COMPILATION OF GEOHERITAGE SITES POTENTIAL FOR GEOTOURISM ALONG THE MALAYSIA-THAILAND BORDER

by

The Malaysian-Thai Working Group

A joint project carried out by
Minerals and Geoscience Department, Malaysia
and
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REPORT

COMPILATION OF GEOHERITAGE SITES POTENTIAL FOR GEOTOURISM ALONG THE MALAYSIA-THAILAND BORDER

(MALAYSIAN SIDE)

By:

The Malaysian Working Group

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PREFACE

This report is a compilation of the geoheritage sites potential for geotourism along the Malaysia-Thailand border area from Langkawi-Tarutao Transect area in the west to Batu Melintang-Sungai Kolok Transect area in the east. Potential geoheritage sites and geotrails had been compiled in this report including the sites that had been developed and conserved as geosites such as in the Langkawi UNESCO Global Geopark. There are total 36 geoheritage sites in these areas.

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1. INTRODUCTION

The Malaysia-Thailand Border Joint Geological Survey project was established as a result of an agreement made during the 7th Meeting of the Joint Commission for Malaysia-Thailand in Kuala Lumpur on 24th-25th January 1995. The first Meeting between the Department of Mineral and Geoscience Department Malaysia (the then the Geological Survey Department) and the Department of Mineral Resources Thailand was held in Kuala Lumpur, Malaysia on 19th August 1998 where both parties had agreed to carry out a joint geological survey along the border of the two countries.

The Term of Reference (TOR) of the Malaysia-Thailand Border Joint Geological Survey project had been agreed by both parties during the second meeting of the Malaysia-Thailand Border Joint Geological Survey Committee (MT-JGSC) held in Hat Yai, Thailand on 10th-11th March 2000. Besides geological study and mineral exploration, work on other disciplines of geology may be carried out. Since then, the Malaysia-Thailand Working Group had been established and successfully undertaking joint geological survey along the common border of the neighbouring countries.

This report is a compilation of potential geoheritage sites across the transects of Langkawi-Tarutao to Batu Melintang- Sungai Kolok. The sites lie within the area which had been mapped out by the Malaysia-Thailand Joint Border Survey Working Group. The compilation of geoheritage sites project had been endorsed by the Malaysia-Thailand Border Joint Geological Survey Committee (MT-JGSC) during the Thirteenth MT-JGSC Meeting that was held on 17th March 2019 at Krabi Front Bay Resort, Krabi Province, Thailand. This study had been carried out in 2019 to 2020 and delayed due to pandemic Covid-19. Therefore, it has been extended to 2022 for the final report compilation.

This joint project is carried out in corresponding to the Malaysian and Thai Government's policy to prioritize and implement projects with a direct benefit for local people. The main objective of this project is to identify and map the geoheritage sites along the border particularly the sites with significant values to be developed as geoheritage sites. In the long run, these identified geoheritage sites will be sustainably developed as tourist attraction destinations that be included in tourism activity of these regions.

Potential localities with significant geological which exhibit scientific, cultural, recreational and aesthetic values were identified, assessed, and compiled in this report.

1.1 Location

The Gubir-Sadao Transect area or Transect 1 covers an area of 80 km long and 20 km wide along the Malaysia-Thailand 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 on the scale 1:50,000; Amphoe Sadao, Amphoe Na Thawi, Ban Prakob Tok, Ban Bahoi and Amphoe Yaha Quadrangles.

The Batu Melintang-Sungai Kolok Transect area or Transect 2 covers approximately 3,400 km^2 along the border. The area in Malaysia (1,890 km^2) is partially covered by eight topographic map sheets on the scale 1:50,000; Kampung Ipoh (3766), Kampung Batu Melintang (3767), Kampung Lubuk Bungor (3866), Kampung Nibong (3867), Rantau Panjang (3868), Kuala Krai (3966), Tanah Merah (3967) and Kota Bharu (3968). The area in Thailand (1,500 km^2), is geographically covered by five topographic map sheets on the scale 1:50,000; Ban Ko Sathon (5421 III), Amphoe Sungai Kolok (5321 II), Amphoe Waeng (5320 I), Ban To Mo (5320 IV), and Amphoe Sisakorn (5321 III) Quadrangles.

