GEOLOGY OF THE GUBIR-SADAO TRANSECT AREA ALONG THE MALAYSIA – THAILAND BORDER

The Malaysian and Thai Working Groups

A joint project carried out by

Minerals and Geoscience Department Malaysia

and

Department of Mineral Resources, Thailand

The Malaysia-Thailand Border Joint Geological Survey Committee

(MT-JGSC)

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Preface

This report together with the accompanying geological map (on a scale 1:250,000) covered the area along the Gubir-Sadao Transect of the Malaysia-Thailand border. This Transect area is approximately 80 km long and 20 km wide. Fieldwork was carried out jointly by both geoscientists from the Minerals and Geoscience Department Malaysia, and from the Department of Mineral Resources, Thailand during the year 2000.

The investigation succeeded in resolving the geological boundaries of the Carboniferous – Triassic and younger sedimentary rocks on both sides of the common border including the continuities of the igneous rocks. Several new fossil localities were discovered during the survey thus contributing to the stratigraphic certainties of the formations. Most importantly, formal formation names were adopted consensually to describe the rock units in the study area.

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GEOLOGY OF THE GUBIR-SADAO TRANSECT AREA ALONG THE MALAYSIA-THAILAND BORDER

by

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Executive Summary

The Malaysia-Thailand Carboniferous-Triassic Geology Boundary Project was launched for implementation as the first pilot project during the Second Malaysia-Thailand Joint Geological Survey Committee (MT-JGSC) Meeting, held in Hat Yai, Thailand, from 10-13 March 2000. Detailed mapping on a scale of 1:50,000 covering the Gubir-Sadao Transect area was carried out and subsequently a geologic map (scale 1:250,000) was produced.

Five lithological units, excluding the unconsolidated sediments namely the Kubang Pasu/Yaha Formation ($C_{kp/yh}$), Cherty unit (PTr_{ch}), the Semanggol Formation/Lampang Group, Saiong beds/Sam Nak O formation ($K_{sa/sn}$) and Koh Mai/Khuan Mai Plai Klong granite ($Tr_{grkm/kk}$) were mapped. The Kubang Pasu/Yaha Formation ($C_{kp/yh}$) is well exposed in both eastern and western sides of the Transect area. The rock unit is characterised by the presence of thick bedded to massive sandstone, argillite and minor siliceous rock. Based on the presence of the bivalve *Posidonomya* sp. in argillite and radiolarian in the siliceous rock, the formation is considered to be of Carboniferous age. The Cherty unit (PTr_{ch}), consisting mainly of chert, is believed to occur only in Malaysia. The Early Permian to Middle Triassic age is designated for the unit on the basis of radiolarian assemblages. The Semanggol Formation/Lampang Group, unconformably overlying the previous formation, is confined to the middle part of the Transect area. The succession is represented by three lithologic units i.e. Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$), Conglomeratic unit/Khuan Chedi Formation ($Tr_{cg/kc}$) and Khlong Kon Formation. The Khlong Kon Formation is believed to be only exposed in Thailand. Palaeontological evidence suggests that the Semanggol Formation/Lampang Group is Middle to Late Triassic in age.

The Saiong beds/Sam Nak O formation ($K_{sa/sn}$) unconformably overlies the Semanggol Formation/Lampang Group. The rock unit forms a prominent elongated ridge trending in a N-S direction across the Malaysia-Thailand border. The main lithology of this formation is fanglomerate where the depositional environment is believed to be a continental deposit laid during the Cretaceous.

Koh Mai/Khuan Mai Plai Klong granite ($Tr_{grkm/kk}$) is the only igneous rock body observed within the Transect area. It is coarse- to medium-grained, porphyritic biotite-muscovite granite of light to pale grey in colour and leucocratic in nature. This granite extends from the Sungai Durian Burong area in Malaysia to the Na Thawi, Pra Khob Tok and Yaha Quadrangles in Thailand. The granite is classified as tin-bearing granite within the Main Range Granite Province.

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1. Introduction

The Gubir-Sadao Transect area (Figure 1) approved by the Malaysia-Thailand Border Joint Geological Survey Committee (MT-JGSC) covers an area extent of 80 km long and 20 km wide along the border. The area in Malaysia is geographically confined to the Padang Terap and Sik districts (Kedah state) that partially cover topographic map sheets (scale 1:50,000); Jitra, Padang Sanai, Nami and Bukit Mudin Besar or within three topographic map sheets (scale 1:63,360) of Kuala Nerang, Bukit Debu and Gubir Quadrangles. The area in Thailand covers Na Thawi, Sadao and Saba Yoi Districts (Songkhla Province) and Yaha District (Yala Province) or within five topographic map sheets (scale 1:50,000); Amphoe Sadao, Amphoe Na Thawi, Ban Prakob Tok, Ban Bahoi and Amphoe Yaha Quadrangles.

Geomorphologically, the Transect area is mainly of mountainous terrain (80%) with the rest (20%) of undulating and intermontane terrains. It is generally covered by dense tropical rain forest, particularly near the border.

Attempt has been made to resolve problems related to the geological boundaries within the Malaysia-Thailand border. However, other aspects such as mineralisation and economic geology are not taken into consideration for this project.

Prior to this project, several issues related to the geological boundaries on both sides of the Malaysia-Thailand boundary area were encountered. They are: -

i. Geological mapping was completed in 1999 (in Malaysia; scale 1:63,360) and 1987 (in Thailand; scale 1:250,000). However, due to security and inaccessibility reasons at that time, the geological boundaries in Thailand were partly based on extrapolations of the geology from adjacent areas in conjunction with aerial photographic interpretation. As a result the geological boundaries between both countries could not be correlated.
ii. Triassic sedimentary rocks were considered to extensively cover the eastern part of the Transect area by Malaysian geoscientists, whereas Thai geoscientists believed the area to be covered by Carboniferous rocks.
iii. There was a minor disagreement on the occurrence of the Jurassic-Cretaceous conglomeratic rocks in the Bukit Pakir Terbang (Khao Pa Kae Toe Bang) in the Pedu area, Malaysia. The occurrence of this rock unit was previously not recorded in Thailand.

1.1 Objective

The objective of this joint geological mapping project, as adopted by the MT-JGSC, is to resolve the geological boundaries of the Carboniferous–Triassic sedimentary rocks, as well as other younger sediments and granites within the Transect area. A detailed systematic geological mapping of the Gubir-Sadao Transect area in Malaysia and Thailand was carried out in June 2000 by geoscientists of the Minerals and Geoscience Department Malaysia and the Department of Mineral Resources, Thailand. It was later followed by a joint field check in Malaysia (10-14 July 2000) and Thailand (15-19 July 2000) by the geoscientists from both countries. Discussions, exchange of ideas and information on general geology, stratigraphy, palaeontology, and structural geology were conducted. Agreements on mapping units were achieved based on fossil evidences and lithological similarities that enabled the Working Group to delineate the geological boundaries. A geological report and geological map (scale 1:250,000) covering the Transect area were jointly prepared by both parties, and were published soon after completion of the project (Figure 2, inside the pocket).

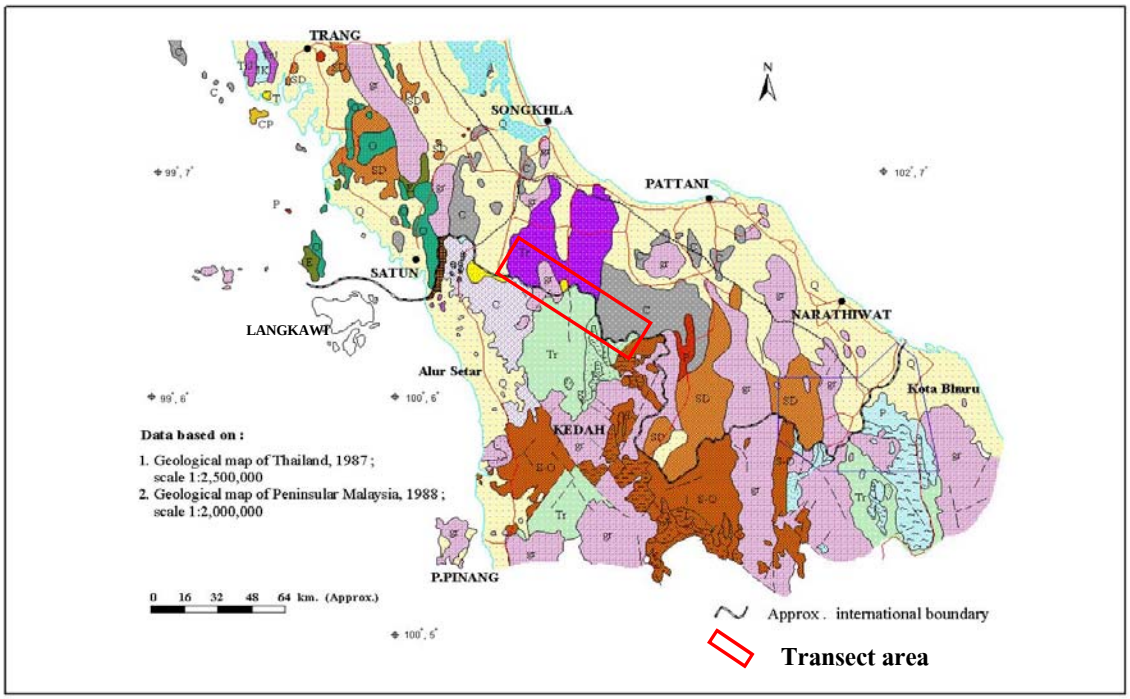

Figure 1: Location map of the Gubir-Sadao Transect area

1.2 Previous works

Most of the inaccessible areas adjacent to the Malaysia-Thailand border project area were considered as "black area" due to subversive activities. No detailed geological mapping was undertaken in Malaysia before 1990's. Systematic geology mapping (scale 1:63,360) carried out by the Minerals and Geoscience Department Malaysia (formerly the Geological Survey of Malaysia) in the above-mentioned areas including the Gubir area was completed by the end of 1999 (Mat Niza Abdul Rahman *et al*., in manuscript). Geology mapping (scale 1:250,000) in Thailand was completed in 1987 and most of geological boundaries were based on aerial photograph interpretation and extrapolation.

