

Nature of the contact between the Taku Schists and adjacent rocks in the Manek Urai area, Kelantan and its implications

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Abstract: The contact between the Taku Schists and the adjacent rocks in the Manek Urai area is interpreted to be conformable based on structural and petrographic evidences. There is no marked contrast between the grade of metamorphism and structural style as claimed by supporters for other suggestions such as unconformable contact and tectonic disconformity.

Resulting from the above interpretation the age of the rocks in the Taku Schists terrane are argued to be Permo-Triassic but older rocks probably Devonian-Carboniferous may also be represented. Another implication is that the age of the tectonizing phase of the regional metamorphism of the Taku Schists may be early to middle Triassic and uplift of the complex is likely to be in the late Triassic.

INTRODUCTION

The purpose of this article is primarily to discuss the nature of the contact between the Taku Schists and adjacent rocks based on a study of a sector of the contact region in the Manek Urai area, Kelantan (Fig. 1). The nature of the contact has important implications as regards the tectonic evolution of Peninsular Malaysia, especially of the Central Belt and the Manek Urai area is well placed for a study of the contact problem.

GEOLOGICAL SETTING

The Taku Schists form a rather extensive body in north Kelantan and as defined and delineated by MacDonald (1967), the body covers an area of about 750 sq. km (Fig. 2). The terrane lies at the northern end of the Central Belt and has a north-south elongation. The terrane is underlain predominantly by pelitic schists with minor amphibolites and gneisses and rare serpentinite. Foliations of the metamorphics define an open anticlinal structure plunging southwards (MacDonald, 1967, p. 89; Hutchison, 1973, p. 261).

The Taku Schists terrane is bordered by Permo-Triassic sequences of sediments and volcanics except at the part of the western side where it is intruded by granitic rocks according to the maps of MacDonald (1967) and Yin and Shu (1973).

The age of the Taku Schists is uncertain as the nature of their contact with the adjacent Permo-Triassic sequences is uncertain except that it cannot be younger than upper Triassic from geochronological studies of the metamorphics (Bignell and Snelling, 1977, p. 22).

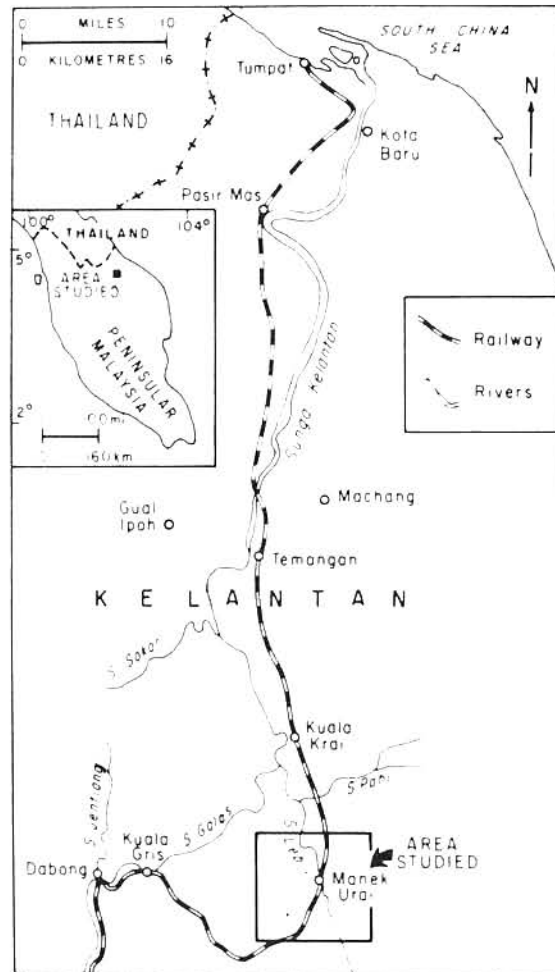


Fig. 1. Location map of the Manek Urai area, Kelantan.

NATURE OF THE CONTACT A REVIEW OF PREVIOUS WORK

The relation between the Taku Schists and the adjacent rocks has been the subject of much controversy in the 1960's. However in the 1970's the controversy apparently *simmered* down mainly due to the lack of new studies of the area. The various suggestions made by previous workers regarding the nature of the contact can be grouped into the following.

1. Unconformity (Hutchison, 1961; Aw, 1964, p. 14; MacDonald, 1967, p. 48).
2. Conformity (Santokh Singh, 1963; Savage, 1925; Chung and Yin, 1980).

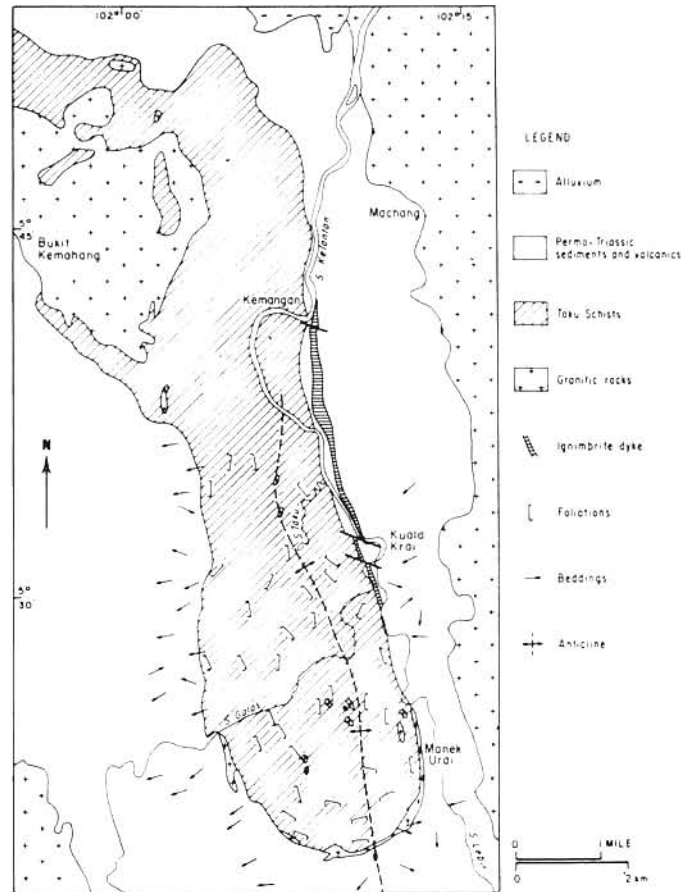


Fig. 2. Geological map of the Taku Schists and adjacent areas (After MacDonald, 1967)

