On the presence of pre-Carboniferous metasediments in the Eastern Belt: A structural view

IBRAHIM ABDULLAH

Program Geologi, Pusat Pengajian Sains Sekitaran dan Sumber Alam
Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor

Abstract: The geological map of Peninsular Malaysia shows that the oldest rocks formation in the Eastern Belt is Carboniferous in age and consist of mainly clastic sedimentary rocks. The rocks had been subjected to low grade regional metamorphism to become metaquartzite and phyllite and generally known as metasediments. The metasediments are unconformably overlain by the Jurassic-Cretaceous continental deposits. Recent finds of plant fossils from the continental deposits in the Bukit Keluang area, Terengganu indicate a Late Permian age. The area was intruded by the Permo-Carboniferous mafic to intermediate igneous rocks, followed by the Late Permian-Early Triassic biotite granite and the Late Triassic granite and finally by the Jurassic-Cretaceous dolerite dykes. Most of the interpreted Carboniferous metasediments show at least two episodes of folding trending towards north-northwest (NNW) or south-southeast (SSE) and north-south (N-S) directions. However, in certain areas, these rocks indicate more complex structures with three generations of folding with the earliest trending east-northeast (ENE), followed by NNW trending folds. From structural point of view, it is suggested that the more complicated metasediments with three generations of folds are of older (pre-Carboniferous) age. The earliest ENE trending folds were probably developed during the mid- Devonian orogeny that was interpreted based on the structural studies in other areas within Peninsular Malaysia.

Abstrak: Peta geologi Semenanjung Malaysia menunjukkan formasi batuan yang tertua yang terdapat di Jalur Timur adalah berusia Karbon terdiri terutamanya daripada batuan sediment klastik. Batuan ini telah mengalami metamorfisme rantau bergred rendah menjadi metakuarzit dan filit dan umumnya dipanggil metasedimen. Metasedimen ini ditindih secara tidak selaras oleh endapan daratan berusia Jura-Kapur. Penemuan terbaru fosil tumbuhan dalam endapan daratan di kawasan Bukit Keluang, Terengganu menunjukkan usia Perm Lewat. Kawasan ini telah direjahi oleh igneus mafik hingga pertengahan berusia Karbon-Lewat, diikuti oleh granit biotit Permian-Lewat-Trias Awal, granit Trias Lewat dan ahkirnya oleh daik dolerit Jura-Kapur. Kebanyakan batuan yang ditafsirkan berusia Karbon menunjukkan telah mengalami dua episod perlipatan mengarah ke utara-baratlaut (UBL) atau selatan-tenggara (STG) dan utara-selatan (U-S). Walau bagaimanapun, di kawasan tertentu, batuan ini menunjukkan struktur yang lebih rencam dengan tiga generasi perlipatan, yang paling awal mengarah ke timur-timurlaut (TTL) diikuti oleh lipatan berarah BL atau (TG) dan UBL atau STG. Daripada sudut struktur, dicadangkan bahawa metasedimen yang lebih rencam dengan tiga generasi perlipatan adalah berusia lebih tua (pra-Karbon). Pembentukan lipatan berarah TTL mungkin boleh dikaitkan dengan orogeni Devon-Tengah yang ditafsirkankan berdasarkan kajian struktur di kawasan-kawasan lain di Semenanjung Malaysia.

INTRODUCTION

The division of the Malaysia Peninsular into three zones known as the Western Belt, Central Belt and Eastern Belt, is generally accepted but, the exact boundaries are different between workers (Hutchison, 1977; Rajah *et al.*, 1978; Tjia, 1987). The boundary between the Western and the Central Belts was drawn by connecting the serpentinite bodies mainly found in Kuala Pilah area, Negeri Sembilan and Bentong-Raub area, Pahang and is known as the Bentong-Raub Line (Hutchison, 1975, 1977). In the areas, where serpentinite is absent, the extension of this boundary is very speculative. Towards the south the Bentong-Raub line is projected either across the Straits of Malacca (Tjia, 1987) or curved to Singapore. The boundary between the Central and the Eastern Belts is drawn along the Lebir Fault in Kelantan and extended southwards to the central part of Johore. The demarcation of the Western, Central and Eastern Belts of Peninsular Malaysia is shown in Figure 1.

This paper will focus on the structural variation found in the rocks mapped as Carboniferous age in the northern part of the Eastern Belt, mainly in Terengganu and north Pahang. The result is compared with rock structures at proven Carboniferous fossil localities to establish the structural trends and styles of the Carboniferous metasediments.