The oldest rock observed in the Transect area is the Carboniferous sequence of the Kubang Pasu Formation (Jones, 1981) in Malaysia or Yaha Formation (Muenlek *et al.*, 1982; Nakapadungrat *et al*., 1988) in Thailand. The Kubang Pasu Formation occurs extensively in central and south Perlis, and north Kedah; whereas the Yaha Formation sequences are distributed to the south of Songkhla and Yala Provinces. Basir Jasin (1995) reported the occurrence of lenticular shaped ribbon chert at the bottom of the Kubang Pasu Formation near Pokok Sena town, north Kedah. He also mentioned that the chert is interbedded with terrigenous clastic sediments derived from a continent. The presence of *Entactinia variospina* indicates the age of chert in the Kubang Pasu Formation is Tournaisian (Early Carboniferous). Sashida *et al*. (1998) reported the occurrence of Early Carboniferous radiolarians in chert lenses intercalated with sandstone and siltstone-dominated sequence at Ban Wang Yai, 12 km east of the Na Thawi town and at Ban Kabang, Kabang District, Yala Province. Sashida *et al*. (2000) later described that these radiolarians as *Entactinia variospina*, *E. vulgaris*,

Astroentactinia multispinosa, *Spongentactinia* sp. and *Triaenospaera* sp. indicative of Early Carboniferous age (Tournaisian).

The Permian-Triassic rocks consisting of the Cherty unit (PTr_{ch}) is only observed in Malaysia. Sashida *et al*. (1992, 1993, 1995) studied the late Middle Permian radiolarians including *Follicullus monacanthus* in the chert beds at Bukit Barak, 25 km northeast of Alor Setar. They also recorded the existence of *Neoalbailella optima* and *N. ornithoformis* Assemblages (Late Permian radiolarians) in chert beds of the same member exposed at Bukit Nyan, 20 km east of Alor Setar. Basir Jasin (1994) discovered Anisian to Ladinian (Middle Triassic) radiolarians from Pokok Pauh, Bukit Tembaga near Pokok Sena (north Kedah, Malaysia) and near Merbau Pulas (south Kedah). The radiolarians are *Pseudostylosphaera coccostyla, P. magnispinosa, P. Japonica, P. compcata, Parasepsagon variabilis, P.* cf. *asemtricus, Eptigium manfredi, Hozmadia rotunda, Acanthosphaera awaenensis, Triassocampe deweveri, T.* sp., *Yeharaia japonica* and *Cryptostephanidium* sp. Spiller and Metcalfe (1995) studied the occurrence of Early Permian to Middle Triassic radiolarians from the Cherty unit (PTr_{ch}). The Permian radiolarians belong to *Follicucullus monachanthus* Zone (Middle Permian), *F. scholasticus* Zone (Guadalupian stage of Late Permian) and *Triassocampe deweri* Zone (Anisian – Ladinian). Basir Jasin (1996) also proposed the presence of Wolfcampian stage (Early Permian) by the occurrence of *Pseudoalbaillella scalprata* m. *rhombothoracata* Zone in the lowermost part of the Cherty unit (PTr_{ch}) at Bukit Kampong Yoi, Bukit Larek and also in the vicinity of Pokok Sena town (Malaysia).

The Middle to Late Triassic rocks consists of the Semanggol Formation of Malaysia and the Lampang Group of Thailand. The term Semanggol was first introduced by Alexander (1959) to describe the Triassic sediments exposed in the Gunung Semanggol area south of the Transect area in Perak. The Semanggol Formation had been studied by various workers in great detail on its stratigraphy, sedimentology, palaeontology, as well as in geophysical aspects (Kobayashi *et al*., 1967; Ahmad Jantan, *et al*., 1987; Abdul Rahim Samsudin *et al*., 1991; and Teoh, 1992).

Kamal Roslan Mohamed Roslan (1989) had informally proposed to raise the rank of the Semanggol Formation to "Semanggol Group". He divided the "Semanggol Group" (from bottom to the top) into three formations consisting of:

i. Tawar chert that is equivalent to the Tawar Formation (Courtier, 1974) and the Chert Member (Burton, 1973)
ii. Bukit Merah Formation (equivalent to the Rhythmite Member of Burton, 1973)
iii. Pedu Formation (equivalent to the Conglomerate Member of Burton, 1973)

However, from the startigraphic nomenclature point of view, the stratigraphic unit of the "Semanggol group" is inadequately defined and the criteria supplied to revise the stratigraphic rank is insufficient for adoption (Geological Society of Malaysia, 1997). Nevertheless, the upper part of the Semanggol Formation is believed to be Triassic (Basir Jasin, 1996). The term Lampang Group was established by Piyasin (1972) as consisting of five formations confined to Lampang Province in northern Thailand. Chaodumrong (1992) restudied the Lampang Group in more detail and he had reclassified the group to seven formations. Based on the bivalves *Daonella, Halobia, Posidonia, Costatoria, Claraia* and *Palaeocardita,* the ammonite *Parathachyceras,* the group ranges in age from Griesbachian to Norian.

The Triassic Lampang Group in Southern Thailand (Na Thawi, Khuan Chedi and Khlong Kon Formations), studied by many workers such as Grant-Mackie *et al*. (1980) and Sashida *et al.* (1999), is mainly distributed in the Na Thawi and Saba Yoi areas. According to Grant-Mackie *et al*. (1980), the Triassic bivalve *Daonella* sp. can be

observed in the Na Thawi area. Recently, Sashida *et al.* (1999) reported that the Khlong Kon Formation in the Saba Yoi area contains Middle to Late Triassic foraminifera.

The Saiong beds in Malaysia is the youngest mappable sedimentary rock unit in the Transect area. The rock unit was believed to be Jurassic-Cretaceous (Ong, 1968 and Hutchison, 1989) and occurs as a N-S trending elongated ridge, approximately 1-2 km wide and 17 km long, forming the Malaysia-Thailand border, east of the Pedu Lake area.

The granites of the Transect area were classified as Triassic Main Range Granite or Triassic Central Belt Granite (Hutchison, 1977; Cobbing *et al*., 1992). Koh Mai/Khuan Mai Plai Klong granite ($Tr_{grkm/kk}$) is the only pluton observed in the Transect area and little research work has been undertaken on this pluton, apart from the work of Zainol Husin and Mohammed Hatta Abd. Karim (in manuscript) along the southern margin of the pluton.

1.3 Current works

Based on the geological data collected and correlations of rock units by geoscientists from both Malaysia and Thailand, the working group had agreed to adopt the stratigraphic names and their equivalents as shown in Figure 3. Schematic stratigraphic columns of the Transect area in Malaysia (Figure 4) and Thailand (Figure 5) were produced.

<table>
<tr><td rowspan="2">ERA</td><td rowspan="2">PERIOD</td><td colspan="4">FORMATION/ UNIT</td><td>FORMATION/ UNIT
(adopted in this report)</td></tr>
<tr><td colspan="3">NORTH PENINSULAR MALAYSIA</td><td>SOUTH PENINSULAR THAILAND</td><td>NORTH PENINSULAR MALAYSIA and SOUTH PENINSULAR THAILAND</td></tr>
<tr><td rowspan="2">CENOZOIC</td><td>QUATERNARY</td><td colspan="3">Alluvium</td><td>Gravel beds</td><td>Terrace and Alluvial Deposits</td></tr>
<tr><td>TERTIARY</td><td colspan="3">Bukit Arang beds (not exposed in the transect area)</td><td>Saba - Yoi Formation (not exposed in the transect area)</td><td></td></tr>
<tr><td rowspan="5">MESOZOIC</td><td>CRETACEOUS</td><td colspan="3">Saiong beds</td><td>Sam Nak O formation</td><td>Saiong beds/Sam Nak O formation</td></tr>
<tr><td>JURASSIC</td><td colspan="3"></td><td></td><td></td></tr>
<tr><td rowspan="3">TRIASSIC</td><td colspan="2">? ? ? ? ? ? ?</td><td rowspan="3">SEMANGGOL FORMATION</td><td>Khlong Kon Formation</td><td rowspan="3">LAMPANG GROUP</td><td>Khlong Kon Formation</td></tr>
<tr><td colspan="2">Conglomeratic unit</td><td>Khuan Chedi Formation</td><td>Conglomeratic unit/ Khuan Chedi Formation</td></tr>
<tr><td colspan="2">Rhythmite unit / Cherty unit</td><td>Na Thawi Formation</td><td>Rhythmite unit/Na Thawi Formation</td></tr>
<tr><td rowspan="2">PALEOZOIC</td><td>PERMIAN</td><td colspan="3"></td><td>? ? ? ? ?</td><td>Cherty unit</td></tr>
<tr><td>CARBONIFEROUS</td><td colspan="3">Kubang Pasu Formation</td><td>Yaha Formation</td><td>Kubang Pasu/Yaha Formation</td></tr>
</table>

Figure 3: The stratigraphic names and their equivalences as adopted for this report.