3. Tectonic disconformity (Hutchison, 1973, p. 262).

In addition, Paton (in Agoes, 1958-1959, p. 2-J) did not clearly state the nature of the contact and Macandie and Canavan (1948, quoted in MacDonald, 1967, p. 48) said they were uncertain. Furthermore, several workers said the contact is affected by movements (MacDonald, 1967, p. 89; Alexander *et al.*, 1961; D. Slater, mentioned in MacDonald, 1967, p. 89).

One of the reasons for the numerous suggestions mentioned above is that the contact of the Taku Schists with the adjacent rocks is rarely exposed. Therefore, the suggestions were made based largely on studies and observations of the nature of the Taku Schists and adjacent rocks.

EVIDENCE FOR UNCONFORMITY

Hutchison (1961) stated that the contact of the metamorphics which are in contact with Carboniferous sediments to the east and west are sharp and apparently unconformable. The so-called Carboniferous sediments have now been found to be Permo-Triassic and according to Hutchison (1961) the age of the sediments was obtained from the 1948 geological map of Malaya of the Geological Survey.

Aw (1964, p. 14) gave more details of the same evidence for an unconformity. He said that the Kelantan Schists (= Taku Schists) have attained the garnet grade of metamorphism whereas the overlying rocks are unmetamorphosed. Furthermore he reported that at the Temangan iron mine the contact between the schists and the shales are exposed and is seen to be rather irregular with lenses of weathered tuff at the contact. These features are interpreted to indicate the presence of an unconformity.

The same argument was also given by MacDonald (1967, p. 48). He said that the contact in the west is at least in part a simple unconformity and in p. 89 he further argued that a *nonconformity of some sort must exist for although dips often appear conformable, the transition from one rock type to another is very sharp and could not possibly be accounted for otherwise.*

Another reason for the presence of an unconformity is that the Taku Schists have gentle dips in contrast to the surrounding sediments which are more steeply dipping (views of S. MacDonald and D. Slater mentioned in Santokh Singh, 1963). However, in a later publication of MacDonald mentioned in the preceding paragraph, the dips of both the Taku Schists and the adjacent rocks were interpreted as conformable.

From the above, it can be summarized that the evidence for an unconformable relationship lies in the supposed marked contrast in metamorphism and structure across the contact. The latter evidence, however, is disfavoured.

EVIDENCE FOR CONFORMITY

Santokh Singh (1963) considered that the Taku Schists are the metamorphosed representatives of the surrounding sedimentary-pyroclastic succession that is no unconformity. He is also sceptical as regards the suggestion that the contact is unconformable for the following reasons:

1. There is an absence of a definite unconformity.
2. There is an absence of basal conglomerate overlying the schists.
3. There is structural conformity of the Taku Schists and adjacent rocks in areas to the south where the outcrop of the Taku Schists generally represents the crestal parts of an anticline and the dip would therefore be expected to steepen in the vicinity of the limbs of the structure.

Other supporters for the absence of an unconformity did not furnish much in the way of evidence but rather statements of belief. Savage (1925) reported that on both

banks of the Sungai Galas (Fig. 2) are continuous outcrops of phyllites which were believed to be sheared volcanic ashes interbedded with the original Raub Series (= the Upper Palaeozoic-Triassic rocks). It is uncertain here whether the phyllites mentioned are part of the Taku Schists. But MacDonald (1967, p. 47) mentioned that the Taku Schists were thought by Savage to be metamorphosed equivalents of sedimentary rocks occurring in the area. Chung and Yin (1980) also imply that the Taku Schists are metamorphosed equivalents of the adjacent rock successions.

It is interesting to note that the main reason for supporting the unconformity suggestion that of contrasting metamorphism has not been proven wrong by supporters for a conformable passage. As it stands, the reasons given by Santokh Singh (1963) do not disprove the suggestion for an unconformable contact but just create some doubts over the interpretation. The view of Savage (1925) was challenged rather apologetically by Alexander *et. al.* (1961) and MacDonald (1967, p. 47) claiming that insufficient field studies were made by Savage (1925).

EVIDENCE FOR TECTONIC DISCONFORMITY

Hutchison (1973, p. 262) suggested that the eastern margin of the Taku Schists is more likely to be a tectonic disconformity rather than a depositional unconformity. Also the western margin is assumed to be a tectonic disconformity similar to that in the east based on similar reasons given below.

1. There is a *sharp contrast in metamorphic grade at the contact i.e. amphibolite grade in the schists and greenschist grade in the adjacent rocks.*
2. There is a contrast in deformation style as the *Taku Schists are characterized by a simple asymmetric structure whereas the lower grade overlying rocks are isoclinally folded and outcrops generally show steep dips.*

These features are interpreted by Hutchison (1973, p. 262) to show that

Taku Schists are tectonically of the infrastructure characterized by high-grade metamorphism but simple deformation, whereas the overlying rocks are of the suprastructure, characterized by greenschist metamorphism, isoclinal deformation and a phyllitic nature.

It should be noted here that in this suggestion it is claimed that there is a contrast in structural style across the contact. The steeply dipping sequences bordering the eastern and western sides of the Taku Schists terrane which dip to the east and west respectively have been interpreted to be isoclinally folded. As mentioned previously, these features have also been interpreted to be steeper sides of an anticline with the Taku Schists forming the core.

