Geol. Soc. Malaysia, Bull. 8, December 1977. pp 45–60.

Palaeozoic redbeds and radiolarian chert: reinterpretation of their relationships in the Bentong and Raub areas, West Pahang, Peninsular Malaysia

N.S. HAILE,[1] P.H. STAUFFER,[1] D. KRISHNAN,[1] T.P. LIM[2] and G.B. ONG[3]

1) Jabatan Geologi, Universiti Malaya, Kuala Lumpur;
2) arawak Shell Berhad, Miri 3) Robertson Research Ltd., Singapore

Abstract: The Foothills Range in the Bentong-Raub area east of the Main Range in Pahang is composed of three distinct rock units: schist, chert/argillite, and redbed conglomerate/sandstone, separated by at least one and probably two major unconformities. Ultrabasic rocks, mainly serpentinite, occur in parts of the range. The chert/argillite unit contains fossil radiolarians, and shows evidence of having been deposited in a marine, reducing environment; whereas the conglomerate/sandstone unit is almost certainly continental and was probably deposited by fluviatile processes, in a piedmont environment. The structure in the Raub area is homoclinal, eastward dipping, whereas in the Bentong area, a major overturned syncline and a complementary anticline, have caused a repetition of the outcrop of the units. Hitherto these units have been regarded as facies of a single stratigraphic unit, the "Bentong Group".

The schist, chert/argillite and conglomerate/sandstone continue along strike from Bentong southeast to the Karak and Jelebu areas, where the argillite contains Lower Devonian graptolites, and have been mapped together as facies of the "Karak Formation" West of Bentong, in the Genting Sempah area a similar sequence of schist, chert/argillite and redbeds has been mapped as facies of the "~~Bentong~~ Group".

Evidence presented here shows that the "Bentong Group" and "Karak Formation" are not valid lithostratigraphic units, but comprise three separate formations of contrasting lithology. The suggested sequence in the Raub-Bentong area is:

(Raub Group: Early Carboniferous and Younger)
Conglomeratic redbeds: Earliest Carboniferous, or Devonian

Unconformity

Chert/argillite: Early Devonian

Probable unconformity

Schist: Earliest Devonian or older

In the Raub and Bentong Districts of Pahang (Fig. 1), between the granite of the Main Range and low-lying areas further east is a chain of hills, the Foothills Range, mostly 600m high or less, extending from Karak north-northwest through Bentong and passing immediately west of Raub. This range is composed of various sedimentary and metasedimentary rocks (intruded by basic dykes and some ultrabasic bodies) trending in this same direction, with general steep easterly dips. Because the Foothills Range includes ultrabasic intrusions and radiolarian cherts and seems to mark a major facies boundary between West Malaya on the one hand and Central and East Malaya on the other, it has been interpreted as marking a "eugosyncline" by Jones (1968), and more recently there has been some speculation of whether it may represent a former subduction zone (Hutchison, 1973; Haile, 1973). In view of its possible regional significance it seems important to clarify, as far as possible, the stratigraphy of the Foothills Range, which still presents many uncertainties and problems.

THE "BENTONG GROUP"

The sedimentary rocks of the Foothills Range in the Bentong and Raub areas are currently referred to as the "Bentong Group" (Alexander, 1959, 1968). The "Bentong Group" dips eastwards below interbedded shale and limestone of the Raub Group, a sequence locally dated as Carbo-Permian (Carboniferous and/or Permian). Richardson (1939) considered the "Arenaceous Formation" (— "Bentong Group") of the Foothills Range to be of the same age as Triassic sandstones in Central Pahang, further east, implying that the sequence must be structurally inverted. He recognized the possibility that the "Bentong Group" might in fact be older than the Raub Group, but at the time Richardson was writing, the view of Scrivenor that all arenaceous rocks in Malaya were post-Permian was apparently the orthodox opinion, and geologists were loth to dissent from this without strong proof. Later Richardson (1946) suggested the name "Foothills Formation" in place of "Arenaceous Formation", and in a subsequent report "Arenaceous Series" (Richardson, 1950). Alexander (1968) considered that the strata are not, in fact, inverted, and young as well as dip to the east; in other words, that the "Arenaceous Series" does not correlate with the arenaceous Triassic rocks further east, but is older than the Raub Group and dips beneath it. For this reason he renamed Richardson's "Arenaceous Series", the "Older Arenaceous Series", and later the "Bentong Group".

The "Bentong Group", as described by Alexander (1968, pp. 44—55), comprises four main lithologic types: (a) rudaceous, (b) arenaceous, (c) lutaceous, and (d) cherty. As appears from the maps of Alexander and Richardson, chert and shale occur more generally in the west of the Foothills Range than to the east, and arenaceous and rudaceous rocks predominate to the east, but Alexander (1968, p. 44—5) states that the lithologies are not confined to any particular horizon, and occur as lenticular bodies, frequently interbedded and passing laterally and vertically one into the other.

Richardson (1939) considered the schist and amphibole schist along the west side of the Foothills Range in the Raub area to be the metamorphic equivalent of the "Calcareous Formation" (the present Raub Group). Alexander mapped these separately, in the Bentong area and shows them as older than the main "Bentong Group"; however, he states that they may be "an earlier extension" of the "Bentong Group"; he is not at all clear about this. In the Genting Sempah area he does not map them separately, but includes them in the "Bentong Group", and in a regional sketch map (his Fig. 5) they are shown as part of the "Bentong Group".