2.0 Lithostratigraphy

2.1 Kubang Pasu /Yaha Formation ($C_{kp/yh}$)

Distribution

The Kubang Pasu/Yaha Formation ($C_{kp/yh}$) is well exposed along both the western and eastern sides of the Transect area; the Sintok area of Kubang Pasu District (Malaysia), Khao Nam Kang, Ban Bang Haeng, Na Thawi District (Thailand) and in the vicinity of Sungai Teliang (Malaysia), Yaha District, Ban Ba Hoi and Ban Nam Chieo (Thailand).

Lithology

The Kubang Pasu/Yaha Formation ($C_{kp/yh}$) in the Sintok area (Malaysia) comprises essentially thick interbeds of argillite, sandstone and tuffaceous sandstone and minor siliceous rock. The thickness of the individual beds ranges from 20 cm to 1 m. The rock sequence, up to 300-350 m thick, was observed along the security road close to the Malaysia-Thailand border in the Sintok area. This rock unit (from bottom to top) is thick-bedded sandstone composed of graywacke-subgraywacke intercalated with thick to very thick grey argillite followed by massive, thick-bedded, well-sorted, graded and cross bedded quartz arenite overlain by thin beds of chert or siliceous shale. The argillite consists of shale, mudstone and a variety of poorly sorted argillo-arenaceous deposits varying from muddy siltstone through graywacke and subgraywacke, of dark grey to predominantly light grey, buff and pink to brick red.

Medium-grained subgraywacke (generally grey to white in colour) is the most common arenaceous rock with lesser quartzite (quartz arenite), feldspathic sandstone (arkose) and grit. The siliceous rock consists of thin-bedded chert and siliceous shale. The chert (ribbon chert) is thin-bedded and usually displays tiny white spots or small holes due to the weathering of fossiliferous materials. Characteristic sedimentary features such as graded bedding, cross lamination, fucoidal marking and slump structures are common. Close to the Koh Mai/Khuan Mai Plai Klong granite ($Tr_{grkm/kk}$), strata of the Kubang Pasu/Yaha Formation ($C_{kp/yh}$) are thermally metamorphosed to either fissile spotted slate or occasionally metaquartzite and quartz-mica schist. Most conspicuously, the spotted rocks contain segregations of quartz-mica spots with incipient chiastolite and cordierite metacrysts.

The Kubang Pasu/Yaha Formation ($C_{kp/yh}$) in the Yaha, Bahoi and Na Thawi (Thailand), approximately 400-450 m thick, can be subdivided into six members in ascending order as follows:

i) The massive to very thick-bedded quartzitic sandstone member consisting mainly of pale brown, well-sorted, medium-grained, massive to very thick-bedded quartzitic sandstone intercalated with mudstone. Individual sandstone beds are up to 4 m thick with a total thickness of 30 m.

ii) The interbedded mudstone and sandstone member overlies conformably on the previous member. The sequence, approximately 180-300 m thick showing obvious fining upwards and coarsening upwards cycles, is composed predominantly of mudstone intercalated with sandstone. The pale greenish-grey, medium-grained, lithic, arkosic and quartzitic sandstone exhibits diagnostic features of wavy and lenticular beds.

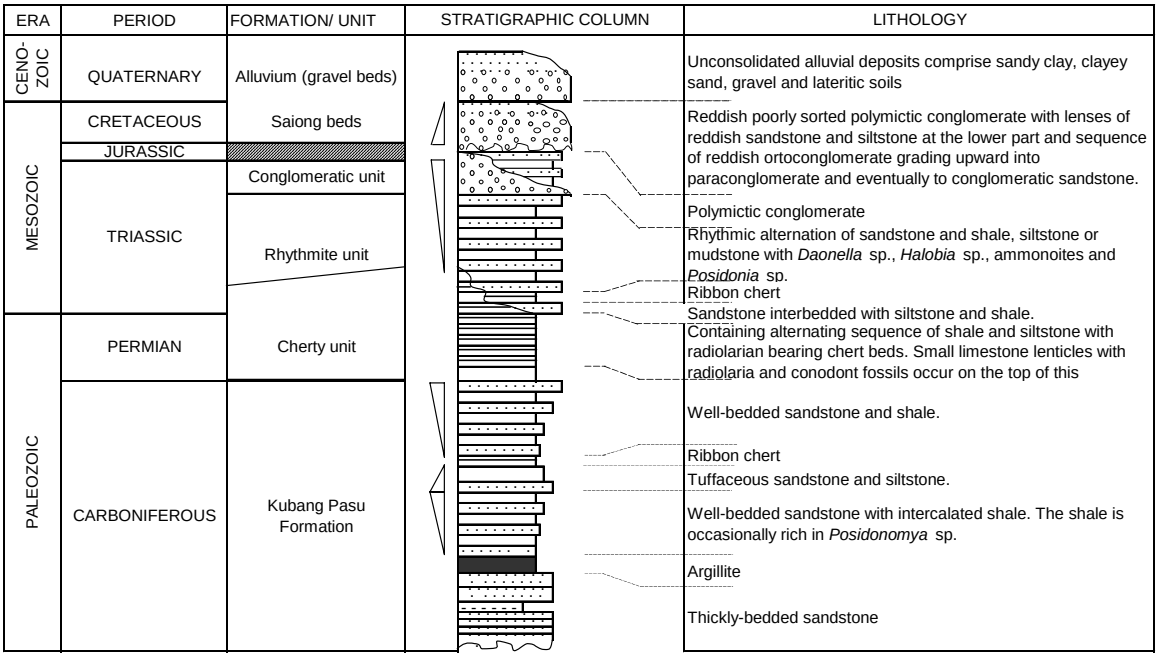

Figure 4: Schematic stratigraphic column of the Gubir – Sadao Transect area in Malaysia (not to scale).

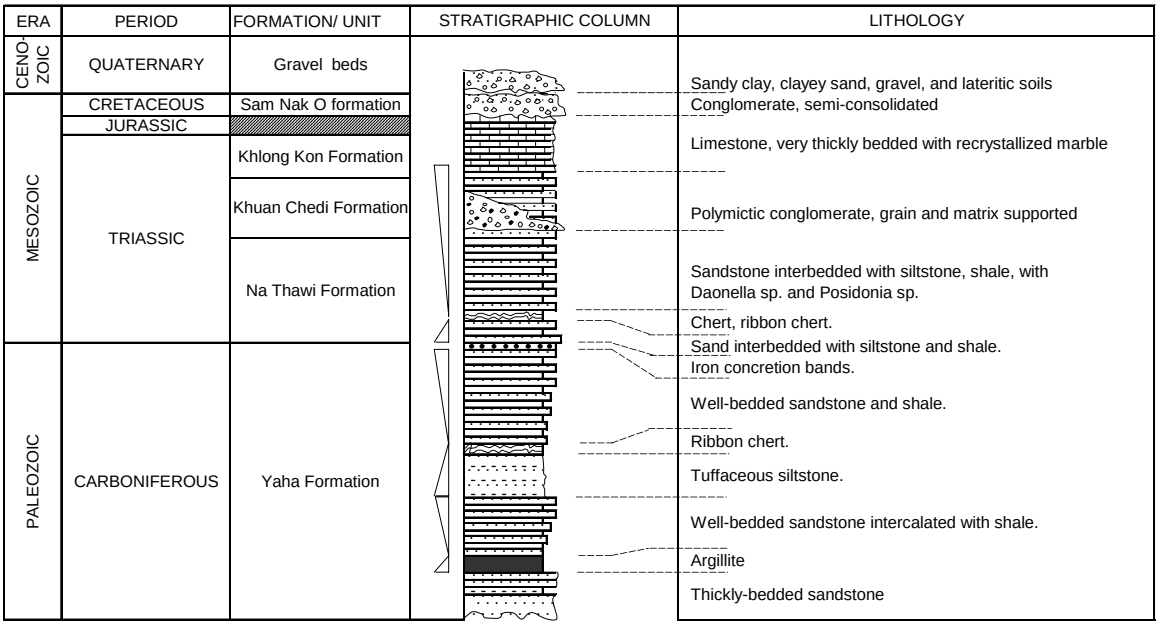

Figure 5: Schematic stratigraphic column of the Gubir – Sadao Transect area in Thailand (not to scale).

iii) The well-bedded, dark grey sandstone member overlies conformably the previous member. The sequence, approximately 15-50 m thick, consists mainly of dark grey to black, fine- to medium-grained, moderately sorted, well wavy-bedded lithic sandstone.

iv) The tuffaceous sandstone intercalated with mudstone member overlies conformably the previous member, and is approximately 10-50 m thick. The sequence comprises intercalations of reddish-brown, medium- to coarse-grained tuffaceous sandstone (which became red soil when weathered), greenish-grey, medium- to coarse-grained, unevenly-bedded graywacke, thick-bedded mudstone and siltstone.

v) The chert member overlies conformably on the earlier member. The 15 m thick sequence comprises mainly thin-bedded (ribbon) chert, changing gradually to siliceous siltstone, which often shows tight and recumbent folding. The Early Carboniferous radiolarians had been reported in the chert member from the Kabang vicinity (Sashida *et al*., 2000).

vi) The evenly bedded shale interbedded with sandstone member is sporadically distributed in the Transect area. The approximately 40-50 m thick sequence overlies conformably the chert member, and is composed of interbedded dark grey mudstone with very fine-grained sandstone. The characteristic sedimentary structures of very thin, evenly bedded and sharp base bedded sedimentary structures exhibited in the sequence reflect flysch-type or outer fan deposits.