THE GEOLOGY OF THE EASTERN BELT

The northern part of the Eastern Belt consists of the Carboniferous meta-sediments, igneous rocks and Jurassic-Cretaceous continental deposits (Singh, 1985). The meta-sediments are the most dominant while the continental deposits occur in a number of small isolated areas. The general geology of the area is shown in Figure 2.

Metasediments

The meta-sediments of the Eastern Belt was mapped as Carboniferous based on the fossils found in Ulu Paka, Terengganu (Chand, 1978), some other places in north Pahang and Terengganu (Jennings & Lee, 1985; Metcalfe *et al*., 1980) and Batu Rakit (Idris & Zaki, 1986) and is known as the Sungai Perlis Bed (Chand, 1978). The earlier geological map of Peninsular Malaysia (Chung, 1973) indicates a number of linear narrow belts of Triassic-Jurassic sedimentary rocks in this belt. However, Tiemoko

Figure 1. Division of the Malaysia Peninsular into the Western, Central and Eastern Belts.

et al. (1992) believed that the interbedded tuffceous sandstone, siltstone, mudstone and minor conglomerate are of Late Permian age.

Igneous rocks

The igneous rocks in this belt are mostly biotite granite and minor rocks of intermediate composition that occur as two elongated bodies known as the East Coast Granite Belts. According to Bignell and Snelling (1977), the granites of this area are of Late Permian-Early Triassic and Late Triassic age. Some of the intermediate igneous rocks are of the Carboniferous age (Snelling *et al*., 1968). Basic to intermediate dykes are widespread in this belt, intruding both meta-sediments and granite (MacDonald, 1967).

Continental Deposits

Continental deposits in this belt can be found in Bukit Keluang area including Pulau Rhu, the western part of Pulau Redang, the southern parts of Pulau Kapas and Gunung Gagau. The rocks in Bukit Keluang and Pulau Rhu are the older group while those in Gunung Gagau are younger. The older continental deposits at Pulau Rhu and Bukit Keluang were grouped into Tembeling Formation and believed to be deposited in a fluviatile-deltaic-lacusatrine environment (Koopmans, 1968) but Kamal Roslan and Ibrahim Abdullah (1994) considered the rocks there as deposited as fanglomerates or in a braided river system. Sedimentary structures and lithofacies associations suggest that the rock at Pulau Redang were deposited in a near shore environment and partly of braided to meandering stream (Che Aziz & Kamal Roslan, 1997).

The older continental deposits at Bukit Keluang and Pulau Redang were mapped as Triassic-Jurassic in age (Chung, 1973), but Singh (1985) has grouped them together with other metasediments as Carboniferous. However, the plant fossils found in the shaly interval within the rock sequence there indicate an Upper Paleozoic age (Khoo *et al*., 1978; Che Aziz & Kamal Roslan, 1977). In Bukit Keluang, the plant fossils suggest that the sediments are of Late Permian age (Mohd. Shafeea Leman *et al*., 1999). In Bukit Keluang and Pulau Kapas, the basal conglomerates of the continental deposits are separated from the metasediments by an angular unconformity. The younger continental deposit known as the Gagau Group was interpreted as of Jurassic-Cretaceous age (Rishworth, 1974).

THE STRUCTURE

The structure of the metasediments of the northern part of the Eastern Belt has been described by many workers. Structural studies had been done at Bukit Chendering (Tjia, 1978; Ibrahim Abdullah *et al*., 2001), Pulau Kapas (Mohamad Barzani, 1988; Ibrahim Abdullah, 2002; Mustafa Kamal 2003), Marang (Ibrahim Abdullah, 2001), Kuala Dungun (Tjia, 1974) and Tanjung Gelang, north Pahang (Yap & Tan, 1980; Tjia, 1983). The structural studies at all those localities indicate that the interpreted Carboniferous metasediments had been subjected to polyphase deformation. Structural studies in most of the areas indicate two phases of folding with fold axes trending towards north-northwest (or south-southeast) and are considered in those areas as relatively simple. However, it was reported that at several localities, such as Bukit Cenering, the eastern part of Rhu Rendang, Marang, along the coastal area of Kemaman, Terengganu and Tanjung Gelang, Pahang, the structures are more complicated compared to Bukit Bucu, Pulau Kapas, the western part of Rhu Rendang and Kuala Abang.