The contrast in grade of metamorphism across the contact is still maintained. However, here, Hutchison (1973, p. 262) gave convincing reasons that the so-called overlying rocks at the eastern margin are weathered greenschists facies phyllites which on tropical weathering are transformed to rocks similar to shales. Therefore, the

contact seen at the Temangan area may be between weathered phyllites and schists and the mudstone at the contact at one point on the banks of the Sungai Lebir revealed by pitting (Alexander, *et al.*, 1961) may also be weathered phyllite. So the transition across the contact may be from phyllites to schists and not from shales to schists as suggested by supporters for an unconformity.

NATURE OF CONTACT OF LOCAL SIGNIFICANCE

At the eastern margin, that is the Temangan area, there are features taken to be evidence for faulting at the contact area (Aw, 1964, p. 14; MacDonald, 1967, p. 89; Alexander *et al.*, 1961). However, such faulted contacts are apparently of local significance.

At the southern and southeastern margins of the Taku Schists terrane, MacDonald (1967, p. 48) reported the occurrence of a *zone of minor igneous intrusion and intense shearing ranging up to one mile in width*. In p. 89, he further mentioned that D. Slater suggested that the contact is a plane of movement along which granite has been intruded, and subsequently, in part, mylonitized. The intense shearing was suggested to be due to movements of the overlying sedimentary and volcanic rocks of differing competency upon the schist surface during the same folding phase (D. Slater, mentioned in MacDonald, 1967, p. 89; Alexander *et al.*, 1961). The nature of the contact in this area will be discussed in greater details later as it is within the Manek Urai area.

GEOLOGY OF THE MANEK URAI AREA

Before the nature of the contact in the area can be discussed it is necessary to give a brief account of the geology of the area considered to be essential for the discussion. A simplified geological map of the Manek Urai area is shown in figure 3. From the map it can be seen that the western part of the area is underlain by the Taku Schists. Bordering the Taku Schists is a zone of low grade regional metamorphics which occurs at the central part of the mapped area. Towards the east the low grade regional metamorphics grade into unmetamorphosed Triassic sedimentary and volcanic rocks. The eastern part of the area is mainly underlain by granitoids of the Boundary Range.

THE TAKU SCHISTS

In the Manek Urai area, the terrane of the Taku Schists is shown in the geological map of MacDonald (1967) to be rimmed by granite (Fig. 2). A geological map of the Taku Schists terrane in Hutchison (1973, p. 257) shows the rim to be catazonal granite and in p. 256 it is mentioned that along the south and southeast margin, the schist body is bounded by an interfoliated band of autochthonous foliated granitic gneiss about 1 km wide.

In Lim (1975), however, it was found that this rim of so-called granite or catazonal granite is made up of several types of quartzofeldspathic gneisses interbanded with pelitic and amphibolitic schists. Along the Sungei Mei, the interbanded gneisses and schists occur for about 0.5 km from the boundary of the Taku Schists terrane. The