Both Richardson' and Alexander's accounts are very general, and lack detailed descriptions of sections. Paleontological evidence is scanty. Triassic fossils have been recorded in the Taba tributary of the Lipis River, about 6 miles north of Raub (L.R. Cox, 1936, cited by Richardson, 1939, p. 23), within the general belt of supposedly Carboniferous and/or Permian Raub Group (and mapped by Richardson as within an outlier of

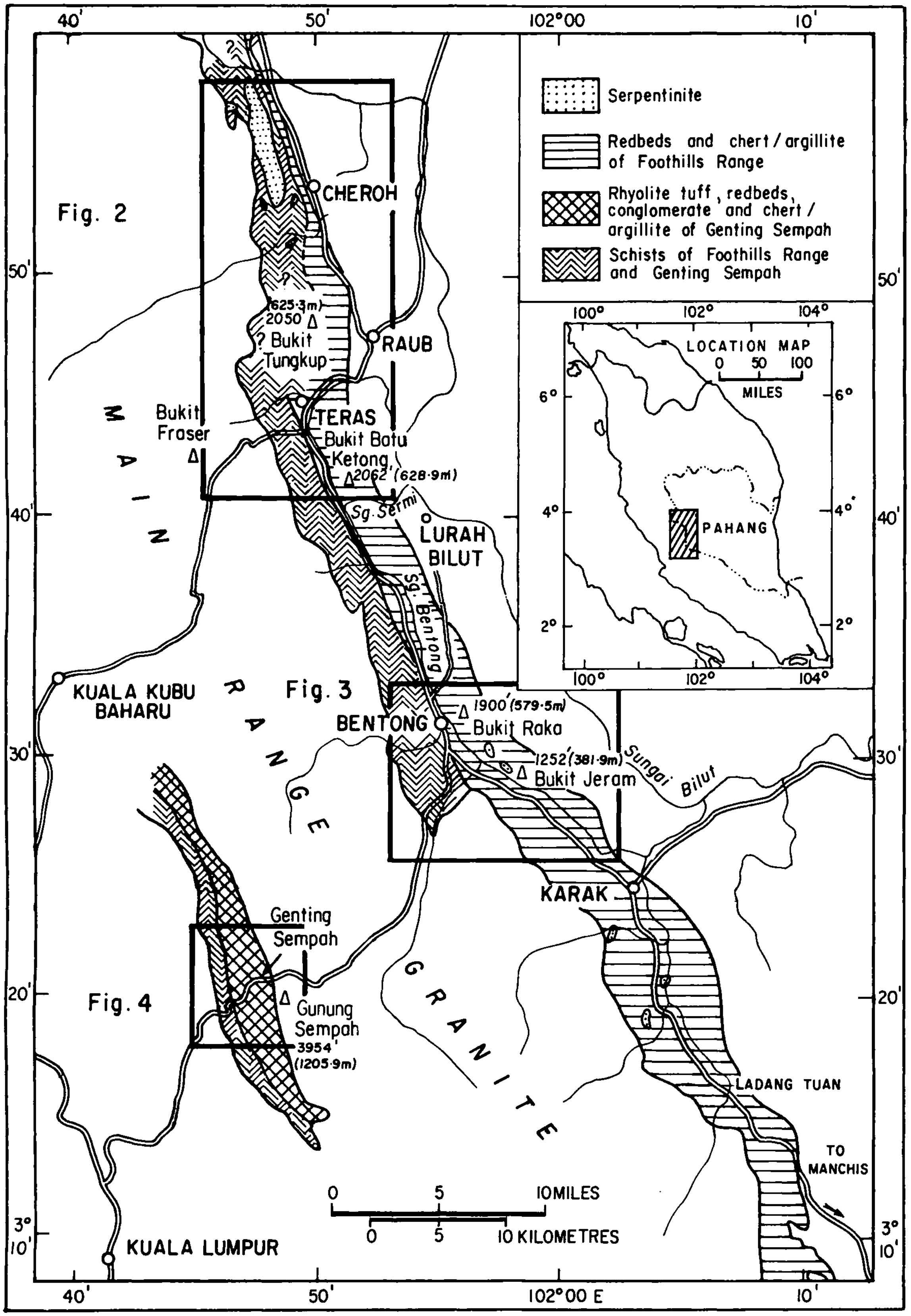

Fig. 1. Map showing general geology of Foothills Range and Genting Sempah.