The Pengkalan Hulu-Betong Transect area or Transect 3 is bounded by latitude 5° 25′ 24″ N to 6° 18′ 0″ N and longitude 100° 57′ 24″ E to 101° 15′ 0″ E, covering a total area of 3,411 km^2 (1,711 km^2 on the Malaysian side and 1,700 km^2 on the Thai side). The Malaysian side of the Transect area is covered by 1:50,000 scale topographic map Sheets 3566 (Gerik), 3567 (Pengkalan Hulu), 3568 (Bukit Mudin Besar) and part of the Sheets 3666 (Tasek Temengor) and 3667 (Belum). On the Thai side, it is geographically covered by four topographic map sheets on the scale 1:50,000; Amphoe Yaha (5221 IV), Amphoe Than To (5221 III), Amphoe Betong (5220 IV) and Ban Ai Yoe Boe Chang (5220 III) Quadrangles.

The Bukit Batu Puteh-Satun Transect area or Transect 4 is bounded by Latitude 06° 25´ N to 06° 50´ N and Longitude 100° 0Ó E to 100° 3Ó E. It covers an area of approximately 1,400 km^2 along the Malaysia-Thailand border. In Malaysia, the Transect area covers an area of 829 km^2 in Perlis and part of Kedah States along the Malaysia-Thailand border. It is bounded by Latitude 06° 25´ N to 06° 45´ N and Longitude 100° 0Ó E to 100° 3Ó E. The Transect area is covered by four 1:50,000 scale Malaysian topographic map sheets; number 3169 (Kuala Perlis), 3269 (Kangar), 3369 (Jitra) and 3270 (Padang Besar). In Thailand, it is geographically covered by five topographic map sheets (scale 1:50,000) of Amphoe Khuan Kalong (5022 IV), Changwat Satun (5022 III), Ban Ko Yao (5021 IV), Ban Khlong Ngae (5022 I), and Amphoe Sadao (5022 II) Quadrangles.

The Belum-Hala Transect area is bounded by latitude 05° 30’ N to 06° 00’ N and; by longitude 101° 15’ E to 101° 35’ E covering an area of 2,020 km^2. On the Malaysian side, the Transect area covers approximately 1,770 km2 along the Malaysia-Thailand border. It is covered by four topographic map sheets on the scale 1:50,000 i.e. nos. 3666 (Tasek Temengor), 3667 (Belum), 3767 (Kampung Batu Melintang) and 3766 (Kampung Ipoh). On the Thai side, the Belum-Hala Transect area covers approximately 350 km^2 along the border and is geographically covered by two topographic map sheets on the scale 1:50,000; Khao Hun Kut (5220 I) and Ban To Mo (5320 IV) Quadrangles.

The Langkawi-Tarutao Transect area or Transect 6 is bounded by latitude 06° 09’ N in the south and 06° 45’N in the north, and by longitude 99° 08’ E in the west and 99°57’ E in the east. On the Malaysian side, the transect area is covered by topographic map sheet on the scale 1:63,360, No.150 (Pulau Langkawi). On the 1:50,000 scale, the study area is covered by topographic map sheets Nos. 3069 (Pulau Langkawi) and 3169 (Kuala Perlis). The total land area of Langkawi Islands is 478 km^2. The transect area on the Thai side

covers approximately 360 km^2 and is geographically covered by two topographic map sheets on the scale 1:50,000; Ko Tarutao (4922 II) and Ban Ko Adang (4822 II) Quadrangles.