Age and correlation

The Kubang Pasu/Yaha Formation ($C_{kp/yh}$) is lithologically and stratigraphically similar on both the western and eastern sides of the Transect area. However, the succession in the west is different from that in the east from the palaeontological point of view. The former is rich in fossils, whereas the latter is poor in fossils. Fossil assemblages of the bivalve *Posidonomya* sp., trilobites, ammonites, brachiopods, crinoids, gastropods and plant remains had been found at Bukit Tunjang and Kampung Baru, Sintok (Malaysia), Ban Bang Haeng, Khao Nam Kang (Thailand) whereas *Posidonomya* sp., crinoids and plant remains had been occasionally found at Ban Nam Chieo and Ban Bahoi (Thailand). However, Sashida *et al*. (2000) reported the presence of radiolarian microfossils in the chert member exposed at Ban Kabang (Thailand) located in the easternmost part of the Transect area. Based on the faunal assemblages, the Kubang Pasu/Yaha Formation ($C_{kp/yh}$) is Carboniferous in age. The base of the Kubang Pasu Formation in north Kedah (Malaysia) may extend down to Late Devonian (Jones, 1981).

Depositional environment

The graywacke intercalated with thick- to very thick-bedded shale followed by massive to thick-bedded, quartz arenite are generally contained the broken fossils as a result of current and wave actions. Various primary sedimentary structures in the coarser lithological units are indicated as a near-shore environment of deposition, probably in either intertidal or upper subtidal zones.

The middle unit in this area is represented by shale and tuffaceous sandstone with *Posidonomya* sp. and crinoids' assemblages. The sequence may be interpreted as having been deposited in the outer shelves, where winnowing process may have led to the deposition of chert and finer-grained sediments. The existence of ribbon chert and

siliceous shale in the upper part of the formation may be due to the increasing supply of silica from volcanic activities. The coarsening and thickening upwards, and fining and thinning upwards sequences at the top part may represent the regressive and transgressive phases, respectively. These phases may have been caused by fluctuation of sea level or tectonism or both in the Late Carboniferous to probably Permian.

2.2 Cherty unit (PTr_{ch})

Distribution

The Cherty unit (PTr_{ch}) crops out extensively in the Sungai Tiang and Kuala Nerang areas, south of the Transect area. The unit is well exposed at Sungai Sebaping, Padang Terap District. Generally, the chert outcrops in the Transect area are small, however, it forms prominent N-S strike-ridges to the south of the Transect area. It is traceable down to Bukit Barak, near the Kuala Nerang area (25 km northeast of Alor Star) and Bukit Nyan, near Pokok Sena (20 km east of Alor Star). Exposures of this unit have not yet been reported in Thailand (Figure 4).

Lithology

The unit consists mainly interbeds of light grey, buff and white, well-bedded pelagic chert grading upward into siliceous shale or mudstone with shale and sandstone. In places, the chert is strongly folded due to slumping. The rock unit is commonly cut by quartz stringers. The chert is lighter coloured as compared to that of the Kubang Pasu/Yaha Formation ($C_{kp/yh}$). The occurrence of limestone lenses on top of the chert unit can be observed at Bukit Barak (10 km south of the Transect area).

Age and correlation

An Early Permian to Middle Triassic age is assigned for the Cherty unit (PTr_{ch}) based mainly on the presence of radiolarians from the cherty beds collected by previous workers. Sashida *et al*. (1992, 1993 & 1995) described the occurrence of late Middle Permian radiolarians, including *Follicullus monacanthus* Ishiga and Imoto from a siliceous limestone block embedded in siliceous shale in the upper part of the lower Cherty unit (PTr_{ch}) exposed at a quarry of Bukit Barak, 10 km west of Kuala Nerang town. They also discovered Late Permian (Dzhulfian to Dorashamian) radiolarians belonging to the *Neoalbailella optima* and *N. ornithoformis* Assemblages in chert beds of the same member exposed at Bukit Nyan, near Pokok Sena (Malaysia). Basir Jasin (1994) had reported the occurrence of thirteen species of Anisian to Ladinian (Middle Triassic) radiolarians i.e. *Pseudostylosphaera coccostyla, P. magnispinosa, P. Japonica, P. compcata, Parasepsagon variabilis, P.* cf. *asemtricus, Eptigium manfredi, Hozmadia rotunda, Acanthosphaera awaenensis, Triassocampe deweveri, T.* sp., *Yeharaia japonica* and *Cryptostephanidium* sp. from Pokok Pauh, Bukit Tembaga near Pokok Sena (north Kedah, Malaysia) and near Merbau Pulas (south Kedah). Spiller and Metcalfe (1995) recorded the occurrence of Late Permian to Middle Triassic radiolarians from the Cherty unit (PTr_{ch}). The Permian radiolarians belong to *Follicucullus monachanthus* Zone, *Follicucullus scholasticus* Zone while the Triassic (Anisian – Ladinian) radiolarians belong to *Triassocampe deweri* Zone.

Basir Jasin (1996) reported the radiolarian assemblages in the chert sequence of the lowermost part of the Cherty unit (PTr_{ch}) at Bukit Kampung Yoi, Bukit Larek and also

in the vicinity of Pokok Sena town. The fauna belongs to the *Pseudoalbaillella scalprata* m. *rhombothoracata* Zone of Wolfcampian stage (Early Permian).

Depositional environment

During Early Permian to Middle Triassic, the south-western part of the Transect area was believed to be a deeper basin, reflected by the presence of outer submarine fan deposits of the Cherty unit (PTr_{ch}).

2.3 Semanggol Formation/Lampang Group

Distribution

The Semanggol Formation/Lampang Group is confined to the central part of the Transect area. The boundaries between the Semanggol Formation/Lampang Group and Kubang Pasu/Yaha Formation (Ckp/yh) in both eastern and western sides are fault contacts. Nevertheless, the occurrence of the Permian hiatus is characterised by the presence of a 10 cm thick iron pan exposed at Ban Trap (Thailand), 25 km north of the Transect area.

Lithology

Generally, the Semanggol Formation/Lampang Group is represented by three lithological units, i.e. Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$), Conglomeratic unit/Khuan Chedi Formation ($Tr_{cg/kc}$) and Khlong Kon Formation as shown in Figure 5. However, the Khlong Kon Formation is only exposed in Thailand. Detailed descriptions of these three units are as follows:

i) Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$)

The rock unit, 100 to 250 m thick, consisting of rhythmic alternation of sandstone and shale or mudstone, is the dominant rock unit of the Semanggol Formation/Lampang Group in the Transect area. In addition, unmappable chert beds had also been reported in the upper part of this unit. Generally, the rocks are light grey in colour, parallel-bedded ranges from 10 to 50 cm in thickness. The graded bedding sandstone shows sharp base grading upward to the overlying shale or mudstone. Primary sedimentary structures, such as scour and ripple marks and load structures can be observed at the top part of sandstone beds. The prominent sandstone of the Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$) in this area is medium- to coarse-grained, typically poorly sorted and can be classified as quartz arenite, litharenite, sublitharenite, graywacke and lithic graywacke. The dominant non-preferred oriented grains of quartz, chert and rock fragments are generally subangular to subrounded and moderate to high sphericity while the interstitial matrix consists of silt-size quartz and clay. Feldspars are very rare and are completely altered, mainly to clay minerals and sericite.

Thick-bedded sandstone, with overall thickness up to 10 m crops out in the Muda Dam (Malaysia) and Na Thawi (Thailand) areas. The sandstone beds, ranging from 0.5 to 1 m thick, are interbedded with thin-bedded shale.

The argilliceous rocks of the formation consist predominantly of shale and mudstone with minor siliceous shale. Generally, the rocks are dark grey when fresh and

pale grey when weathered. Petrographically, the rocks consist of fine-grained quartz and clay minerals. Based upon XRD analysis, the shale generally consists of illite, kaolinite, quartz and feldspar of various amounts (Kamal Roslan Mohamed, 1989). The well-laminated shale, 1 cm to 1 m thick, is normally interbedded with sandstone.

Coarsening upwards sequences of sandstone can be recognised at the place where the conglomerate occurs as beds or lenses intercalated within the Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$). It is characterised by a sequence grading from sandstone to conglomeratic sandstone and eventually conglomerate.

ii) Conglomeratic unit/Khuan Chedi Formation ($Tr_{cg/kc}$)

This unit forms north-south trending elongated hills or ridges along the western part of the Muda Dam (Malaysia) and Khuan Chedi (Thailand) areas. The unit is composed predominantly of conglomerate, sandstone interbedded with mudstone and shale which shows obvious cycles of fining upwards sequence.

The conglomerates of the Conglomeratic unit/Khuan Chedi Formation ($Tr_{cg/kc}$) are normally grey in colour (fresh) and slightly brown (weathered). It is a poorly sorted clast-supported polymictic conglomerate, consisting of clasts of sandstone, shale, mudstone, quartz and chert which are normally rounded to subangular. The clast size varies from gravel to pebble. The pebble-sized clasts are generally rounded and spherical or egg shaped, while the smaller clasts are subangular to subrounded and are generally irregular in shape. The interstitial matrix comprises fine-grained quartz and sericite.

iii) Khlong Kon Formation

The Khlong Kon Formation is confined to the central part of the Transect area particularly in the vicinity of Ban Nam Chieo (Thailand). The limestone of the Khlong Kon Formation consists of pale grey, massive, oolitic limestones, forming steep karstic hills up to 240 m high. The formation thins southwards and appears to be absent on the surface in Malaysia. However, about 10 km south of the Transect area, a small outcrop of limestone lenticles, exposed on top of the Cherty unit (PTr_{ch}) in the earth quarry at Bukit Barak near Kuala Nerang town may resemble part of the limestone facies. Metcalfe (1990) recovered some conodonts samples from the limestone lenticles including *Metapolygnathus polygnathiformis* indicative of Carnian age (early Late Triassic). This small unit may be correlatable with part of the Khlong Kon Formation.