Area of relatively simple structure

Bukit Bucu, Pulau Kapas, the western part of Rhu Rendang, Marang and Kuala Abang, Dungun can be considered as having relatively simple structures. In the Carboniferous fossil locality at Bukit Bucu (Idris & Zaki, 1986), the inter-bedded sandstones and shales are folded and show very simple structure (Figure 3). The beds are striking NNW and steeply dipping towards ENE or WSW, generally in normal position but sometimes overturned with younging direction towards NE. The whole Bukit Bucu forms an anticline plunging NNW. Cleavage is not well developed and the rocks here had been subjected to

Figure 2. Geology of the northern parts of the Eastern Belt.

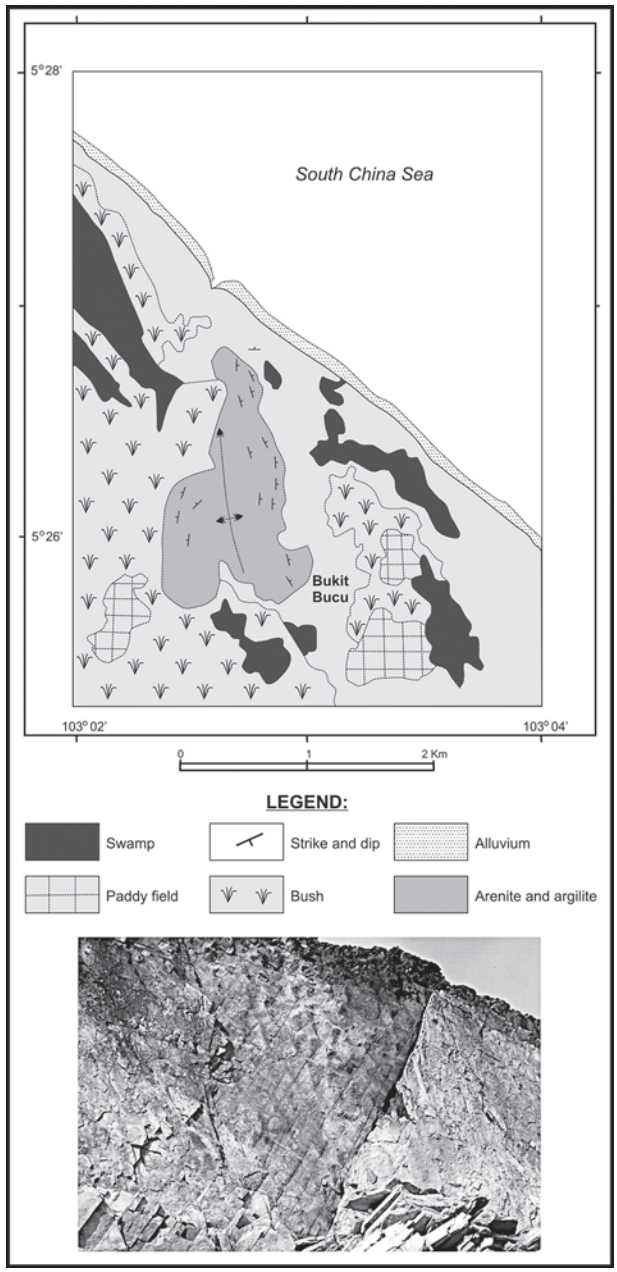

Figure 3. Structure map of Bukit Bucu area (top). Steeply dipping interbedded sandstone and shale at Bukit Bucu (bottom).

very low grade metamorphism (Figure 3) with the sedimentary structures such as graded bedding still well preserved in the fine grain sandstones and siltstones. Medium scale and crenulations folds are present but no report of the second generation cleavage occurred in this area.

