present it appears that there is a superimposition of contact metamorphism by the

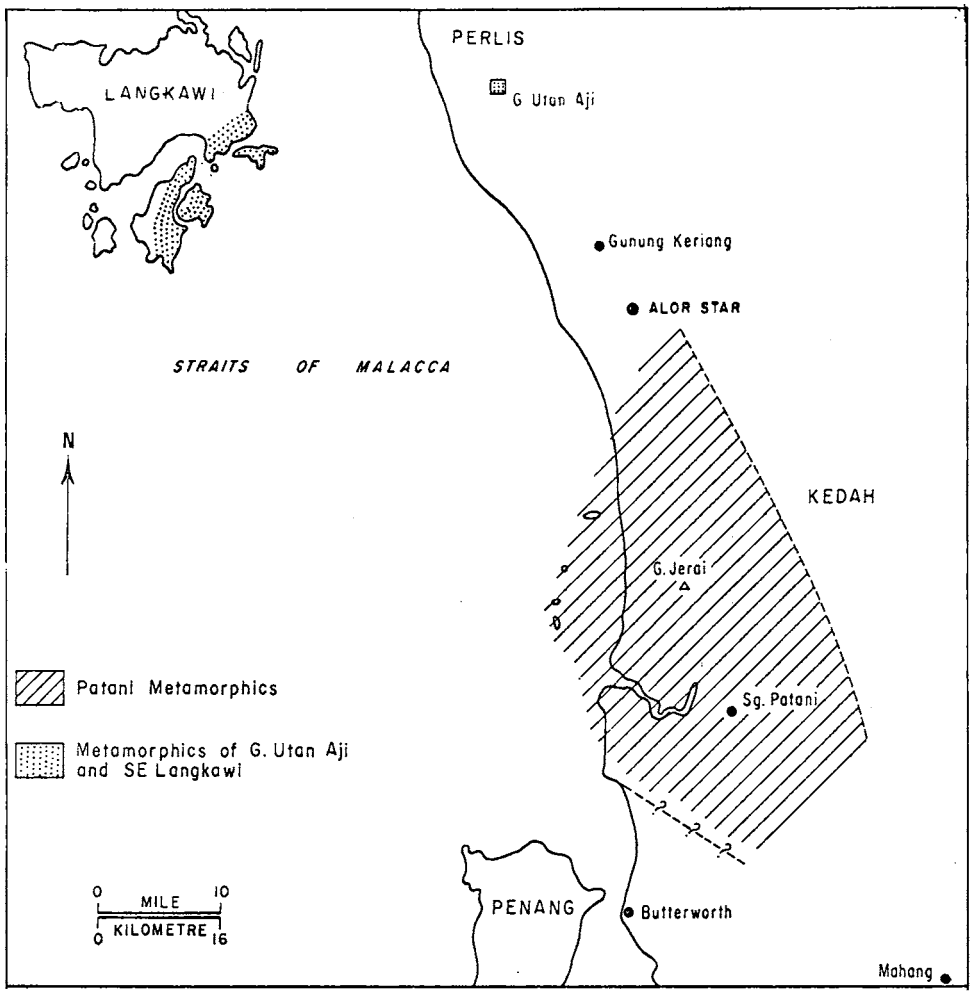

Fig. 6. Possible extension of the Patani Metamorphics terrane.

granite on the regional metamorphics but its extent is uncertain. However, it is possible that the regional metamorphism had attained temperatures for the development of biotite in pelitic and psammitic rocks.

The regional metamorphism came to an end by Middle Carboniferous or slightly later. It is believed that the onset of the metamorphism maybe at least in the early Devonian with phases of uplift and deformation in the mid to late Devonian and mid Carboniferous. The Jerai granite is interpreted to be post-tectonic or late tectonic to the latter event and not syntectonic as suggested by Hutchison (1973, p.285).

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