Sashida *et al*. (1999) divided the Khlong Kon Formation into four facies i.e. lime-mudstone facies, pelloidal bioclastic packstone-grainstone facies, onchoidal lithoclast packstone facies and laminated microbial facies.

In Thailand, the limestone facies commonly contains the Middle to Late Triassic smaller foraminifera and algae (Sashida *et al*., 1999). Based on lithology and fossil assemblage, the formation was deposited in a carbonate platform during the Middle to Late Triassic.

Age and correlation

The age of the clastic sediments of the Semanggol Formation is assigned to Middle-Late Triassic which can be correlated with that of the Lampang Group. Kobayashi (1964) recorded the presence of *Halobia comata* (Early Carnian), *Halobia talauana* (Middle Carnian) and *Halobia aonitii* and three other *Halobia* species that indicate

Middle Carnian to Early Norian of Late Triassic age. Tamura *et al*. (1975) recorded the discovery of the ammonites *Paraceratites* sp. (Anisian) and *Paratrachyceras* sp. (Ladinian) in the Pokok Sena area. Teoh (1992) who mapped the Sungai Tiang area reported the presence of *Posidonia* sp., *Daonella* sp. and *Serpulites* sp. of Anisian to Norian of Middle to Late Triassic age. In Thailand, Grant-Mackie *et al*. (1980) reported the presence of the Triassic bivalve *Daonella* sp., which can be observed in the Na Thawi area. Sashida *et al*. (1999) described that the Khlong Kon Formation in the Saba Yoi area (Thailand) contains Middle to Late Triassic foraminifera including *Malayspirina* cf. *fontaineivachard* which indicates late Anisian to middle Norian (late Middle to Late Triassic).

Triassic fossils had been recently found within the Transect area in Malaysia (see Appendix 2 & 3). In the Gubir area (Malaysia), some Triassic fossils *Halobia* cf. *cassiana*, *Posidonia* cf. *wengensis*, *Posidonia* sp. and *Unionites* sp. had been found in weathered shale of the Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$) at several localities along the road-cut from Kampung Gulau to Kampung Gubir. Ong (1968) recorded the occurrence of Middle to Late Triassic *Posidonia* sp., *Halobia* sp. and *Daonella* sp. in the Gubir area. The Triassic ammonites and *Posidonia* sp. had also been recently discovered at Bukit Tok Janggut and Ladang Utara in the Padang Terap area.

Within and adjacent to the Transect area in Thailand, the Middle to Late Triassic bivalves *Daonella* sp., *Halobia* sp., *Posidonia* sp. and ammonites had been recently found in the Semanggol Formation/Lampang Group particularly in the Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$) and Conglomeratic unit/Khuan Chedi Formation ($Tr_{cg/kc}$) (see Appendix 4).

The Middle to Late Triassic smaller foraminifera was recognised in the Khlong Kon Formation at the vicinity of Ban Nam Chieo (Sashida *et al.,* 1999).

Based on palaeontological evidence, Middle to Late Triassic age is assigned to the Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$), the Conglomeratic unit/Khuan Chedi Formation ($Tr_{cg/kc}$) and the Khlong Kon Formation.

Depositional environment

During the Middle to Late Triassic, the western part of the Transect area was in the deeper basin which dominated the outer (distal) submarine fan environment of the Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$). The central part of the Transect area was within the shallower basin as indicated by the deposition of the inner (proximal) submarine fan environment of the Conglomeratic unit/Khuan Chedi Formation ($Tr_{cg/kc}$). The deposition of carbonate platform of the Khlong Kon Formation reflects the shallowest basin of these marine successions.

2.4 Saiong beds/ Sam Nak O formation ($K_{sa/sn}$)

Distribution

The Saiong beds/Sam Nak O formation ($K_{sa/sn}$) is restricted to the north and northeast of Kedah, Malaysia and in the vicinity of Ban Sam Nak O, Thailand. The rock unit displays a prominent elongated ridge trending north-south along the Malaysia-Thailand border. The best outcrop occurs at Bukit Pakir Terbang (Khao Pa Koe Toe Bang), east of Pedu Lake.

Lithology

Generally, the Saiong beds/Sam Nak O formation ($K_{sa/sn}$), approximately 600 m thick, consists of reddish clast-supported fanglomerate and cycles of fining upwards sequences consisting of orthoconglomerate grading into paraconglomerate and then grading further into conglomeratic sandstone. Fanglomerate, the dominant rock type in the Saiong beds/ Sam Nak O formation ($K_{sa/sn}$), consists predominantly of subangular to subrounded, multi-coloured (dominantly red), semi-consolidated to consolidated sediments. Clasts are subangular, low sphericity and poorly sorted, comprising sandstones, siltstones, limestones, cherts, vein quartz and occasionally granite pebbles. These clasts range in size from about 1 cm to about 50 cm in diameter. The interstitial matrix comprising silty sand is commonly red in colour. Lenses or thin discontinuous beds of reddish shale, mudstone and sandstone occur occasionally.

Age and correlation

The age of the Saiong beds/Sam Nak O formation ($K_{sa/sn}$) cannot be determined definitely as no fossil has yet been found. The age of this rock unit (in Malaysia) had earlier been assigned to be Jurassic to Cretaceous based on the fact that it is overlain unconformably the older Middle to Late Triassic Semanggol Formation/Lampang Group. Recently, exposures of the Saiong beds/Sam Nak O formation ($K_{sa/sn}$) were carefully examined by the Joint Malaysian-Thai Working Group (early July 2000). It was agreed that the Saiong beds/Sam Nak O formation ($K_{sa/sn}$) is well correlated with the Phun Phin Formation exposed about 100 km north of the Transect area, where nonmarine Cretaceous bivalves *Trigonioides* sp. and *Unio* sp. have been found at the topmost part of the underlying Lam Thap Formation. Therefore, the age of the Saiong beds/Sam Nak O formation ($K_{sa/sn}$) is assigned to Cretaceous.

Depositional Environment

The lower part of the Saiong beds/Sam Nak O formation ($K_{sa/sn}$) is composed of poorly sorted, clast-supported conglomerate with subangular to subrounded clasts. This is interpreted as the upper segment of the alluvial fan. The angularity and large size of clasts suggest that they were deposited relatively close to the source area and most probably deposited as debris-flow deposits. The upper part of the unit possesses fining upward sequences that consist of orthoconglomerate with subangular to subrounded clasts grading into paraconglomerate and eventually into conglomeratic sandstone. This indicates that the upper part of the Saiong beds/Sam Nak O formation ($K_{sa/sn}$) was deposited as water-laid deposits in the middle to lower segment of the alluvial fan. With regard to their clasts imbrication, the current direction during the deposition of the rock unit was most probably westwards.

The sandstone beds intercalated within the conglomerate might have been deposited by moderate water currents, whereas the shale or mudstone beds could have been deposited during the time when the water became almost stagnant in the lower fan segment. These indicate that there were different current strengths (energy regimes) that deposited the different rock units in the Saiong beds/Sam Nak O formation ($K_{sa/sn}$).

2.5 Terrace (Q_{tr}) and Alluvial (Q_{al}) Deposits

In general, the unconsolidated terrace and alluvial deposits are widely distributed in the western part of the Transect area. The terrace (Q_{tr}) deposit is approximately 70-100 m thick, consisting of subangular to subrounded clasts of mainly sandstone, quartzite, quartz, and chert, with sand and silt matrix. The unconsolidated gravel deposit is

interpreted as a Pleistocene terrace deposit affected by neotectonic events. The later contains sediments transported by rivers, e.g. gravel, sand, silt and clay, in the Holocene.

2.6 Igneous rocks

The igneous rock exposed in the central part of the Transect area is the Koh Mai/ Khuan Mai Plai Klong granite ($Tr_{grkm/kk}$). Small stocks of the main pluton, ranging from 0.5 to 1.5 sq. km, occur to the west of Bukit Koh Mai. This granite is part of the Main Range Granitoid province, formed by collision of the Sibumasu and Eastmal-Indochina continents during the Triassic (Hutchison, 1977 and Cobbing *et al*., 1992).

The Koh Mai/Khuan Mai Plai Klong granite ($Tr_{grkm/kk}$) intruded the Carboniferous Kubang Pasu/Yaha Formation ($C_{kp/yh}$) in the western part of the Transect area. In the eastern part, the Triassic Semanggol Formation/Lampang Group was also intruded by this granite. The emplacement of this granite resulted in an extensive contact metamorphic aureole of the Kachi hornfels (Zainol Husin and Mohammed Hatta Abd. Karim, in manuscript). The very high level intrusion of granite raised up the metasedimentary rocks as a roof pendant.