In Pulau Kapas, the rocks had been folded into tight inclined to overturned folds plunging towards NNW or SSE and NS (Mohd Barzani, 1988; Ibrahim Abdullah, 2002). Reversed faults which are almost parallel to the axial plane cleavages were developed. The following deformation (D_2) amplified and refolded the earlier structures (Mustaffa Kamal, 2003). In the western part of Rhu Rendang, some of the steeper limbs of the tight folds are modified and rotated further by thrust faults. As a result, some of the steeper limbs become overturned. Crenulation folds and cleavages (S_2) trending NNW related to the second deformation (D_2) were developed. The structure of the area is shown in Figure 4. In Kuala Abang the recumbent fold was refolded. Here, the second-generation open upright folds that also plunge to the SSE are well developed on the gentle limbs of the first generation fold (Figure 5A). In thinly bedded fine sandstones and siltstones, crenulation folds and cleavages (S_2) were developed (Figure 5B). The first (D_1) and the second deformations (D_2) are dominated by ductile deformation. The rocks in this area became more brittle and further deformation lead to faulting, beginning with the formation of NS striking dextral faults as a result of compression from the NNE. This NS dextral transpressive deformation was considered as a major deformation event affecting the Eastern Belt (Mustaffa Kamal, 2003). The conjugate lateral fault system formed after that as a result of the later EW compression.

From the above discussion, it is very clear that all

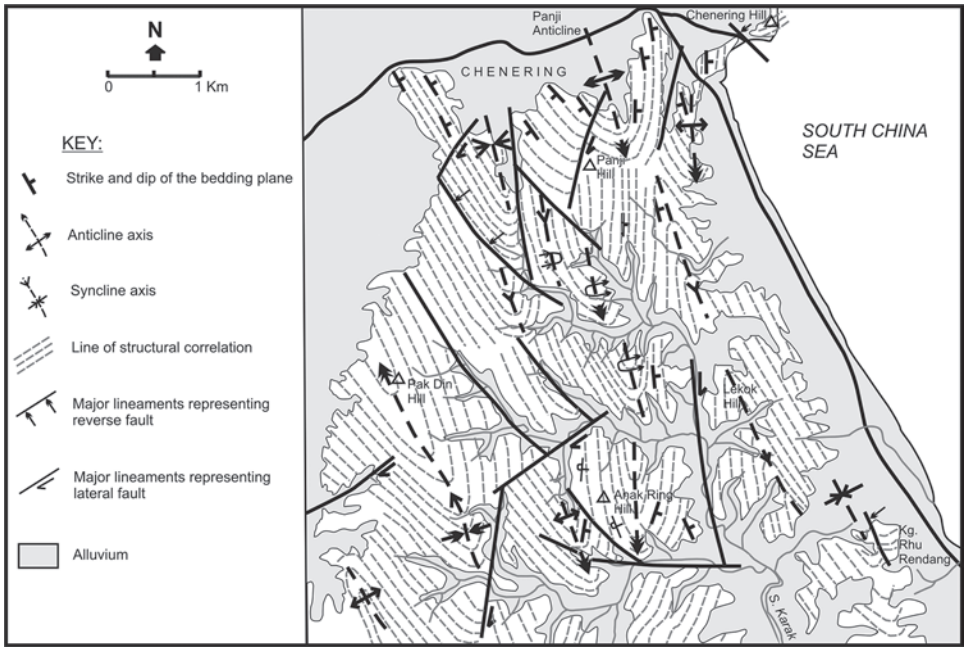

Figure 4. Structural geology map of Rhu Rendang and Cendering area, Terengganu.

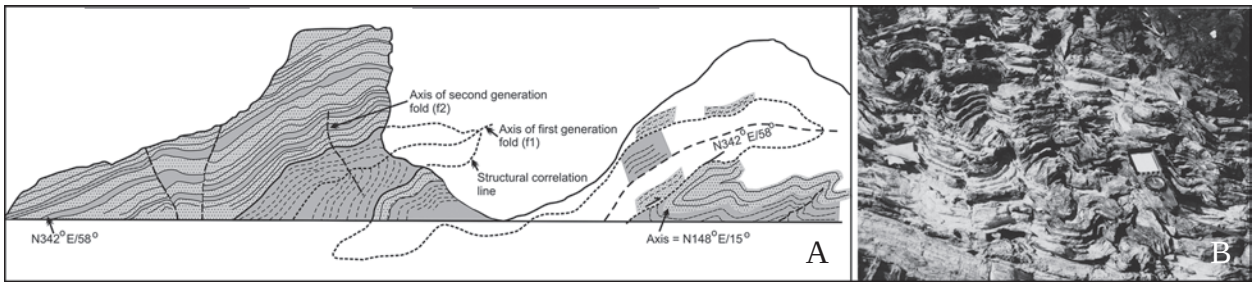

Figure 5. A) Structural sketch of Kuala Abang area.B) Crenulation folds and cleavages(S2) on the gentle limb of the first generation fold of Kuala Abang area.

workers agreed that the earliest deformation event in this belt had produced tight inclined to overturned folds in the Carboniferous meta-sediments in the Eastern Belt. This structure can be observed at Bukit Bucu, Batu Rakit, Pulau Kapas, the western part of Rhu Rendang and Kuala Abang. This NNW or SSE and NS trending folds were modified later by the subsequent brittle deformation that were responsible in producing the lateral fault system or reactivation of the earlier formed faults.