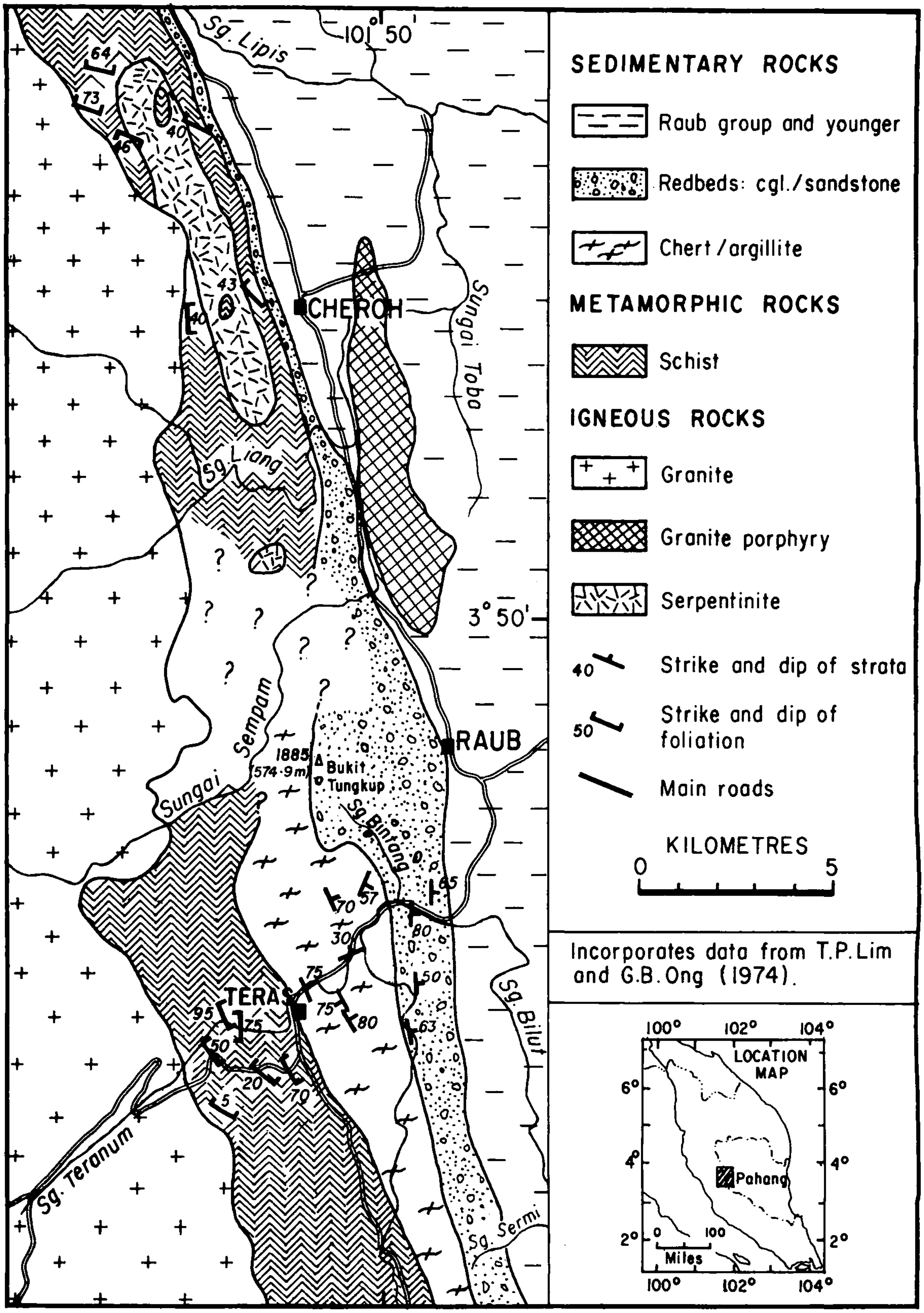

Fig. 2. Geological map of the Raub area.

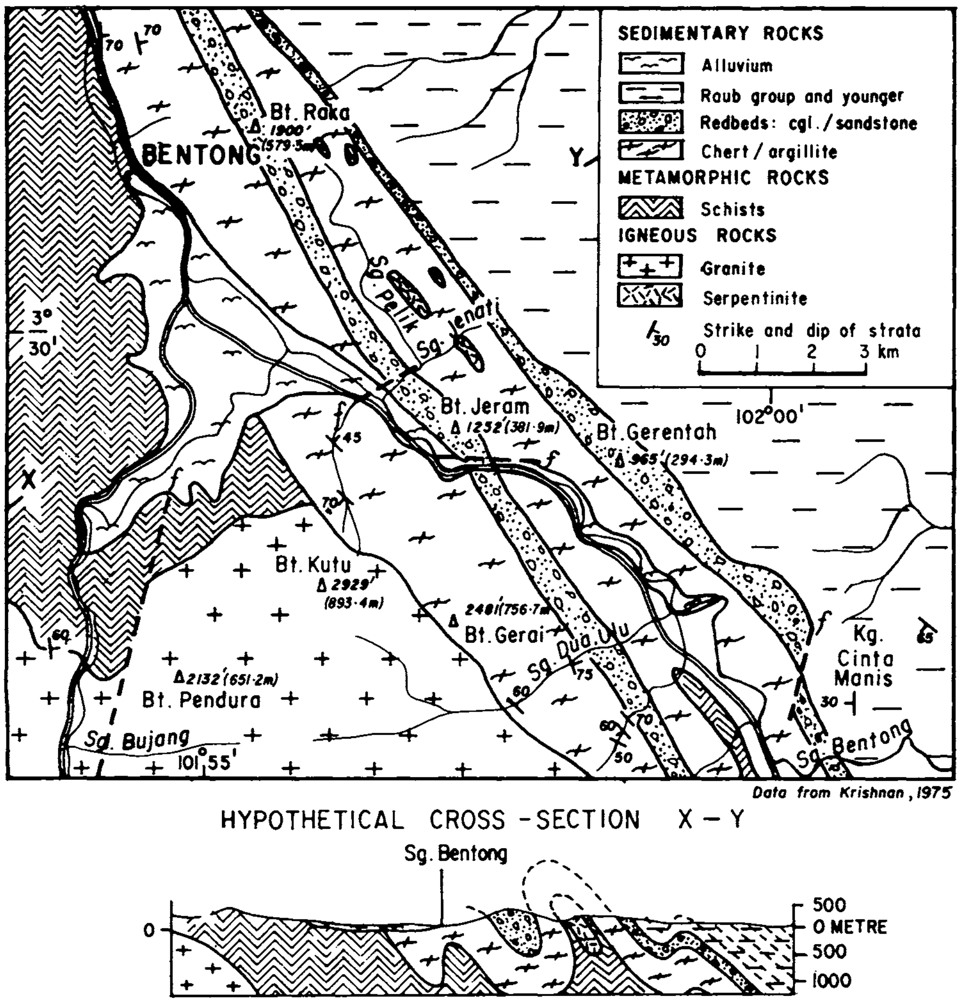

Fig. 3. Geòlogical map of the Bentong area.

"Arenaceous Formation"); and jellyfish and brachiopods found in the Raub Group near Cheroh indicate a Lower Carboniferous age (Tan and Sivam, 1971; Yancey, 1972). To the north of the Raub area, in the Lipis District, in calcareous rocks that lie along the strike of the Raub Group of the Bentong and Raub Districts, fossils of supposedly Carbo-Permian age were found (Muir-Wood, 1948, p. 1–5, cited by Alexander, 1968, p. 59). Graptolites originally identified as Lower Sulirian, later as Lower Devonian, were recovered from shale interbedded with rhyolite tuff south of the Bentong area in the "apparent southern prolongation of the Older Arenaceous Series" (Alexander, 1968, p. 22, footnote; Jones, 1970).