The granite of the Koh Mai/Khuan Mai Plai Klong pluton is characterised by pale grey with black spots, medium- to coarse-grained porphyritic biotite-muscovite granite. The phenocrysts are generally euhedral, occupying about 5 – 15% by volume. It had undergone sericitisation, indicated by the cloudy surfaces of feldspars. The small stock granitoids are generally aplite and leucogranite that have undergone albitisation and silicification. They also show a two-phase variant characterised by two generations of quartz. These phenomena indicate that the rock had undergone a hydrothermal overprint by the late phase fluids. Such secondary structures are considered to have been generated by late high-level pervasive emplacement of highly fractionated, residual magmatic fluids into an already coarse crystallised and essentially consolidated primary texture host (Cobbing *et al*., 1992).

The granite emplacements were responsible for much of the mineral wealth in the area. Tin-tungsten mineralisation is intensively distributed adjacent to the granite bodies, especially around Bukit Kachi, Sintok (Malaysia) and Khuan Mai Plai Klong (Thailand). Underground mining activities around the Bukit Kachi was reported since 1922 (Willbourn, 1926). The mineral deposits generally occur as a simple vein-type and stockwork swamps either in the granite itself or within the surrounding hornfelsic rocks. They are associated with late stage hydrothermal fluids and are believed to have taken place soon after crystallisation of the granitic rocks. Schwartz *et al*. (1995) classified the tin-tungsten in the Sintok area as a medium-scale deposit. The hypogene minerals are composed of wolframite, cassiterite, chalcopyrite, pyrite, arsenopyrite, scheelite and molybdenite, with tourmaline and fluorite gangue minerals.

No radiometric age determination of these granites had been reported. However, the post-Triassic age of intrusion is marked by cross-cutting relationship indicated by the intrusion of this granite into the Triassic Semanggol Formation/Lampang Group.

3. Structural geology

Peninsular Malaysia and Thailand were formed as part of the Sibumasu block. Its northern to northwestern fold-mountain regional trend is a southward continuation of the

trend extending from eastern Myanmar through Thailand. This trend also continues southward to Peninsular Malaysia, the Banka and Billiton Islands, and eastwards to Indonesian Borneo.

After the collision between the Sibumasu and the east Malaya-Indochina blocks, the Late Triassic Indosinian Orogeny took place. This major tectonic event resulted in rock deformation in the Malay-Thai Peninsula.

The Carboniferous successions in the Transect area are generally folded into series of isoclinal and tight folds resulting in a series of repeated and overturned sequences in the rock units, especially in the chert beds. The open fold style is the major structure of the Triassic rocks, whereas the gentle fold is the typical feature of the Cretaceous rocks.

The NNW-SSE and N-S trending fold axes are sub-parallel to the long axis of the Malay-Thai Peninsula and most of the bedding planes dip towards the east with various dip angles.

In the Yaha area, at least three phases of deformation can be clearly observed, particularly along the NW-SE trending fault zones as indicated by the presence of crenulation cleavages and kink bands.

Faulting in the area is conspicuous with three main N-S, NW-SE, and NNE-SSW directions. Strike-slip, normal, and high-angle reverse faults are present in the Transect area. The major fault zone trends N-S. The thrust fault is characterised by overthrusting westwards of the Carboniferous succession on to the Triassic successions in the Na Thawi and Yaha areas. The NW-SE faults show mainly sinistral sense of movement, whereas NNE-SSW faults show dextral.

4. Discussion and Conclusion

4.1 Discussion

i. Lithostratigraphically, rocks of the Kubang Pasu/Yaha Formation ($C_{kp/yh}$) exposed in both eastern and western sides of the Transect area, are generally similar. However, palaeontologically the succession is quite different. Rocks exposed in the western side, i.e. at Kubang Pasu, Sintok, Na Thawi, and Ban Bang Haeng, are rich in Carboniferous fossils. On the other hand, the succession exposed in the eastern side, i.e. at Sungai Teliang, east of Muda Lake and Ban Bahoi, Yaha District is poor in fossil except for radiolarian assemblage in the chert beds.

ii. Locally, the Permian and Triassic siliciclastic rocks are lithostratigraphically similar to the Carboniferous siliciclastic rocks. The occurrence of significant faunas was used to distinguish them.

iii. The boundary between the Semanggol Formation/Lampang Group and Kubang Pasu/Yaha Formation ($C_{kp/yh}$) in the Transect area is inferred as a fault contact. Nevertheless, the occurrence of a Permian hiatus is characterised by the presence of a 5 to 10 cm thick iron pan exposed at Ban Trap (Thailand), 25 km north of the Transect area. Consequently, the Permo-Triassic rock overlies unconformably the Carboniferous rocks.

iv. The Semanggol Formation of Malaysia may be revised to the "Semanggol Group", which is equivalent to the Lampang Group of southern Thailand. However, this is subject to further detailed study. In this report the Cherty unit (PTr_{ch}) is "temporarily" separated as a single unit from the "original" Semanggol Formation as deduced by the differences of the ribbon chert from those of the Rhythmite and Conglomeratic units in terms of lithostratigraphy, palaeontology and palaeoenvironment.

4.2 Conclusion

i. The Kubang Pasu/Yaha Formation ($C_{kp/yh}$), 300-350 m thick, consists of thick-bedded to massive quartzitic sandstone, argillaceous strata, sandstone intercalated with mudstone, thin-bedded chert, black chert and rare volcaniclastic sediments. The succession exhibits cycles of marine transgressive and regressive sequences. Fossil assemblages of the bivalve *Posidonomya* sp., ammonites, trilobites, crinoids and plant remains in argillaceous strata and radiolarians in chert beds, indicate an Early to Middle Carboniferous age. The hiatus took place during the Permian period.

ii. The Cherty unit (PTr_{ch}), previously included in the Semanggol Formation, is now separated as a single unit ranging in age from late Middle to Late Permian, based on the radiolarian content.

iii. The Semanggol Formation/Lampang Group of Middle to Upper Triassic is subdivided into three lithostratigraphic units (in ascending order): the Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$), the Conglomeratic unit/Khuan Chedi Formation

($Tr_{cg/kc}$), and the Khlong Kon Formation. The Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$) consists of well- and evenly-bedded sandstone, siltstone, mudstone, shale and chert (rhythmite or turbidite). The Conglomeratic unit/Khuan Chedi Formation ($Tr_{cg/kc}$), represented by conglomerate, graywacke and shale, is interpreted as an inner (proximal) submarine fan. The Khlong Kon Formation consisting dominantly of limestone was deposited in carbonate platform. Middle Triassic bivalves, *Daonella* sp. and *Posidonia* sp., and ammonites are the significant fauna in the Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$) and Conglomeratic unit/Khuan Chedi Formation ($Tr_{cg/kc}$) whilst Middle to Late Triassic foraminifera is common in the Khlong Kon Formation.

iv. During the Triassic, the western part of the Transect area was a deeper basin which was dominated by the outer (distal) submarine fan environment of the Rhythmite unit/Na Thawi Formation ($Tr_{rt/nt}$). In the eastern part of the Transect area, the inner (proximal) submarine fan deposits prevailed as indicated by the presence of the Conglomeratic unit/Khuan Chedi Formation ($Tr_{cg/kc}$), and the carbonate platform is represented by the Khlong Kon Formation.

v. The continental fanglomerate belonging to the Saiong beds/Sam Nak O formation ($K_{sa/sn}$) overlies unconformably the Triassic rocks. It crops out in the central part of the Transect area as a narrow N-S ridge and is interpreted as an alluvial fan deposited in a long and narrow intermontane basin during the Cretaceous.

vi. The Pleistocene gravel beds and Holocene alluvial plain unconsolidated sediments cover most of the western part of the Transect area.

vii. Late Triassic coarse-grained porphyritic granites and related rocks of the Koh Mai/Khuan Mai Plai Klong pluton intruded the Carboniferous and Triassic rock sequences. Contact metamorphism and the associated late stage mineralisations can be observed in the country rocks.

viii. Structurally, the Carboniferous succession is characterised by isoclinal and tight folds especially in the chert beds. Triassic sequence generally exhibits open folds, whereas the gentle folds are typical features of the Cretaceous rocks. Strike-slip, normal, reverse and thrust faults are conspicuous with three main directions, viz. N-S, NW-SE and NNE-SSW.

ix. Generally, in the Malay-Thai Peninsula, sedimentation took place continuously throughout the Paleozoic and Mesozoic eras, but minor breaks can be observed due to the instability of the depositional basin.

x. A better understanding of the geology, palaeontology and structure of the Transect area obtained from the joint project has led to resolving the problems related to the geological boundaries of the Carboniferous-Triassic sedimentary rocks.

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7. Appendices

Appendix 1: List of samples in the Transect area (Thailand).