Areas of more complicated structures.

Although the structures at Pulau Kapas, the western part of Rhu Rendang and Kuala Abang, are already considered as complicated by many geologist, there are a number of areas in these parts have more complicated structures. Certain area at Bukit Cendering, Terengganu (Tjia,1978; Ibrahim Abdullah *et al*., 2001), the eastern part of Rhu Rendang (Ibrahim Abdullah, 2001), parts of Dungun (Tjia,1974), parts of Chukai, Kemaman and Tanjung Gelang, Pahang (Yap & Tan, 1980; Tjia, 1983) have a different regional structural trend compared to the other areas in this belt. Tjia (1974, 1978) interpreted that the ENE structural trends in the Bukit Cendering and Kuala Dungun areas are the oldest, resulting from compression from the NNW. The major structural trend of this area is shown in Figure 6A. Subsequently, this structural trend was superimposed by the later deformation that produced inclined to recumbent fold trending NNW or SSE during D_2 (Figure 6B) and N-S trending open folds during D_3 (Figure 6C).

In a structural study in Rhu Rendang area, Ibrahim Abdullah (2001) has shown that the eastern part of this area has the earlier almost EW trending fold refolded into a NNW direction during D_2 (Figure 7). The structural style in this area is very similar to what was reported in Bukit Cendering. A similar structural trend was also reported from Tanjung Gelang, Pahang (Yap & Tan, 1980). Based on the structural studies in all those areas, it was suggested that the area had suffered three phases of folding. N-S faulting and conjugate lateral faults related to E-W compression are also reported.

DISCUSSION AND CONCLUSIONS

The structural studies and reports from a number of areas that were mapped as Carboniferous metasediments of the Eastern Belt of Peninsular Malaysia clearly show structural variations in term of complexity, structural trends and phases of deformation. In Bukit Bucu, where Carboniferous fossils were reported, show the simplest structure with NNW trending folds. Furthermore, the rocks

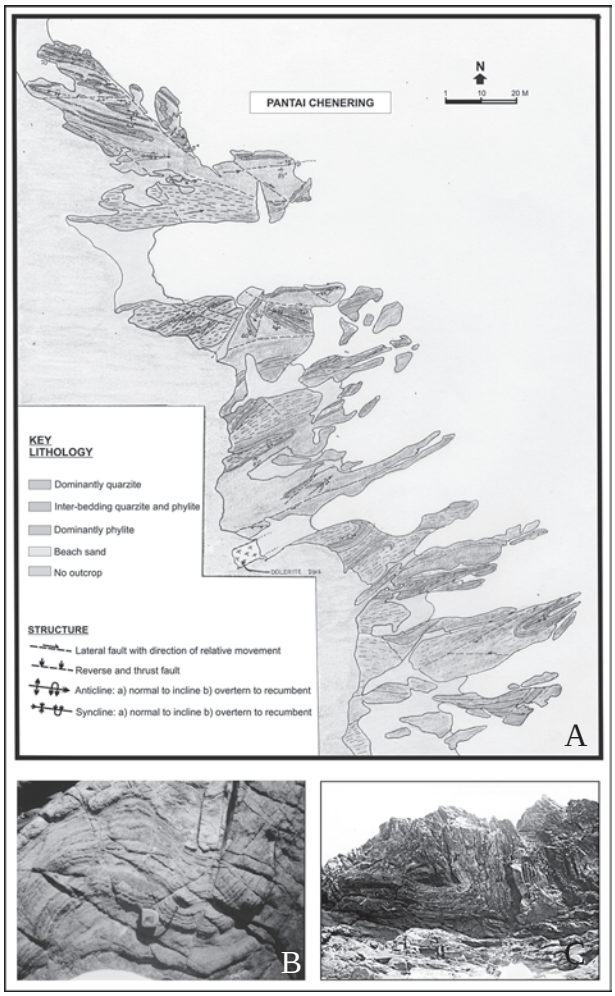

Figure 6. A) Structural map of Pantai Cendering showing the general ENE trend. B) Recumbent folds that was developed during D_2. C) Open fold of D_3 deformation.