On the whole we agree with the sequence proposed by Alexander, although the structure may be more complex than supposed; for example, the Raub Group includes the supposed outlier of Triassic near its western (and therefore supposedly older) margin, and we found, in the Dong River about 5.5 km east of Kampong Dong, an exposure of high-grade metamorphic rocks, within the area mapped as Raub Group.

It is evident that further systematic mapping will be necessary to sort out the stratigraphy and structure of this area. We do not have enough field data to attempt a general revision but wish to draw attention particularly to what appears to be the anomalous inclusion of redbeds and radiolarian chert in the same lithostratigraphic unit and suggest hypotheses for further testing. For this reason we are confining our attention to the "Bentong Group" and the underlying schist sequence.

PRESENT FINDINGS: LITHOLOGY

Reconnaissance (by Haile and Stauffer) was done on a number of one day trips and during a student mapping course from 29 July to 4 August 1972. Subsequently three of us mapped in detail some portions of the range as part of the B.Sc. (Honours) course. T.P. Lim (1972) mapped the Cheroh area (north of Raub) in 1972, and G.B. Ong (1974), in 1973 mapped an area south-west of Raub (figure 2); in 1974, D. Krishnan (1975) mapped an area around Bentong (figure 3).

Schists

The schists of the Foothills Range are predominantly quartz-mica schists, with some other pelitic varieties, such as quartz-graphite schist and subordinate lenses of amphibole schist. Lim (1972, p. 20–21) established that in the Cheroh area the schist contains biotite as well as muscovite, sericite, chlorite, and carbonaceous matter, and considered the rock to belong to the epidote-biotite subfacies of the greenschist facies. Amphibole schist (UM 8113*) is found in lenses several hundred metres long within the quartz-mica schist, and also included in serpentinite (in Sungai Batu north of Cheroh, see Lim 1972, p. 12). It has possibly been derived from calcareous rocks or basic igneous rocks; Lim considered an igneous origin more likely on the basis of geochemical study (Lim 1972, pp. 63–68).

The schists are strongly folded, and show micro-folding and crenulation indicating that they have been folded at least twice. Their intense folding and schistosity can hardly be attributed to their position on the flanks of the granite, which intrudes them, and it seems likely that they are separated from the overlying chert/argillite (which shows a less intense folding, and no foliation) by a major unconformity, or a strike fault. There is no marked discordancy in general strike between the schists and overlying beds despite the differences in metamorphic grade and tectonism. The schist outcrop extends 37 km (23 miles) along a north-northwesterly trend, and is truncated at both ends by granite. We agree with Alexander that the schists are the oldest metasediments in the area, but consider that they are a separate unit, distinct from the overlying chert and redbeds.

Chert Sequence

The chert sequence comprises black and grey chert, often pyritic and locally radiolarian, and black and grey shale, slightly phyllitic shale, argillite, and subordinate sandstone and siltstone. The share is commonly pyritic, and in one place west of Sungai Bintang (southwest of Raub) contains oblate pyrite concretions 30 mm across. The chert is well bedded, usually in beds a few centimeters thick, and the sequence is locally intensely folded. Locally, conglomeratic shale, comprising black shale with clasts of chert, is seen (e.g. west of Sungai Bintang). Along the road to Lurah Bilut, near the contact with the overlying redbeds, a road cut shows intensely folded vertical black chert and cross-bedded grey sandstone giving way to the east to conglomeratic black shale, enclosing cobbles and boulders of chert, and of grey sandstone as much as as 1 m across. The deposits may be of depositional slump origin or perhaps have been formed purely by tectonic disruption, and represent small-scale melange.

Redbed Sequence

The most striking feature of the clastic sequence apparently overlying the chert/argillite is its primary red colour. Almost all the fresh rocks we have seen in this sequence, whether conglomerate, sandstone, or mudstone, show this striking red colour, typically between greyish red (10R 4/2) and dark reddish brown (10R 3/4) on the wet surface (Munsell Rock Colour Chart). Red rocks were seen in large exposures in the Bilut River south of Raub, in many stream sections west and northwest of Raub, in road cuts on the road to Lurah Bilut and in tributaries of the Bilut draining the Foothills Range southwest of Lurah Bilut, and in stream sections and road cuts east of Bentong.

It is surprising that neither Richardson nor Alexander mentions this distinctive red colour in his general description of the strata. Both describe the clastic rocks and the chert together (Richardson, 1939, p. 21; Alexander, 1968, p. 46). In his section on chemical analyses of arenaceous rocks, however, Alexander (p. 47) mentions "yellow, orange, brown, and even red varieties of weathered shale and phyllite" and "buff and maroon-colour varieties" of arenaceous rocks. It seems that Richardson and Alexander regarded the red colour either as of no significance or as resulting from weathering.

We are convinced that the sequences examined by us are true redbeds, and that the colour is primary. In fact one of us (NSH) made a special search for grey, unoxidized shale within the redbed sequence, in order to collect some for palynological studies; none was found. It is of course possible that in parts of the range not examined by us red beds are less predominant.

The most conspicuous lithology of the redbed sequence is poorly sorted boulder, cobble, and pebble conglomerate in very thick lenses forming high steep ridges. Examples are Bukit Tungkup (625 m; 2050 ft) west of Raub; Bukit Batu Ketong (628 m; 2062 ft) west of Kampong Bulong, between Bentong and Teras; Bukit Raka (579 m; 1900 ft) east of Bentong, and Bukit Jeram (382 m; 1252 ft) on the Bentong-Karak road (Fig. 1). Judging from the size of the ridges, the conglomeratic lenses may be as much as 500 m thick and extend for several kilometres along the strike. In stream traverses the conglomerate is seen to be very poorly sorted and to form lenticular bodies; thicknesses in excess of 200 m have been seen (e.g. in Sungai Sermi, figure 1). The red or brown colour is due to fine hematite dust in the muddy matrix (as observed e.g. in specimens UM 5171, 5172 from the Pelik tributary of the Bentong River, southeast of Bentong, Fig. 3). The clasts include sandstones vein quartz, chert (some radiolarian), and a very fine-grained rock, possibly glassy tuff.