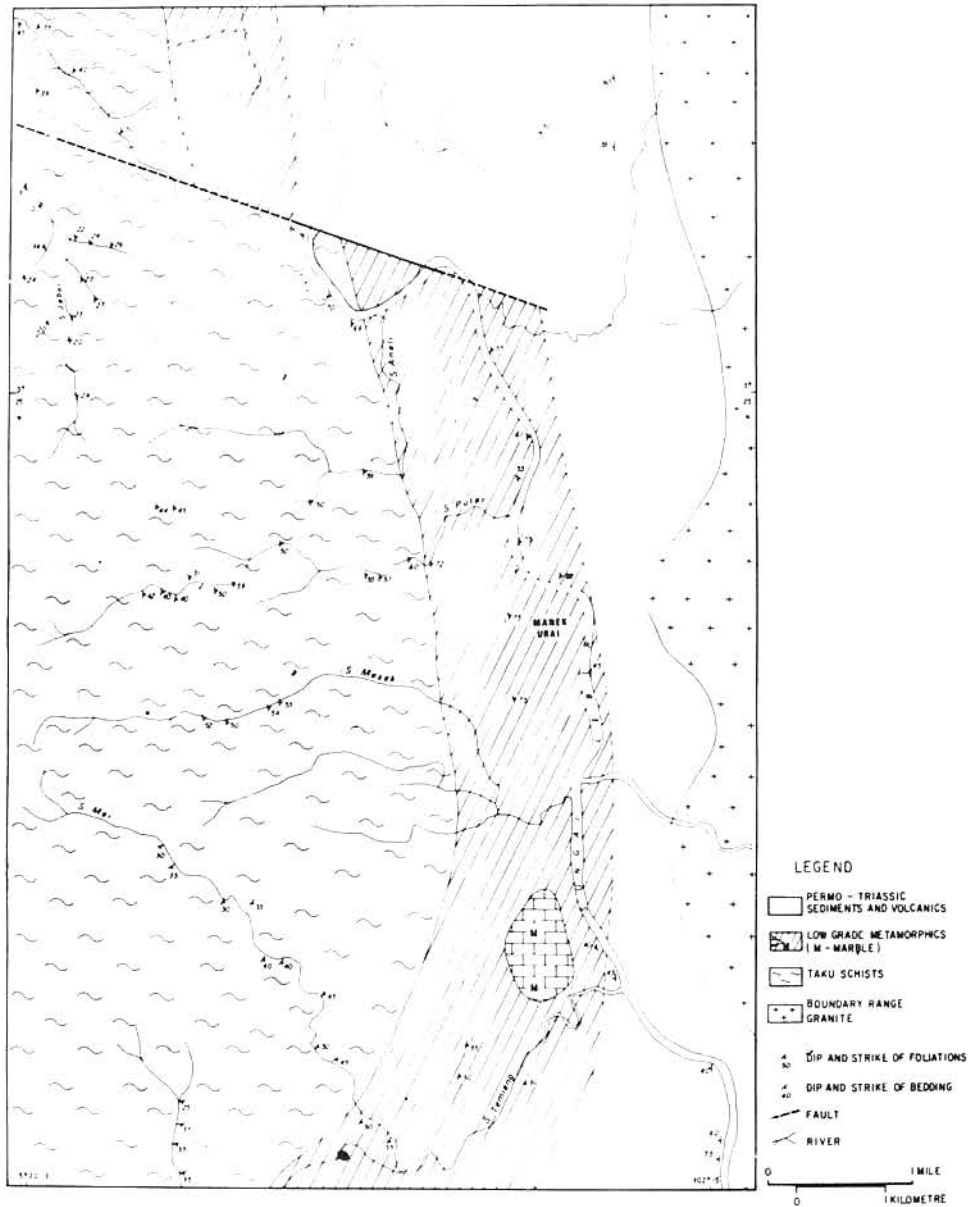


Fig. 3. Simplified geological map of the Manek Urai area.

gneissic bands do not appear to be thick and bands as narrow as 0.5 m occurring in between pelitic schists have been found in Sungai Mei.

It is possible that this rim may not even be predominantly underlain by gneisses. The gneisses occur as sporadic exposures in the streams and being more resistant to weathering than the pelitic schists they are more likely to be preserved than the intervening pelitics. Depicting this rim as granite therefore does not truly describe the rock types present and gives a false impression of its abundance in the terrane.

Two main types of gneisses occur. Both of them contain abundant cataclastic relics of plagioclase, alkali feldspar and quartz embedded in a finer grained quartzofeldspathic groundmass. One type contains minor amounts of crudely aligned biotite plates while the other type shows well-formed biotite foliations and more intensely granulated relics. Some of the plagioclase also show zoning. It is interpreted here that the gneisses are originally either acid volcanics or granitic sheets emplaced before the regional metamorphism. The latter, however, seems to be more likely.

Further into the Taku Schists terrane porphyroblastic garnetiferous amphibolite and mica schists are exposed. These garnetiferous rocks are especially common in the middle and upper parts of Sungai Mei and the adjacent Sungai Mesek. This is in contrast to the amphibolitic and pelitic rocks at the rim of the terrane which are non-garnetiferous.

At the upper part of Sungai Mei, a specimen from either an exposure or loose block has been found to contain small kyanite grains occurring in the midst of fibrous sillimanite masses.

THE LOW GRADE METAMORPHICS

In the Manek Urai area, the low grade metamorphics bordering the Taku Schists terrane are represented by grey and green phyllites, metabasalts, greenschists and marble. This confirms the earlier mentioned view that the transition from the Taku Schists to the adjacent rocks is from schists to phyllites and not from schists to sediments.

The most predominant type of low grade metamorphics in the area is the phyllite with the grey variety being the more common. The greenschists and metabasalts are interbedded with the phyllites. The marble occurs as small hills south of Manek Urai.

The grey phyllite is made up predominantly of feldspars, quartz and white micas with subordinate amounts of opaque and white micas, opaque minerals and rock fragments. The foliation of the rock is defined by preferred orientation of white micas, streaks of opaque minerals and lenses of quartzofeldspathics in a fine grained groundmass. The feldspars are relics showing cataclastic features and plagioclase is zoned and saussuritized. The rock fragments contain small plagioclase laths in fine grained groundmasses and are most probably volcanic rocks. The grey phyllite groundmasses and are most probably volcanic rocks. The grey phyllite is most probably of tuffaceous origin.

The green phyllite is composed mainly of schistose masses of chlorite and grains of epidote and plagioclase. The plagioclase shows cataclastic features and is saussuritized. Opaque minerals in minute quantities are disseminated throughout the rock.

The greenschist is quite similar to the green phyllite except that it contains calcite as well. The metabasalt is a less tectonized rock containing relics of diopsidic augite phenocrysts embedded in a groundmass of epidote, plagioclase and chlorite. The marble is only very slightly magnesian and contains a little white mica and quartz.

From the above, it can be concluded that the low grade metamorphics in the area are predominantly metamorphosed volcanics and tuffaceous rocks, some even of rather basic compositions such as the greenschist and metabasalt.

THE UNMETAMORPHOSED SEDIMENTARY AND VOLCANIC ROCKS

The unmetamorphosed sedimentary and volcanic rocks in the Manek Urai area consist of interbedded shale and volcanics such as pyroclastics, acid ash flow rocks and acid porphyritic lavas (Lim, 1975). The junction of these rocks with the adjacent belt of low grade metamorphics is not clear but is probably gradational. Most of the exposures of the unmetamorphosed rocks occur east of the Sungai Lebir but there are also occurrences west of the river especially at the southern part of the area.

THE BOUNDARY RANGE GRANITE

In the area, the Boundary Range granite is made up of granodiorite and adamellite containing orthoclase and biotite among other usual minerals in such rocks. Locally the adjacent sediments have been thermally metamorphosed by the granite body.

Granitoids from the Boundary Range granite have yielded Upper Triassic radiometric ages according to Bignell and Snelling (1977, p. 15-18).

STRUCTURE

As late faulting has little or no relevance to the discussion of the nature of the contact, only folding will be emphasized here. However, in Lim and Khoo (1976) it has been expressed that evidence for the presence of the major Lebir Fault is lacking in the area.

In the Manek Urai area, the foliations of the metamorphics in both the Taku Schists and the adjacent low grade metamorphics have been seen to be concordant to the beddings and instances of foliations at an angle to the beddings have not been encountered. The concordance of the beddings and foliations of the metamorphics in the Taku Schists has also been reported in MacDonald (1967, p. 89).

Plots of foliation poles of the metamorphics in the Taku Schists and the low grade metamorphics are shown in figure 4. Interpretation of the results will be given later when the nature of the contact is discussed.