Sample No.	Locality	Description	Unit
B100*	9971138, along the stream, south of Ban Sam Nak O	- Light brown and black patch, duration, no mica, grain-supported, coarse-grained polymictic orthoconglomerate. Clasts are angular shape, low spericity white quartz, black chert and some pale yellow siltstone (2-3 cm in diameter). Some grains show a platy shape, poorly sorted, immature mineral and texture, fine- to medium-grained sandstone matrix.	Tr (Khuan Chedi)
B101	Same location as above		Tr (Khuan Chedi)
B102*	Same location as above	- Same as above. - The lower is light brown (weathered), dense, no-mica, grain-supported, fine-grained, quartzitic sandstone poorly-moderate sorted submature in mineral and immature texture. Some pebbles of pale yellow mudstone, black chert and quartz (1 cm in diameter) were occurred. The upper is brown (weathered), soft, fiable, no mica, siltstone. Contact of both is gradational.	Tr (Khuan Chedi)
B103*	004135, along stream, south of Ban Sam Nak O	- Many colour, duration, no-mica, grain-supported, coarse-grained poly mictic orthoconglomerate, Clasts are colourless to smoky quartz, black chert, white siliceous rock and pale yellow siltstone (1-3 cm in diameter). Almost grains (except black chert) show subrounded to rounded shape, high sphericity, fine- to medium-grained sandstone matrix, poorly sorted, immature in mineral and texture.	Tr (Khuan Chedi)
B104*	005135, along stream, south of Ban Sam Nak O	- Dark grey to black, argillite-rich and some micaceous, fissility, shale-siltstone	Tr (Khuan Chedi)
B105	008135, stream, south of Ban Sam Nak O	- Same as B100	Tr (Khuan Chedi)
B106	Same location as above		Tr (Khuan Chedi)
B107	008140, ridge, SE of Ban Sam Nak O	- Same as B103 - Many colour, duration, no mica, grain-supported, medium- to coarse-grained polymictic orthoconglomerate. Most clasts are pale yellow to white siltstone to very fine-grained sandstone. The others are black and white chert and colourless to smoky quartz (1-2 cm in diameter). Most grains are angular to subrounded (in quartz) shape, low to spehericity and are disturbed, poorly sorted, immature in texture and mineral, fine- to medium-grained sandstone matrix.	Tr (Khuan Chedi)
B108	003142, along stream, south of Ban Sam Nak O	- Same as B104	Tr (Khuan Chedi)
B109	Sam location as above	- Same as B102	Tr (Khuan Chedi)

Sample No.	Locality	Description	Unit
BXX	730231, Na Tha Wi sheet, Crest management		C
B111	203085, Ba Hoi-Kabang road	- Reddish brown, dense, some micaceous, grained-supported, very fine-grained arkosic sandstone, well sorted, mature texture and submature mineral.	C
B112	Same location as above	- Graywacke? or lithic sandstone (sample lost). - Dark grey to black, quartzitic sandstone (sample lost)	C
B113*	208952, SW of map, near country boundaries	- Light greenish grey to light brown with black spot, dense, massive, no calcerous, grain-supported, fine-to fine- to medium-grained, lithic sandstone to protoquartzite. Composition of quartz > feldspar. Rock fragments are chert, heavy mineral and some	C
B114*	041127 Ba Hoi-Nam Chieo	biotite?, poorly –moderately sorted, immature-submature texture and immature mineral.	C
B115	043124 Ba Hoi-Nam Chieo	- Light greenish grey, dense, massive, no calcareous, grain-supported, fine-grained lithic sandstone to protoquartzite. Mineral composition is quartz (>50%), feldspar and rock fragments, moderate to well sorted, submature to mature texture and submature	C
B116	054121 Ba Hoi-Nam Chieo	mineral, rare of mica.	C
B117*	056117 Ba Hoi-Nam Chieo	- Same as B118 - Same as B121	C
B118*	057118 Ba Hoi-Nam Chieo	- Light brown to light greenish grey (weathered), dense, massive, no calcareous, matrix-grain-supported, fine-grained graywacke to lithic sandstone. Composition of quartz = feldspar and chert, dark grey mudstone-slate are found fragments, poorly-moderately sorted, immature-submature texture and mineral, spot clasts of feldspar and mudstone found.	C
B120a*	058118 Ba Hoi-Nam Chieo	- Light grey with white spot, dense, massive, no calcareous and mica, grain-supported, medium-grained lithic sandstone to arkosic sandstone. Feldspar-quartz rich, moderate	C
B120b*	Same location as above	to well sorted, submature texture and mineral. - Brownish red (weathered?), dense, massive mudstone, feldspar-rich. Some mica is found, conchoidal fracture.	C
B120c*	Same location as above	- Light greenish brown, friable, some micaceous, matrix- to grain-supported, siltstone to very fine-grained graywacke or lithic sandstone. Feldspar and some rock fragments are found, moderately sorted, submature texture and immature minerals, plant remains are	C
B120d*	Same location as above	dominant.	C
B120e*	Same location as above	- Light greenish grey to greenish grey, friable, massive, dirty, no calcareous, matrix-grain-supported, fine- to medium-grained graywacke or lithic sandstone. Feldspar-rich, fine-grained sandstone matrix, poorly sorted, immature to submature texture and minerals.	C
B120h	Same location as above	- Light greenish grey, dense, massive, mudstone, some feldspar (small spot) are found. - Light grey (weathered) to dark grey (fresh), dense, very homogeneous and massive, No	C

Sample No.	Locality	Description	Unit
B121*	058115 Ba Hoi-Nam Chieo	calcareous, mudstone to claystone? conchoidal fracture. - Same as B117.	C
B122	060115 Ba Hoi-Nam Chieo	- Dark grey to black, dense, massive, biotite-rich?, grain-supported, fine- to medium-grained lithic sandstone with 0.1 cm quartz vein, dirty, moderate to well sorted, mature	C
B123*	Same location as above	texture but immature minerals. - Graywacke? or lithic sandstone (sample lost).	C
B124	062114 Ba Hoi-Nam Chieo	- Light brown and white spot, dense, massive, grain-supported, quartz-rich, fine- to medium–grained quartzitic sandstone to protoquartzite white spot of feldspar rich,	C
B125	070110 Ba Hoi-Nam Chieo	some rock fragments, moderate to well-sorted submature-mature texture and	C
B126	071109 Ba Hoi-Nam Chieo	submature minerals.	C
B127	077096 Ba Hoi-Nam Chaeo	- Same as B121	C
B128a	078095 Ba Hoi-Nam Chieo	- Same as B118	C
B128b	Same location as above	- Same as B121 - Same as B145 light greenish white very fine-grained siliceous rock, conchoidal fracture. - Same as B118	C
B129	079095 Ba Hoi-Nam Chieo	- Light brown (weathered) or greenish grey (fresh) with white spot, dense, dirty,	C
B130*	080094 Ba Hoi-Nam Chieo	massive, grain-supported, medium-grained lithic sandstone. have rip up clasts of platy green to purple shale (2-3 cm in diameter), feldspar-rich, some rock fragments, poorly	C
B131*	084094 Ba Hoi-Nam Chieo	sorted, immature texture and mineral (like B120c). - Same as B118	C
B132*	094097 Ba Hoi-Nam Chieo	- Light grey (weathered) to dark brown (fresh) and some black, very dense massive to laminated, chert, some silicified and radiolaria abundant.	C
B133	110093 Ba Hoi-Nam Chieo	- Dark grey, dense, no mica and no calcareous, grain-supported, quartz-rich, fine- to medium-grained quartzitic – protoquartzite, some rip-up clasts of black shale, well	C
B134*	113097 Ba Hoi-Nam Chieo	sorted, mature texture and submature mineral.	C
B135	113096 Ba Hoi-Nam Chieo	- Light greenish grey, dense, massive, interlocking grain, fine- to medium-grained	C
B136	113.5096 Ba Hoi-Nam Chieo	quartzitic sandstone. It is well sorted, mature texture and mineral.	C
B137	149110 Ba Hoi-Ka Bang	- Same as B147	C
B138	160103 Ba Hoi-Ka Bang	- Same as B118 but finer grain (fine- to medium-grained)	C
B139	Same location as above	- May be coarse-grained tuffaceous rock? (sample lost)	C
B140	170102 Ba Hoi-Ka Bang	- Same as B130 but darker colour (dark grey chert)	C
B141	208085 Bai Hoi-Ka Bang	- Same as B118	C
B142	170168 Ba Hoi-Wang O	- Same as B123	C
B143	145126 Ba Hoi-Wang O (Ban Lam Ya)	- Same as B118 - Same as B121 - Same as B145	C

Sample No.	Locality	Description	Unit
B144*	130168 Lam Ya Nua	- Same as B117	C
B145*	135162 Lam Ya Nua	- Same as B117	C
B146a	147118 Ba Hoi-Lu Bo Bun Yang	- Dark grey to black, dense, very fine-grained sandstone (or silicified mudstone), fisility-like or cleavage.develop, conchoidal fracture. - Interbedded of light yellow and dark grey band, dense, laminated, silicified rock or chert, close-spaced joint.	C
B146b*	Same location as above	- Same as B123	C
B147*	209158 Lu Bo Bun Yang	-	C
B148	Same location as above	- Light greenish grey, dense, massive, some dirty, grain-supported, no calcareous and no mica, fine-grained quartzitic sandstone to protoquartztie, rare of feldspar, rip-up clast of 0.3-1 cm dark grey shale well sorted, submature minral, submature-mature texture.	C
B149*	949193 East of Ban Sam Nak O	- Same as B117 but cleaner, light yellow (weathered), friable, massive, grain-supported, fine- to medium- grained arkosic sandstone, feldspar and some rock fragment-rich, moderate to well sorted, submature texture and mineral.	Tr (Na Thawi)
B150a*	949188 East of Ban Sam Nak O	- Rhyolitic tuff? or sheared rock? or pyroclastic rock? or tuffaceous coarse-grained sandstone? (lost). - Light brown and white spot, dense, massive, grain-supported, fine-grained quartzitic sandstone. Feldspar is abundant, well sorted, mature texture and submature mineral.	Tr (Na Thawi)
B150b*	Same location as above	- Light purple with white spot, friable to duration, imbrication, matrix-supported. Medium-grained polymictic paraconglomerate. Clasts are colourless to smoky quartz (15%) pale yellow siltstone (0.3-1 cm in diameter = 75%) and other rock fragments. Most grains show subroundeded to rounded shape, low sphericity, medium-grained sandstone matrix, poorly sorted, immature in mineral and texture. - Same as B150a (matrix) but finer clasts grain, It looks like lithic sandstone with clasts of siltstone and feldspar is coarse-grained, conglomeratic sandstone	Tr (Na Thawi)
B150c*	Same location as above		Tr (Na Thawi)
B151*	9291158 near country boundary	- Same as 150a (matrix) but coarser clasts, friable, imbrication, coarse-grained polymictic paraconglomerate. Most clasts (80%) are white to yellowish white siltstone to mudstone (0.3-0.5 cm in diameter), some 20% clasts are quartz and red siltstone Most grains show subrounded to rounded shape, low sphericity, medium-grained sandstone matrix, poorly sorted, immature in mineral and texture. - Dark grey to black, lamination, very fine-grained sandstone, argillite-rich, well bedded, well sorted, mature texture but immature minerals. - Light grey, dense, massive, recrystalline limestone, some calcite veins, greyish green,	Tr (1^{st})
Limestone*	031143 Ban Nam Chieo		C
Tepa sandstone	134993 Tepa stream		Tr (Na Thawa)
Sandstone*	937160 near country boundary		Tr (1^{st})