A good sequence of the redbeds is exposed in Sungai Sermi (a tributary of the Bilut, which it joins at grid reference 723 457, south east of Kampong Balong, Fig. 1). There the east-dipping redbeds are exposed from their base (on black chert), intermittently until limestone of the Raub Group is reached, although the upper contact is not seen.

Study of thin sections of these rocks reinforces the impression that they are a non--marine and probably piedmont fluvial sequence. A granule conglomerate from near the top of the sequence in the Bilut Gorge, southwest of Raub on the main road to Bentong (UM 7955), shows a poorly sorted, immature texture. The larger clasts are mainly subangular to angular, but do include, interestingly, an occasional well-rounded quartz grain. These large clasts are mainly lithic fragments derived from sedimentary and metamorphic rocks of types to be found in the underlying schist and chart/argillite sequences. Fine-grained chert, veined by quartz and showing only a few doubtful recrystallized Radiolaria, is the most abundant clast type. Other clasts are moderately sorted quartz sandstone, weakly lithified; phyllite, sericite-chlorite schist, and sericite schist showing very strong mass extinction; well-foliated fine-grained quartz-mica schist; metamorphic quartzite, showing a sutured mosaic of fine to coarse grain size; vein quartz; and one or two clasts of a fine-grained rock, possibly tuffaceous. The total absence of granitic debris, and the strong conformity of the clast types to the underlying rock types in the Raub area, are very striking.

The matrix of the rock consists of smaller subangular to subrounded quartz grains and a small amount of silt and clay, sometimes forming thin discontinuous laminae through the rock. These laminae have been disrupted by adjustments during mechanical compaction, which has been the main process by which the rock was lithified. Many of the sedimentary clasts (not including chert) have been distorted and squeezed in this process. Hematite occurs abundantly, as a coating on the clasts, filling cracks and cavities in some fractured clasts and as complete fillings of some former pore spaces. Some of the cherty clasts also appear to have a primary red colour given by hematite.

The general impression from the texture of this rock is that it has never been very deeply buried and has certainly not been subjected to any greatly elevated temperatures since its deposition. A certain amount of overburden was required to provide the mechanical compaction, but this need not have been very great.

A sample of red mudstone from lower down in the Bilut Gorge section, alongside the main road, (UM 7956) reveals an equally immature but finer-grained texture, consisting of angular to very angular fine quartz grains (again with the curious occasional very well rounded one), together with a few larger clasts of chert, in a dark and fine-grained hematitic matrix. Some possibly organic structures (plant fragments?) are very poorly preserved.

A red pebble picked up in Sungai Sempan, about 7 km northwest of the Bilut Gorge section (Fig. 2) proved upon sectioning to be a hematitic quartzite, consisting of a simple mosaic of quartz, "stippled over" with patchily distributed finely-divided hematite. This

rock could be the metamorphosed equivalent of some of the redbeds from the "Bentong Group", suggesting that some portion of that sequence may have been more deeply buried and involved in metamorphism.

INTERRELATIONSHIPS OF THE ROCK UNITS

In the writers' opinion three distinct lithostratigraphic units form the Foothills Range:

3. Redbeds
2. Chert/Argillite
1. Schist

Relationship of schist to chert/argillite and redbeds

We agree with Alexander that the schist is the oldest unit and consider that since it readily forms a mappable unit it should be accorded formation status as soon as a suitable type section is designated. Its metamorphic grade is clearly higher and its folding more intense than in the overlying chert/argillite, and although the contact has not been seen, the two units are probably separated by an unconformity. The actual contact may be faulted in most places.

In the Cheroh area, in the northern part of the Raub District, T.P. Lim has established that the redbeds lie unconformably directly on the schist (Lim, 1972).

Relationship of the chert/argillite to the redbeds

As we have stated, both Richardson and Alexander assigned the chert/argillite and redbeds to the same unit, regarding them as facies. Alexander (1968, p. 45) states: "It is evident that these four main facies of the Older Arenaceous Series have been very irregularly developed. Field evidence above shows that they are frequently interbedded and that they pass laterally and vertically one into the other, frequently assuming lenticular forms." He gives no detailed section descriptions to back up this assertion. There is, of course, no question that in the redbeds, conglomerate, sandstone, and siltstone/mudstone are in close relationship. In the chert/argillite sequence, likewise, chert, argillite, sandstone, and black conglomeratic shale are interbedded.

We have, however, seen no evidence of interbedding of chert with the redbeds, and consider that the depositional environment represented by the chert/argillite is in such contrast to that of the redbeds, that it is highly unlikely that the two are interbedded. The black pyritic, carbonaceous, radiolarian chert and black, pyritic argillite represent deposition in a low energy, reducing marine environment, whereas the redbeds are just as clearly the result of deposition in a high energy, highly oxidizing environment, almost certainly fluviatile, probably in a piedmont setting.

Except in the Bentong area, the chert/argillite and redbeds each crop out as single belts, with the redbeds on the east, which accords with a general eastward-dipping homoclinal structure.

We consider the redbeds are most probably unconformable upon the chert/argillite for the following reasons:

1. The chert/argillite is strongly folded, whereas the redbeds show a much less intense folding;

2. An unconformity of conglomerate on chert was observed in Sungai Pelik, along a section which has been affected by faulting (Krishnan, 1975 p. 20). Elsewhere, discordance of attitude has been seen (e.g. in Sungai Kerong).