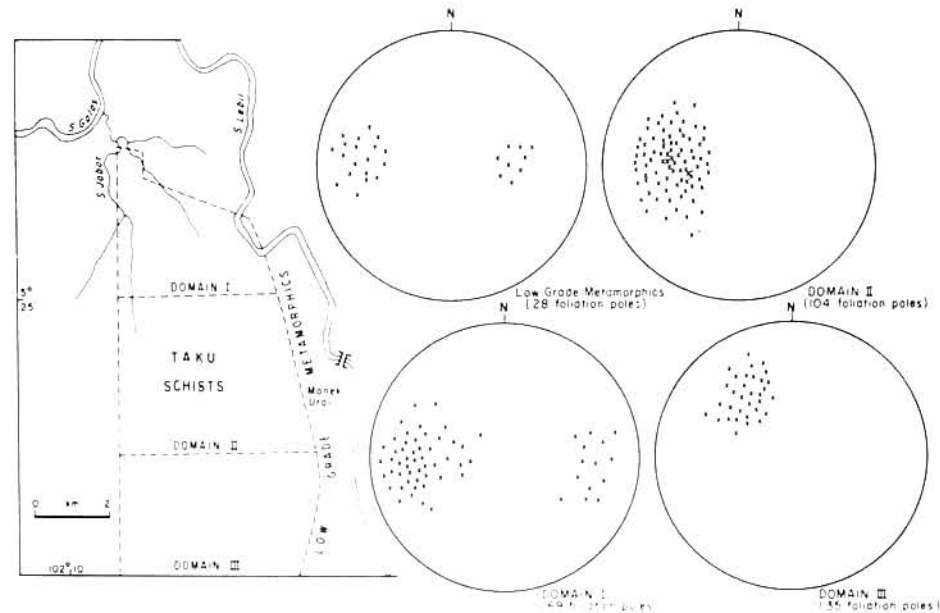


Fig. 4. Foliation poles of metamorphics in the Manek Urai area.

Minor folds have also been seen in the Taku Schists and the low grade metamorphics. In Sungai Jabor the metamorphics are sometimes thrown into open folds which show no evidence of new cleavage development. The phyllites sometimes show intense folding and tight folding has been seen in the marble. Nowhere has isoclinal folding been seen.

NATURE OF THE CONTACT IN THE MANEK URAI AREA

The nature of the contact in the Manek Urai area will be interpreted from two lines of evidence—petrographic and structural.

PETROGRAPHIC EVIDENCE

The petrography and distribution of the metamorphic rocks suggest there is metamorphic zonation from chlorite to possibly sillimanite of the Barrovian type in the area. Chlorite zone rocks are represented in the belt of low grade metamorphics bordering the Taku Schists. The succeeding zones are largely in the Taku Schists terrane where pelitic schists are also reported to contain biotite, garnet, staurolite, kyanite and sillimanite (MacDonald, 1967, p. 49). A provisional map showing the metamorphic zonations is shown in figure 5.

Chlorite Zone

The mineralogy and texture of much of the rocks in the low grade metamorphics area resemble those in rocks of chlorite zones in classic areas. The development of

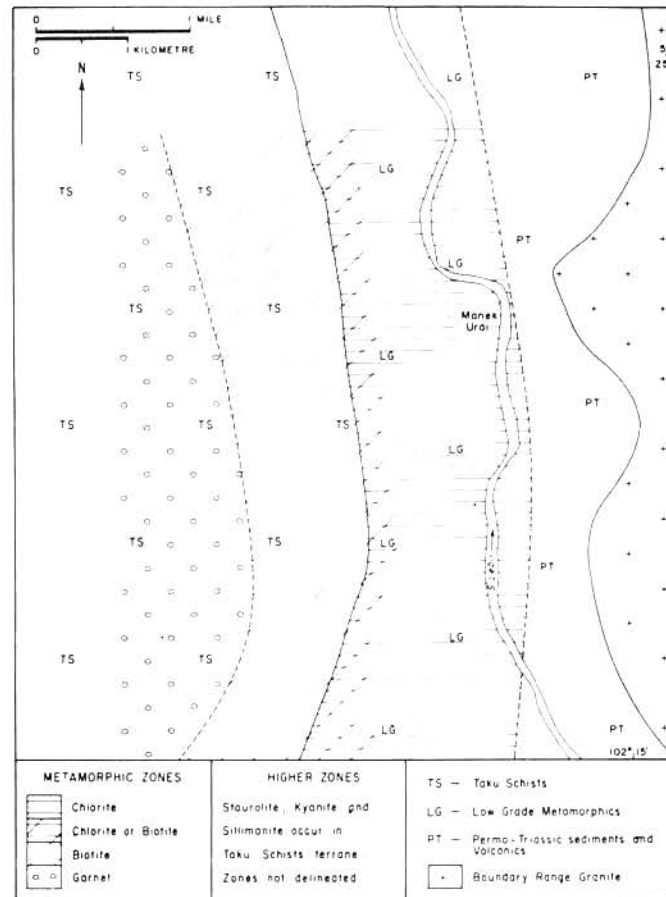


Fig. 5. Metamorphic zonation of metamorphics in the Manek Urai area.

minerals such as chlorite, white mica and epidote and the presence of abundant cataclastic relics are characteristic of chlorite zone metamorphism such as in Unst (Read, 1934).

Chlorite zone metamorphism is characterized by the prevalence of dynamic effects over the thermal effects. The temperature attained is not high enough to cause much or rapid recrystallization and so cataclastic relics are often preserved. In the rocks of the Manek Urai area it is therefore not surprising that even zoning of relict plagioclase grains is not destroyed by metamorphism.

Biotite Zone

The first biotite-bearing rocks to appear going from the low grade metamorphics belt to the Taku Schists terrane are the quartzofeldspathic gneisses which define the boundary of the Taku Schists terrane in the area. Certainly these rocks have attained at

least the conditions of the biotite zone. However, since they are the first group of rocks to be biotite-bearing after the chlorite zone, the simplest interpretation is that these rocks mark the entry into the biotite zone or already within the biotite zone.