For the purpose of this compilation, some revision has been made to the boundary of the transect area especially to the area located on the easternmost part of the Malaysia-Thailand border area (refer geological map attached on the back cover of this report).

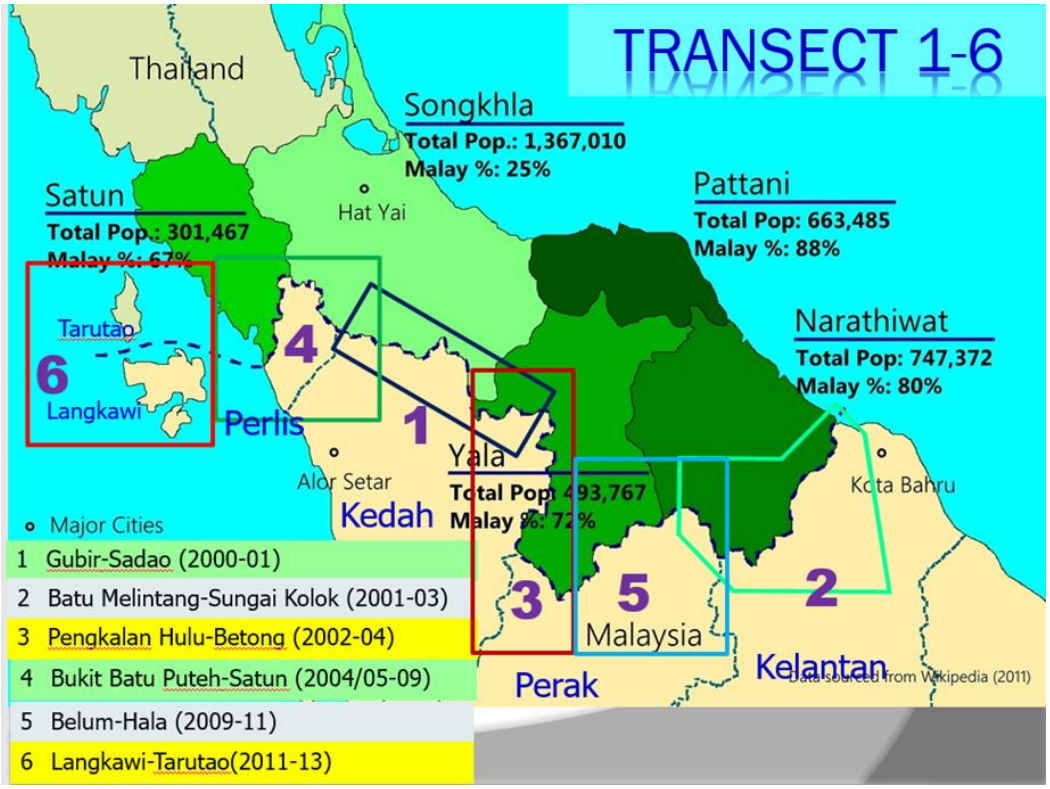

Figure 1: Area covers by Transect 1 to Transect 6 across Malaysia-Thailand border.

1.2 Physiography

Geomorphologically, the Malaysia-Thailand border area is dominated by mountainous and intermontane terrains covered by dense tropical rain forest, particularly in the central part where the Royal Belum Forest Reserve and the Hala-Bala Wildlife Sanctuary are situated on the Malaysian side and on the Thai side respectively**.** Some areas are occupied by relatively undulating terrain covered by rubber and oil palm plantations. The low-lying area in the western and eastern part of the border areas are covered by Quarternary deposits.

On the Malaysian side, the highest elevation is Gunung Ulu Kebeng (1,403 m above MSL) located in Belum area, while on the Thai side is represented by Khao Ta We (1,182 m above MSL) located in Narathiwat Province.

The main drainage systems on the Malaysian side are formed by Sungai Teliang-Sungai Muda in the western part, Sungai Perak in the central part and Sungai Kelantan in the eastern part. The main river on the central part of the Thai side is the Hala River originated from the Hun Kut-Bu Lo mountainous area.