3. The conglomerates contain common clasts of radiolarian chert.

Raub area. Richardson shows some chert rather near the eastern boundary of the "Bentong Group", which would be high up in the sequence if the homoclinal structure is continued. However, we were unable to find any of these mapped chert occurrences in the well exposed section along the Bilut Gorge southwest of Raub.

The absence of the chert/argillite sequence to the north, around Cheroh, indicates that the redbeds overstep directly onto the schist towards the north. The relationship of the formations southwest of Raub and in the Cheroh area is shown on Fig. 2; the area between Raub and Cheroh has not been remapped in detail (see figures 1 and 2) and this area is presently (1974) under restriction for security reasons, and hence not fully accessible. It is clear that north from Raub not only does the chert sequence disappear (probably eroded before the redbeds were deposited) but the redbeds thin considerably from an estimated 1500 m near Raub (Ong, 1974, p. 11) to a maximum of 250 m in the Cheroh area (from the map of Lim 1973).

Detailed mapping by G.B. Ong in the area south-west of Raub has confirmed that the redbeds and chert/argillite are distinct sequences almost certainly spearated by an angular unconformity (Ong, 1974). Although he did not find an exposed contact between the formations, Ong cites a discordance in dip near the contact, and differences in structural style and in grade of metamorphism, as evidence for unconformity. However, further south the evidence for an unconformity is not quite so clear. The general strike of schist, chert, and redbeds, as seen in the field and on air photographs, shows a considerable degree of concordance, which is expressed in the rather regular width of outcrop of the three units over much of their extent. In Sungai Sermi, a grey sandy conglomerate which appears to be the base of the redbeds, has exactly the same strike and dip as underlying black chert a few metres away (the actual contact is not exposed).

Bentong area. In the Bentong area chert/argillite and schist occur on both sides of the conglomerate/sandstone ridge of Bukit Raka, with a second less conspicuous belt of conglomerate/sandstone to the east of the eastern belt of chert/argillite. Thus if a simple homoclinal structure is assumed, the chert/argillite and schist would appear to be interstratified here within the conglomerate/sandstone unit. However, Krishnan (1975) has interpreted the structure in this area as an overturned, nearly isoclinal syncline, centered on the conglomerate hills, Bukit Raka and Bukit Jeram, with a complementary overturned anticline immediately to the east of this, centred on the eastern belt of chert/argillite (see Fig 3).

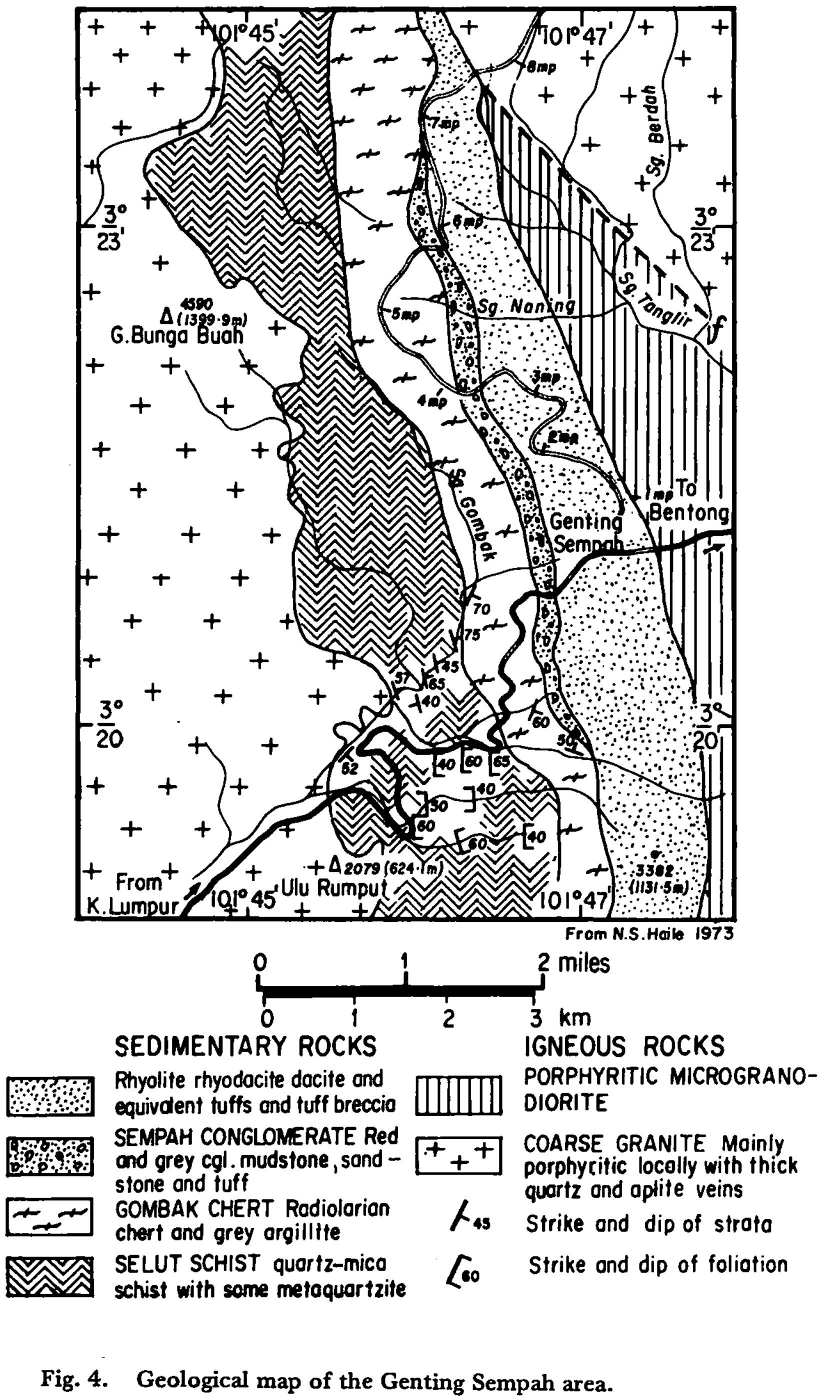

Fig. 4. Geological map of the Genting Sempah area.