The type and mineralogy of the rocks occurring at the margin of the Taku Schists terrane are consistent with the petrography of biotite zone rocks. The occurrences of schists and gneisses in the biotite zone is well known. It is also not surprising that cataclastic relics of coarse grained rocks are preserved as the grade of metamorphism of the biotite zone is still low.

As the strikes of the biotite-bearing rocks in the Taku Schists are perpendicular to the direction of increase in grade of metamorphism it cannot be assumed that the boundary of the Taku Schists is also the line joining first appearances of biotite. It is possible that the low grade metamorphics near the boundary of the Taku Schists may have been metamorphosed under the conditions of the biotite grade but biotite failed to develop due to unfavourable rock compositions. Two specimens of grey phyllite from the low grade metamorphics were analysed in Lim (1975). The compositions are plotted in figure 6 and they fall in the phengite field Mather (1970). This shows that the rocks are unlikely to develop biotite unless the conditions of the higher grade part of the zone (that is close to the garnet) are attained. The boundary of the biotite zone may or may not coincide with the boundary of the Taku Schists terrane although it may be speculated that the boundary may be closeby.

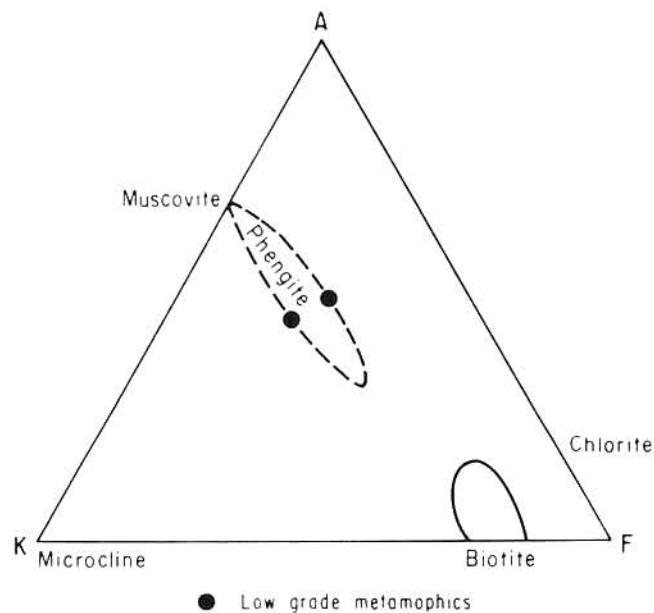


Fig. 6. Plots of compositions of some low grade metamorphics in AKF diagram of Mather (1970).

Garnet Zone

At the Sungai Mei, the first appearance of almandine garnet in pelitic rocks occurs about 300 m upstream from biotite-bearing but garnet-free rocks near the margin of the Taku Schists terrane. Rocks at the middle part of Sungai Mei, Sungai Putat and Sungai Mesek are garnetiferous and are likely to be garnet zone rocks.

Higher zones

Staurolite has not been found in the area although it has been found elsewhere in the Taku Schists. So the end of the garnet zone in the area is uncertain. Kyanite and sillimanite occur in the area and also elsewhere in the Taku Schists testifying to the presence of zones higher than the garnet in the Taku Schists.

The scarcity of staurolite is clearly due to unfavourable rock compositions as staurolites can only develop in rather restricted compositions (Hoshek, 1967). As a result of this reason staurolite is generally scarce in metamorphic terranes.

Interpretation of the contact

The presence of the distinctive kyanite, the progression of the lower zones from chlorite to garnet and also the occurrence of staurolite and sillimanite point to a Barrovian type of metamorphic terrane for the Taku Schists. This interpretation is different from the suggestions of Hutchison (1973, p. 260) that the Taku Schists belong to the low pressure intermediate type of metamorphism. The occurrence of andalusite in the Taku Schists terrane is ascribed to contact metamorphism (Khoo, 1980).

The belt of low grade metamorphics and the Taku Schists terrane together represent a metamorphic terrane with zonation progressing from chlorite, biotite, garnet to higher grade zones of staurolite, kyanite and sillimanite which on presently available evidence are not well defined. There is no marked change in grade of metamorphism across the contact of the Taku Schists. There is no unconformity.

STRUCTURAL EVIDENCE

Late Folding

With reference to figure 4, it can be interpreted that the Taku Schists in the Manek Urai form the eastern limb of an open plunging antiform. Rocks in Domain III lie close to the nose of the southwards plunging antiform while those in Domain II occur on the limb. In Domain I some elements of the western limb are present. The style of folding of the low grade metamorphics can be seen to be somewhat similar to the Taku Schists. There is no sharp contrast in style across the contact of the Taku Schists but evidence of conformity.

The folding referred to above is evidently late and not coeval with metamorphism. There is no new development of cleavage associated with this folding.

Early Folding

Early folding of the Taku Schists and the low grade metamorphics is associated with development of foliations parallel to beddings. Recumbent or isoclinal folding is

implied. From the development of the late plunging open antiform and the zone of gneissic bands which curves round the nose of the antiform it seems that early recumbent folding associated with regional metamorphism is more likely.

Interpretation of the contact

Although some of the foliations and beds of the low grade metamorphics are now steeper than in the Taku Schists across the contact, the evidence given above shows that there is no sharp contrast in deformation style across the contact for both early and late folding. There is *no* unconformity.

PRESENT INTERPRETATION

The petrographic and structural evidence detailed above favours a conformable contact between the low grade metamorphics and the Taku Schists. The evidence is also against all the reasons given for an unconformable relationship or for the presence of a tectonic discontinuity. The so-called reasons for the last two suggestions are not true in the light of the new data from the Manek Urai area.

The oft repeated point that there is a marked difference in grade of metamorphism across the contact has in fact never been conclusively demonstrated. The interpretation is based either on

(a) the transition from shale or mudstone, which are actually weathered phyllites, to schists

or

(b) evidence of grade of metamorphism of the Taku Schists not from rocks at the contact but from rocks occurring elsewhere in the terrane.