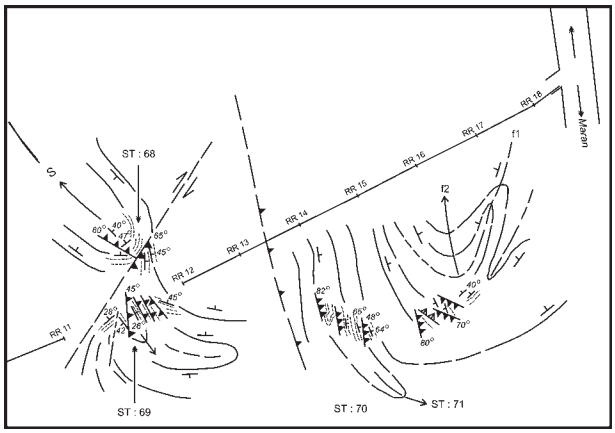

Figure 7. Structural map of the eastern parts of Rhu Rendang area showing E-W trending fold superimposed by NNW fold.

here are very much less affected by regional metamorphism. The structure at Pulau Kapas, the western parts of Rhu Rendang, Rantau Abang are more complicated. There is evidence of almost co-axial superimposed folding, both fold axes trending toward NNW (or SSE) and NS. Apparently the rocks here had suffered some degree of low-grade regional metamorphism. At a number of areas along the coast of the Eastern Belt, the structure appears to be more complicated with the earliest folds trending ENE to E (or W) due to D_1 being refolded by the later deformation trending NNW to N due to D_2 and D_3. The D_2 and D_3 in the structurally more complicated areas are correlated with the D_1 and D_2 of the relatively simpler structural areas. Fossils here not been found yet from the structurally more complicated areas and the metamorphic grade in these areas can be considered as low, since many sedimentary structures are still preserved, although in some places, phyllite was already well formed. Therefore, from structural point of view, the age of the metasediments in these areas should be interpreted as older than Carboniferous (i.e. pre- Carboniferous) in age. This interpreted pre-Carboniferous meta-sediments had suffered the earliest deformation related to the compression from NNW.

However, this interpretation is not yet conclusive. More stratigraphic and paleontological work need to be done in this area. Currently, the stratigraphy of the area is very simple. To get a better picture about the deformation suffered by the rocks of different structural styles and trends, a study of the metamorphic grade and metamorphic facies should be conducted so that, the tectonic and structural development of the eastern belt of Malaysia Peninsula will become clearer.

ACKNOWLEDGEMENT

The writer likes to thank the head of the Geology Programme, Universiti Kebangsaan Malaysia for his permission to use the facilities of the Geology Programme in this study. The staff of the Geology Programme are also thanked for their support in completing this study.

REFERENCES

BIGNELL, J.D. & SNELLING, N.J., 1977. Geochronology of Malayan granite. *Overseas Geol. And Min. Resources* 47, London, H.M Stationary Office.

CHE AZIZ ALI & KAMAL ROSLAN MOHAMED, 1997. Conglomerate of the eastern zones: genetic relationship between Murau, Pulau Redang, Pulau Kapas and Bukit Keluang conglomerates (in Malay). *Sains Malaysiana* 26(1): 1-18.

CHAND, F., 1978. Geology and mineral resources of the Ulu Paka area, Terengganu. *Geol. Surv. Malaysia, Dist. Mem*. 16, 124p.

CHUNG, S.K., 1973. Geological map of West Malaysia. 7th Edition. Geological Survey of Malaysia.

HUTCHISON, C.S., 1975. Ophiolite in Southeast Asia. *Bull. Geol. Soc. America* 86: 797-806.

HUTCHISON, C.S., 1977. Granite emplacement and tectonic subdivision of Peninsular Malaysia. *Bull. Geol. Soc. Malaysia* 9: 187-207.

IDRIS, M.B. & ZAKI, S.M., 1986. A carboniferous shallow marine fauna from Bukit Bucu, Batu Rakit,

Terengganu. *Newsletter of the Geol. Soc. of Malaysia* 12(6): 215-219.

IBRAHIM ABDULLAH, 2001. Gaya struktur kawasan Cendering-Rhu Rendang, Marang, Terengganu: satu cadangan kehadiran batuan Pra-Karbon di Jalur Timur Semenanjung. *Proc. Geol. Soc of Malaysia Annual Geological Conf. 2001*, 79-83.