Exposures are rather sparse, but the interpretation explains the repetition of lithologic belts in a manner consistent with the idea that the schist, chert/argillite and conglomerate/sandstone are three distinct formations, and is moreover supported by the following evidence:

1. The conglomerate ridge at Bukit Raka and Jeram is higher than elsewhere in the range and this can be explained by the structurally doubled thickness of conglomerate exposed along the axis of the syncline;
2. Rather indistinct scour marks and graded bedding along Sungai Pelik indicate that the sequence of chert/argillite east of the conglomerate/sandstone ridge youngs to the west, whereas that west of the ridge presumably youngs to the east;
3. The occurrence of schist (certainly older than the chert/argillite) east of Bukit Raka along a narrow trend in the center of chert/argillite outcrop can only be explained by erosion along an anticlinal crest there, or by faulting;
4. A line of small ultrabasic bodies, in places mantled by schist, is located along the crest of the postulated anticline. The faulted crests of tight anticlines are a common site for the squeezing up of pods of serpentinite.

EXTENSIONS BEYOND THE BENTONG AND RAUB AREAS

Genting Sempah

A belt of "Bentong Group" 1–2 km wide, trending north-northwest and having an easterly dip, was mapped by Alexander at Genting Sempah, about 22 km west of the Foothills Range. It was regarded by him as a roof pendant on the Main Range granite, enclosed by "granite and differentiates." Some detailed mapping of this part has been done by us, with other members of staff and students of the Department of Geology, since 1966, which has already been the subject of a preliminary paper (Haile, 1970). It has been found (see figure 4) that the belt of "Bentong Group" at Genting Sempah comprises a lower sequence of schist ("Selut schist") succeeded to the east (along a probably faulted contact) by chert/argillite ("Gombak chert"). Moreover, the "granite and differentiates" mapped by Alexander immediately east of the "Bentong Group" here are actually a sequence of conglomeratic redbeds with ignimbritic tuff ("Sempah conglomerate") overlain in turn by thick rhyolite and dacite. The Sempah conglomerate overlies the Gombak chert unconformably.

This sequence at Genting Sempah is therefore similar to that in the Foothills Range. The suggested correlation of the two sequences is shown in figure 5. The main difference between the two areas is the presence within the Sempah conglomerate of tuff, and the thick, in part ignimbritic, rhyolites overlying the Sempah conglomerate. Radiometric age determinations on these rhyolites indicate ages of about 270 Ma, i.e. early Permian (Bignell 1972 p. 117; Bignell and Snelling, in press). Thus the rhyolite and redbeds of Genting Sempah may therefore be the lateral equivalents of the acid tuffs in the Raub which are probably early Carboniferous or Devonian (see below). The volcanic rocks of

Genting Sempah may therefore be the lateral equivalence of the acid tuffs in the Raub Group, which are interbedded with marine sediments of Carboniferous to Permian age. It appears possible that the Genting Sempah area (and the Main Range generally) was land from the Carboniferous onward, and that the marine deposition of the Raub Group did not reach the Genting Sempah area. Alternatively, the Raub Group may have previously extended across the Main Range, forming part of the cover over the granite which has subsequently been eroded. A more detailed study of the Raub Group, and especially the transition from the underlying redbeds, should be valuable.

Karak and Jelebu areas.

The formations here described continue south of Bentong on either side of the Karak to Manchis road to the neighbourhood of Bukit Ngah, Jelebu area, some 60 miles south-southeast of Bentong (south of the area shown on map 1) where they have been mapped as Karak Formation by geologists of the Geological Survey of Malaysia (Jaafar Ahmad, 1975). It appears that the term Karak Formation is used as an exact equivalent to the "Bentong Group" of Alexander. Progress reports describe a sequence similar to that in Raub and Bentong, of schist overlain by chert, shale and conglomerate (Shu, 1970, 1971). Fossils have been found in carbonaceous shale in the Karak Formation at a few localities along this part, and the fauna from one of these has been described in detail and dated as Lower Devonian on the basis of the occurrence of a graptolite, *Monograptus* cf. *praehercynicus* Jaeger (see Jones, 1970). Shu states (1971, p. 72) that the Karak Formation comprises "a conformable sequence of sandstone, quartzite, and carbonaceous shale interbedded with thick lenses of conglomerate and chert." In his stratigraphic column he shows the conglomerate as forming the upper part of the formation, and not as interbedded with the main chert/argillite sequence, so possibly the relationship is similar to that described further north.

We have not done any systematic work in this area, but a reconnaissance near the fossil locality described by Jones (from Ladang Tuan near mile 129 on the Karak – Manchis road; see figure 1) shows the rock there to be grey bedded chert (with black sulphide-rich patches up to 3 m across) and grey shale (locally very finely fissile). In a new road cuting near the bridge over Sungai Telemong the chert and shale are well exposed, and over a zone at least 30 m wide are disrupted into a bouldery shale, comprising blocks of chert up to 2 m across in completely disrupted "scaly shale." The rocks there are similar in lithologic and tectonic aspect to the chert sequence of the Bentong-Raub area to the north-northwest. This supports Alexander's view that the fossils found there have a bearing on the age of the rocks in the Bentong area; but we would suggest that the inference applies only to the chert sequence, and that the schists and redbeds may be considerably older and younger, respectively. If an early Devonian age is accepted for the cherts of the Bentong-Raub area, the age of the redbeds is early Devonian to early Carboniferous, most probably mid to late Devonian.