In a typical Barrovian metamorphic terrane there will of course be a marked difference in grade of metamorphism between a sillimanite grade rock and a chlorite grade rock but problems of contact relationship can only arise if they are in contact. Statements of marked difference in grade of metamorphism across the contact are either unsubstantiated impressions or made on grounds now known to be erroneous.

If there is an unconformity, it is to be expected that if the overlying rocks have been metamorphosed to low grades the underlying rocks, the Taku Schists, should show signs of widespread retrograde metamorphism. Apart from the usual late diaphoretic alterations, the Taku Schists show no evidence of retrograde metamorphism. On this ground the suggestion for an unconformity cannot be accepted as well.

The unconformity and tectonic discontinuity suggestions appear to have been proposed on the basis of late folding style. Early deformation of the rocks has not been considered. In both the Taku Schists and the low grade metamorphics the foliations have always been seen to be parallel to bedding. This shows structural similarity rather than contrast.

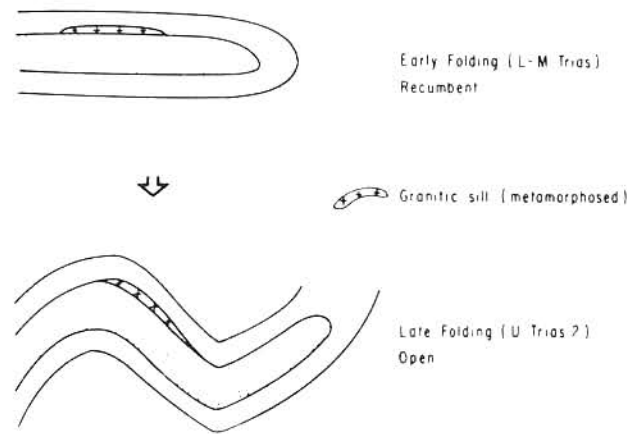


Fig. 7. Probable structure of the Taku Schists and adjacent rocks.

The probable E-W sections across the Taku Schists terrane and the adjacent rocks according to the present interpretation are shown in figure 7.

IMPLICATIONS

The interpretation for a conformable contact between the Taku Schists and the adjacent rocks results in two implications which are discussed below.

AGE OF THE METAMORPHICS

The low grade metamorphics which grade into unmetamorphosed rocks are most probably of similar age which is shown to be Permian - L. Triassic according to the geological map of Gobbett (1972) and Triassic according to the geological map of Yin and Shu (1973). As there is no unconformity, the rocks of the Taku Schists terrane are likely to be Permian or older. Indeed, Yin and Shu (1973) showed it to be Permian. Hutchison (1973, p. 262) said that the age *remains an open question, but it may well be Lower Palaeozoic*. MacDonald (1967, p. 8) said that the Taku Schists are *certainly older than Carboniferous* although his geological map indicated *possibly pre-Carboniferous?* In this study we agree with Yin and Shu (1973) that Permian rocks occur in the Taku Schists terrane but possibly older rocks are also included and presently exposed.

The Permo-Triassic Central Belt trinity of elastics, volcanics and limestones are not fully represented in the Taku Schists terrane although they are all present in areas adjacent to the terrane such as in the Manek Urai area. Marble is most conspicuously absent in the Taku Schists terrane. However, it may be argued that the occurrences of limestone become lesser towards north Kelantan and hence the absence (Fig. 8). Good evidence of occurrences of metamorphosed acid volcanics is rather scarce in the Taku Schists. There is a possibility that some quartzofeldspathic gneisses which occur not only in the Manek Urai area but also elsewhere such as in Sungai Jabor may be originally acid volcanics. Also a very distinctive white muscovite-quartz schist which

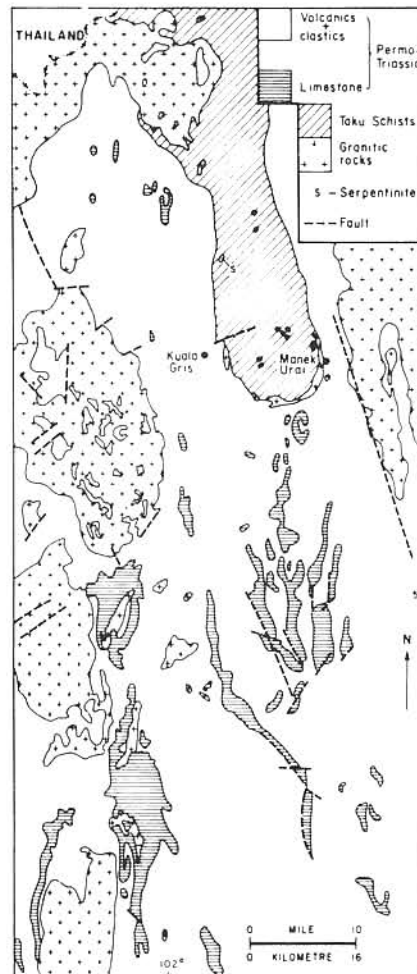


Fig. 8. Distribution of limestones in northern part of Central Belt (mainly after Yin and Shu, 1973).

occasionally occurs in the Taku Schists may be the higher grade equivalent of a distinctive white phyllite with relics of embayed quartz crystals found in the low grade metamorphics adjacent to the Taku Schists near Kuala Geris. This white phyllite is likely to be a metamorphosed altered acid pyroclastic. The rather frequent occurrence of basic amphibolites and an occurrence of black schists at Kampung Tiok near Gual, Ipoh, may indicate that common basaltic rocks and some black mudstones are present in the original rock sequence. These rocks are, however, not similarly represented in the Central Belt sequences.

P.C. Aw (personal communication) has brought to our attention of the similarities of the compositions of Taku Schists rocks and those of the Lower Palaeozoic Foothills Formation. Indeed there are similarities in the occurrence of amphibolites, black

schists, pelitic schists and even serpentinites. However, metamorphosed equivalents of conglomeratic rocks and cherts have so far not been encountered in the Taku Schists although these two are major rock types in the Lower Palaeozoic sequence.