IBRAHIM ABDULLAH, 2002. Struktur dan sejarah canggan batuan di Pulau Kapas, Terengganu. *Bull. of the Geol. Soc. of Malaysia* 45: 345-350.

IBRAHIM ABDULLAH, CHE AZIZ ALI & KAMAL ROSLAN, 2001. Pantai Cendering, Terengganu: satu geotapak struktur geologi. Abstrak Persidangan Kebangsaan Warisan Geologi, Langkawi.

JENNINGS, J.R., &B LEE, C.P., 1985. Preliminary note on the occurrence of Carboniferous age coal and *in situ* plant fossils in the eastern Peninsular Malaysia. *Newsletter of the Geol. Soc of Malaysia* 11(3): 117-121.

KAMAL ROSLAN & IBRAHIM ABDULLAH, 1994. Bukit Keluang Formation: sedimentology and a proposed new lithostratigraphic unit (in Malay). *Sains Malaysiana* 23(1): 1-21.

KHOO, T.T., YAW, B.S., KIMURA,T. & KIM, J.H., 1988. Geology and paleontology of Redang Island, Terengganu. *Journ. Southeast Asia Earth Sciences* 2:123-130.

KOOPMANS, B.N., 1968. The Tembeling Formation-a lithostratigraphic description (West Malaysia). *Geol. Soc. Malaysia Bull* 1: 23-43.

MACDONALD, S., 1967. The geology and mineral rersources of north Kelantan and north Terengganu. *Geol. Surv. Mem*. 10, 202p.

METCALFE, I., IDRIS, M. & TAN, J.T., 1980. Stratigraphy and paleontology of the Carboniferous sediments in the Panching area, Pahang, West Malaysia. *Geol. Soc. Malaysia Bull*. 13: 1-26.

MOHAMAD BARZANI GASIM, 1988. Geologi struktur Pulau Kapas, Marang, Terengganu. *Sains Malaysiana* 17(1): 3-15.

MOHD. SHAFEEA LEMAN, KAMAL ROSLAN, IBRAHIM ABDULLAH, CHE AZIZ, UYOP SAID & AHMAD JANTAN, 1999. The age of Bukit Keluang Formation and its significance towards tectonic development of the Eastern Belt of Peninsular Malaysia. Extended Abstract Geol. Soc. of Malaysia Annual Conference 1999, Desa Ru Johor, 15-17.

MUSTAFA KAMAL SHUIB, 2003. Transpression in the strata of Pulau Kapas, Terengganu. *Bull. Of the Geol. Soc of Malaysia* 46: 299-306.

RAJAH, S.S., CHAND, F. & AW, P.C., 1978. Mineral resources, Peninsular Malaysia, *Ann.Rep. Geol. Survey Malaysia* 1978.

SINGH, D.S., 1985. Geological map of West Malaysia. 8th Edition. Geological Survey of Malaysia.

SNELLING, N.J., BIGNELL, J.D. & HARDING, R.R., 1968. Age of Malayan Granites, *Geol. En Mijnbouw* 47: 358-359.

TIEMOKO, S.Y., AHMAD, J. & TAN, T.H., 1992. Lower Carboniferous turbiditic sandstones from Cheneh and Bukit Besi area Terengganu, Malaysia: a model for encient submarine fan. Kolokium ke-6, Fakulti Sains Fizis dan Gunaan, Universiti Kebangsaan Malaysia, Bangi.

TJIA, H.D., 1974. Sesar sungkup dan canggan bertindan di Kuala Dungun, Terengganu. *Sains Malaysiana* 3(1): 37-66.

TJIA, H.D., 1978. Multiple deformations at Bukit Cenering, Trengganu. *Geol. Soc. Malaysia Bull.* 10: 15-24.

TJIA, H.D., 1983. Canggaan bertindan di Tanjung Gelang, Pahang. *Sains Malaysiana* 12(2): 101-117.

TJIA, H.D., 1987. The Bentong Suture. *Proc. Reg. Conf. Geol.Min. Hyd. Res. of Southeast Asia. Jakarta*, 73-85.

YAP, L.S. & TAN, B.K., 1980. Deformation of the upper Paleozoic rocks at Tanjung Gelang, Pahang. *Bull. Geol. Soc. Malaysia* 12: 45-54.

Manuscript received 5 April 2004
Revised manuscript received 18 October 2004