Sample No.	Locality	Description	Unit
Granite*	Ban Prakob	dense, massive, dirty, grain-supported, fine-grained lithic sandstone, quartz and rock fragments rich, some feldspar and biotite? clasts, moderately sorted, submature texture and immature minerals (andesite-like). - Same as B151	Tr (granite)
	Song Ke mine, not sure	-	C
Spotted *slate?	730231, Na Tha Wi sheet,	- White (fresh) or orange (weathered) and black spot, massive, medium-grained porphyritic biotite-muscovite granite, phenocrysts are feldspar; white show albite twin (in 2x1 cm in size and 5-10% by volume). Groundmass consists of quartz (40%) feldspar (50%) biotite (5%) and muscovite (5%).	C
Brake rock*	Crest management		C
	Same location as above	- Same as B121	C
Brake rock*	Almost area of CP		
Micaceous sandstone	058118 Ba Hoi-Nam Chieo	- Dark grey, soft, friable, baked mudstone to shale, mostly argillite component.	C
Interbed rk		- Same as above but have porous secondary rocks, highly metamorphosed. - Light brown (weathered), friable, matrix-supported, micaceous, fine-grained wacke sandstone, quartz and rock fragments rich, plant remains abundant, poorly to moderately sorted, immature in texture and minerals. - Interbedded of thin bedded (0.5 cm) of 1. Light brown to white, duration, siltstone-very fine sandstone? which are silicified or silicceous rock and 2. Light grey, fissile, soft, siltstone to mudstone.	

Appendix 2: List of fossil collected in the Transect area (Malaysia).

No.	Northing	Easting	Location	Fossils	Age
1.	713672.84	274206.93	Near Kg. Baru (new road to Northern University of Malaysia)	Ammonoids Bivalve – *Posidonomya* sp.	Carboniferous
2.	713446.43	280953.66	Near main entrance to Northern University of Malaysia	Ammonoids - *Agathiceras* sp.(?) Pecten	Carboniferous
3.	702674.57	295813.07	Ladang Utara	*Posidonia* sp. *Daonella* sp. Ammonoids	Triassic
5.	701638.93	299281.85	Bukit Tok Janggut	*Posidonia* sp. *Daonella* sp. *Halobia* sp.	Triassic
6.	707170.04	301644.48	Sg. Durian Burung (in the sugar cane field)	*Posidonia* sp. *Daonella* sp. Crinoid stems	Triassic
7.	707750.14	302150.14	Sg. Durian Burung (road cut)	*Daonella* sp. Ammonoids	Triassic
8.	692261.98	317191.91	Foothill of Bukit Pakir Terbang	*Posidonia* sp.	Triassic

Appendix 3: List of fossil localities in the Transect area (Malaysia).

(collected by earlier workers)

No.	Grid reference	Location	Fossils	Age
1.	QS 993016	Padang Sari	*Posidonia wengensis*, Ammonite	Triassic
2.	QO 027088	Durian Burung	*Halobia* sp.	Triassic
3.	QO 024072	Durian Burung	*Posidonia* sp., *Halobia* sp.	Triassic
4.	QO 083058	Sg. Haat Nyei	*Halobia* sp., Crinoid stems	Triassic
5.	QO 098126	Sg. Ahning	*Posidonia* sp.	Triassic
6.	QO 077104	Sg. Ahning	*Posidonia* sp., *Halobia* sp.	Triassic
7.	QO 082097	Sg. Ahning	*Posidonia* sp., *Halobia* sp., Crinoid stems	Triassic
8.	QT 058999	Sg. Sintok	*Posidonia* sp.	Triassic
9.	QT 081994	Sg. Kah Ing	*Posidonia* sp., Crinoid stems	Triassic
10.	QO 107009	Sg. Kuak	Ammonite	Triassic
11.	QO 105007	Sg. Kuak	*Posidonia* sp., *Halobia* sp.	Triassic
12.	QO 044018	Sg. Kah Ing	*Posidonia* sp.	Triassic
13.	QO 029090	Durian Burung	*Halobia* sp.	Triassic
14.	QN 988038	Bt. Batu Hitam	*Posidonia* sp., *Halobia* sp., Plant remains	Triassic
15.	QN 990055	Sg. Agon	*Posidonia kedahensis*, *Halobia* sp., Crinoid stems	Triassic
16.	QO 011043	Sg. Padang Sanai	*Posidonia* sp., Crinoid stems	Triassic
17.	QO 018046	Sg. Padang Sanai	*Posidonia* sp., *Halobia* sp.	Triassic
18.	QN 997067	Charok Damar	*Posidonia* sp., *Halobia* sp., *Daonella* sp.	Triassic
19.	QN 992085	Charok Airut	*Halobia* sp.	Triassic
20.	QN 959071	Sg. Sebaping	*Posidonia* sp.	Triassic
21.	QN 987075	Bt. Nguan	*Halobia* sp.	Triassic
22.	QN 985081	Bt. Nguan	*Posidonia* sp.	Triassic

Appendix 4: List of fossil localities in the Transect area (Thailand)

Sheet	Grid reference	Description	Age
Na Thawi	761392	- Bivalve ; *Astarte* sp.	Triassic
	823326	- Bivalve ; *Halobia of. Cassiana*	Upper Triassic
		- Crinoid stems	
	764354	- Bivalve ; *Astarte* sp.	Triassic
	786314	- Ammonite	Triassic
	786313	- Bivalve ; *Astarte* sp.	Triassic
	783311	- small brachiopod ; *Chonetes* sp.	Carboniferous
		- Bivalve	Carboniferous
	809453	- Worm burrow	
		- Bivalve ; *Halobia* cf. *cassiana*	Triassic
		- Ammonite	Triassic
	881286	- Worm burrow	
		- Bivalve ; *Halobia* sp.	Triassic
		- Bivalve ; *Astarte* sp.	Triassic
	755451	- Ammonite ; *Sirenites* sp.	Triassic
		- Bivalve ; *Astarte* sp.	Triassic
	776307	- Bivalve ; *Ariculopecten* sp.	Carboniferous
		- Bivalve ; *Posidonomya* sp.	Carboniferous
		- Ammonite ; *Goniatites* sp.	Carboniferous
	753292	- Bivalve ; *Edmondia* sp.	Carboniferous
		- Bivalve ; *Posidonomya* sp.	Carboniferous
		- Brachiopod ; *Chonetes* sp.	Carboniferous
		- Ammonite ; *Agathiceras* sp.	Carboniferous
	754292	- Ammonite ; *Goniatites* sp.	Carboniferous
		- Brachiopod ; *Chonetes* sp.	Carboniferous
		- Bivalve ; *Posidonomya* sp.	Carboniferous
		- Bivalve ; *Nuculopsis* sp.	Carboniferous
	705370	- Trilobite ; *Macrobole kedahensis*	Lower Carboniferous
		- Ammonite ; *Agathiceras* sp.	Carboniferous
		- Brachiopod ; *Chonetes* sp.	Carboniferous
		- Brachiopod ; *Nucleouspira* sp.	Carboniferous
		- Bivalve ; *Posidonomya* sp.	Carboniferous
		- Bivalve ; *Schizodus* sp.	Carboniferous
		- Crinoid stems	

Sheet	Grid reference	Description	Age
	747286	- Crinoid stems	Carboniferous
		- Bivalve ; *Edmondia* sp.	Carboniferous
	755292	- Crinoid stems	Carboniferous
Na Thawi	755292	- Brachiopod ; *Chonetes* sp.	Upper Carboniferous
	738275	- Bivalve ; *Allorisma* sp. ?	Upper Carboniferous
		- Bivalve ; *Nuculopsis* sp.?	Carboniferous -Middle Permian
	738276	- Ammonite ; *Agathiceras* aff. *suessi*	Carboniferous
	683439	- Bivalve ; *Allorisma* sp.?	Carboniferous
		- Ammonite ; *Goniatites* sp.?	Carboniferous
Ba Hoi	754292	- Bivalve ; *Posidonomya* sp.	Carboniferous
	705277	- Bivalve ; *Posidonomya* sp.	Carboniferous

Appendix 5: List of the Malaysian Working Group
(Minerals and Geoscience Department Malaysia)

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Mr. Narong Uma	

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Figure 2: Geology map of The Gubir-Sadao Transect area along the Malaysia-Thailand Border