Another line of evidence for determining the age of the Taku Schists is the Lower Palaeozoic radiometric age of the Kemahang granite (Bignell and Snelling, 1977, p. 23). Acceptance of this age would lead to the conclusion that in the Taku Schists terrane there are Lower Palaeozoic or older rocks. However, Khoo (1980) has argued against the acceptance of this age based on geological evidence.

From geological considerations there are reasons to believe that rocks older than Permian occur in the Taku Schists terrane. If pre-Permian rocks do occur they seem to have a rock assemblage with distinctive differences from those of the Lower Palaeozoic Foothills Formation although there may be some similarities. However, very little is known about the Devonian and Carboniferous rocks in the Central Belt apart from the exposure of graptolitic carbonaceous mudstone of Lower Devonian age at the top of the Foothills Formation and Viséan limestone near Kuala Lipis (Jones, 1973, p. 53; Gobbett, 1973, p. 82). It may be speculated that perhaps the Carboniferous and Devonian may be represented in the Taku Schists terrane.

AGE OF THE METAMORPHISM

A discussion of the age of the regional metamorphism of the Taku Schists and also the adjacent low grade metamorphics is fortunately aided by the K-Ar ages of two specimens (S49 and S50, see Fig. 2) from the Taku Schists terrane (Bignell and Snelling, 1977, p. 22-23). One is a quartzofeldspathic gneiss referred to as sheared granite in Bignell and Snelling (1977, p. 23) from Sungai Anali in the Manek Urai area and the other is a mica schist from the western flank of the Taku Schists. They gave 215 ± 8 Ma and 219 ± 9 Ma respectively. These ages are now believed to be Upper Triassic by Bignell and Snelling (1977, p. 22) and not Middle to Lower Triassic as mentioned in MacDonald (1967, p. 47) and Hutchison (1973, p. 260).

Bignell and Snelling (1977, p. 22-23) interpreted that these ages indicate metamorphism (or metamorphic temperature climax) of the Taku Schists is pre-Permian. To come to this conclusion they argued that metamorphic complexes are formed at depths and probably cool down slowly and so there may be a time lag between metamorphic climax and the time when the minerals formed during this temperature climax could retain significant quantities of argon. They took this time lag to be at least 100 Ma. Hutchison (1973, p. 260) interpreted the age to be related to uplift of the rocks to higher crustal levels.

Considering the location of the specimens which were collected from the margins of the Taku Schists terrane, the age of the adjacent rocks (Permian-L. Triassic or Triassic) and the evidence for a conformable contact, the suggestion of pre-Permian metamorphism or temperature climax will be unacceptable. The 100 Ma time lag before argon retention may be grossly over estimated. The grade of metamorphism of the specimens which are of the biotite grade and the rate of uplift will have to be considered. If argon retention begins when the rocks cooled down to 200°C, then the

biotite grade rocks will only have to cool down about 200 °C from the temperature climax in order to begin argon retention. This stage could have been easily attained in a rapidly uplifted orogen and the Central Belt seems to be so. It is uncertain whether the pre-Permian suggestion has been made taking into account the possibility of rapid uplift (see Bignelling and Snelling, 1977, p. 7). We consider the suggestion of pre-Permian metamorphism as unjustifiable on geological grounds.

We agree with the interpretation of Hutchison that the K-Ar ages date uplift and cooling of the Taku Schists. The revised age of Upper Triassic for the ages fit in well with the Central Belt stratigraphy. In the Central Belt marine sedimentation came to an end in the late Triassic followed by major folding and uplift. The late Taku Schists antiformal may be formed during this major phase of folding of the Central Belt.

The concordance of foliations and beddings in rocks of both the Taku Schists and the adjacent low grade metamorphics, which are likely to contain elements of the Lower Triassic, would point to a Early to Middle Triassic phase of tectonizing metamorphism with development of the early recumbent folding. The onset of earlier phases of metamorphism e.g. pre-tectonic is uncertain and difficult to determine. It is possible for sedimentation to occur at the top of a basin while the sediments lower down are undergoing metamorphism (Read and Watson, 1978, p. 47).

The development of porphyroblasts such as garnet and kyanite was after the tectonizing metamorphism but before the late Triassic uplift. It is possible that

TABLE 1
HISTORY OF THE TAKU SCHISTS TERRANE AND ADJACENT AREAS.

Period	Sedimentation	Deformation and Metamorphism	Magmatism
Late Triassic		Uplifting, Cooling, Open folding with N-S axes. Contact metamorphism (?)	Intrusive granites (?)
Middle Triassic		Climax of regional metamorphism and development of post-tectonic porphyroblasts of garnet, staurolite, kyanite and sillimanite. Recumbent folding and syn-tectonic metamorphism	
Early Triassic	Shales, fine arenites, acid to intermediate pyroclastics, limestones.		Early intrusive granites (?) Basic volcanics.
Permian (including Devonian-Carboniferous (?))	Shales, fine arenites, limestone (?), pyroclastics (?).		Basic volcanics. Ultramafic flows (?)

recumbent folding resulted in thickening of the metamorphosed sedimentary pile thereby increasing the load pressure for the development of kyanite.

A summary of the history of the complex, likely to be incomplete, is shown in Table I.

CONCLUSIONS

Structural and petrographic evidence from the Manek Urai area supports a conformable contact for the Taku Schists and adjacent rocks. Suggestions for an unconformable contact or a tectonic disconformity are found to be based on erroneous premises. The age of the rocks of the Taku Schists is Permo-Triassic and it is suggested that elements of the Devonian-Carboniferous may well be present. The age of the tectonizing metamorphism is believed to be Lower to Middle Triassic and it resulted in recumbent folding. Uplift of the complex is interpreted to be in the late Triassic and open folding may have occurred during this time.

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