GEOTECTONIC IMPLICATIONS

The juxtaposition, pointed out here, of continental redbeds and possibly deep-water marine radiolarian cherts and associated sediments, within the "Bentong Group" indicates that within this "group" is a major stratigraphic or structural boundary. The field evidence indicates that the boundary is an unconformity, probably complicated by minor faulting. The suggestion that the Foothills Range contains a former subduction zone has rested on the presence within it of radiolarian chert, serpentinites, and amphibole schists which might be metamorphosed basic volcanic rock. The juxtaposed redbed sequence is consistent with this hypothesis in so far as it implies considerable structural movements such as might be associated with subduction. In addition, the presence further west of possibly contemporanous rhyolitic to dacitic volcanism would fit a pattern of a westward-dipping Benioff zone.

However, the Foothills Range appears to lack some expected features of a former subduction zone, as for instance glaucophane schist, major melange, flysch sediments, and jaditized greywacke. We therefore regard the suggestion that it contains a palaeo-subduction zone as far from proved, and as being at this stage still only a possibility worth further investigation. The geochronology of the sedimentary and volcanic sequences, a further search for fossils (particularly in the redbeds), combined with radiometric work on the rhyolites to east and west, and detailed mapping of the Foothills Range and Raub Group, would be obvious next steps to take.

ACKNOWLEDGEMENTS

We are grateful to Encik Nik Mohamed and the two dozen or so Third Year Geology students who participated in mapping exercises in the Raub area, and to Dr. C.S. Hutchison, Dr. T.E. Yancey and other members of the University of Malaya Department of Geology for useful discussions. Mr. Mohamed Majid and Mr. S. Srinivas drafted the figures.

REFERENCES

Note: Copies of the unpublished theses cited are available for consultation in the Klompe Reading Room, Department of Geology, and Main Library, University of Malaya. and in the Library of the Geological Survey of Malaysia, Ipoh.

Alexander, J.B., 1959. The Pre-Tertiary stratigraphic succession in Malaya: *Nature 183*, 230–232.

Alexander, J.B. 1968. The geology and mineral resources of the neighbourhood of Bentong, Pahang, and adjoining portions of Selangor and Negri Sembilan. *Me MGeol. Surv. Dept. West Malaysia 8*, 250 pp.

Bignell, J.D. 1972. *The geochronology of the Malayan granites.* Unpulb. D. Phil. Thesis, Exford.

Bignell, J.D., Snelling, N.J., and Harding R.R. (in press) The geochronology of the Malayan granites: *Overseas Geol. and Mineral Resources*, Inst. Geol. Sciences, London.

Haile, N.S., 1970. Rhyolitic and granitic rocks around Genting Sempah, Selangor and Pahang, Malaysia, with a definition of a proposed new formation, the Sempah Conglomarate: *Geol. Soc. Malaysia, Ipoh Discussion Meeting Abstracts*, 1–4.

Haile, N.S., 1973. The recognition of former subduction zones in Southeast Asia: *in* Tarling, D.H. and Runcorn, S.K. (eds.), *Implications of continental drift to the earth sciences, 2*, p. 885–892. London: Academic Press.

Hutchison, C.S., 1973. Tectonic evolution of Sundaland: a Phanerozoic synthesis: *Bull. Geol. Soc. Malaysia 6*, 61–86.

Jaafar Ahmad, 1975. Geological map of Karak/Temerloh Sheets 3C/9 & 3C/10 Scale 1. 63 360 to accompany *Memoir 15*, Geological Survey Malaysia *(text in press)*.

Jones, C.R., 1968. Lower Paleozoic rocks of Malay Peninsula: *Bull. Amer. Assoc. Petrol. Geol. 52*, 1259–1278.

Jones, C.R., 1970. On a Lower Devonian fauna from Pahang, West Malaysia: *Bull. Geol. Soc. Malaysia. 3*, 63–75.

Krishnan, D., 1975. *Geology of the Bentong area. Pahang, West Malaysia*, Unpubl. B.Sc. (Hons.) Thesis, Department of Geology, University of Malaya.

Lim, T.P., 1970. *Geology of the Cheroh area, Raub, Pahang, West Malaysia*, Unpubl. B.Sc. (Hons). thesis, Department of Geology, University of Malaya.

Ong, G.B., 1974. *Geology of an area southwest of Raub, Pahang*. Unpubl. B.Sc. (Hons.) thesis Department of Geology, University of Malaya.

Richardson, J.A., 1939. The geology and mineral resources of the neighbourhood of Raub; Pahang, Federated Malay States, *Mem. Geol. Surv. Dept. Fed. Malaya 3*, 166 pp.

Richardson, J.A., 1946. The stratigraphy and structure of the Arenaceous Formation of the Main Range foothills, F.M.S., *Geol. Mag. 83*, 217–29.

Richardson, J.A., 1950. The geology and mineral resources of the neighbourhood of Chegar Perah and Merapoh, Pahang, Malaya: *Mem. Geol. Surv. Dept. Fed. Malaya 4*, 162 p.

Shu, Y.K., 1970. Geology of Jelebu District, New Series Map Sheet 95 (Progress Report): *Malaysia Geol. Survey Ann. Rept. for 1968*, pp. 94–99.

Shu, Y.K., 1971: The geology of new series map sheet 95, Jelebu District, Negeri Sembilan (Progress Report): *Malaysia Geol. Survey Ann. Rept. for 1969*. p. 72–81.

Tan, B.K., and Sivam, S.P., 1971. A fossil "Portuguese man-of-war" (Velellidae) from the Paleozoic of the Raub area, Pahang: *Newsl. Geol. Soc. Malaysia 33*, 8–12.

Yancey, T.E., 1972. Carboniferous fossils from the "Raub Group" near Cheroh Village, western Pahang, West Malaysia: *Newsletter Geol. Soc. Malaysia 34*, 5–9.