The Langkawi-Tarutao area is located in the Straits of Melaka, about 50 km to the west of Satun Province. Tarutao Island, the largest island having 26.5 km long and 11 km wide, belongs to the Tarutao National Marine Park. The Adang-Rawi area is located in the Andaman Sea. It is located approximately 90 km west of Satun Province and belongs to the Tarutao National Marine Park. The study area consists of totally twenty-eight islands; Rawi and Adang Islands are the largest ones, covering an area of about 2 sq km; Lipe, the southernmost island of Adang, covers an area of about 2 sq km and is classified as a famous tourist place where large hotels and resorts, and restaurants have been constructed.

Langkawi Islands of the Malaysian side is an archipelago of 99 islands. Pulau Langkawi is the largest island in the archipelago. The other smaller islands including Pulau Dayang Bunting, Pulau Tuba, Pulau Singa Besar, Pulau Timun, Pulau Langgun, Pulau Rebak Besar and Pulau Beras Basah. The higher ground occupies most of the central part of the islands. The highest reliefs reach a maximum height of 881 m (Gunung Raya) and 708 m (Gunung Machinchang) that are located in the central and western part of Pulau Langkawi respectively. Gunung Raya is made up of the Raya Granite, whilst Gunung Machinchang is made up predominantly of metasandstone of the Machinchang Formation. Most of the lower ground and the coastal areas are overlain by unconsolidated marine and terrestrial Quaternary deposits.

Topography of Tarutao Island area is generally high mountainous, undulating and coastal landforms with the maximum elevation of 708 m above MSL. Semi-evergreen rain-forest blankets about 60 percent of the island, and pure mangrove swamps are found near the river mounts in the northern, eastern and southern parts of the island. General landform of the island consists of a rather smooth, but abruptly elevated coast on the western side of the island. The rocky cliffs are abruptly high up above the coast from a few metres to a few hundred metres. Small limestone islands (less than one km long) along the eastern coast are well recognized. A limestone cave and large sink holes occur in the limestone mountain onshore north of the island. Smooth escarpments forming ridges of the sandstone ranges are in contrast with the rough surface topography of limestone cliff displayed in an aerial photograph. Persistent and low-lying escarpments are present along the eastern limbs of the anticlines.

In the Adang-Rawi area, the middle part of Adang, Rawi and Ba Tuang Islands is high slope mountainous terrain with thick forests. Beach sands, white and black colour, are generally found along the bay and coast of islands. The highest mountain peak is above 703 m from mean sea level, located on Adang Island. Flat plateau of shallow coral reef is distributed east and north of Adang, Lipe and Bitsi Islands. The average depth of sea floor surrounding the islands is approximately 40 m below MSL and the deepest sea floor, 75 m below MSL, is situated in the western part of Ba Tuang Island.

The area overlain by Quaternary sediments is generally flat and low-lying, is utilised for paddy (*Oryza sativa*), rubber and palm tree cultivations. Several isolated sand ridges, trending almost parallel to coastline, are located close to the coastal area. At the river mouths where the sediments are dumped into the sea, the coastline builds seaward especially in the Kelantan delta (Bosch, 1988). The old fluvial channel scars can be observed from aerial photographs of the flat and low-lying areas close to the present river systems. Small rivers can be seen surrounded by levees.

On the Thai side, the pre-Quaternary areas can be geomorphologically distinguished as high mountain and terrace in the western part, undulating and rolling landforms at the central part, and flat areas in the eastern part. In Sungai Kolok area, the topography has basically shown remarkable higher level of high mountain range in the western part gradually decreasing to the coastal plain in the east. The highest elevation at Khao Ta We is 1,182 m above MSL, and 1-2 m in the flat areas of Ban Khok Yang, Ban Pa Da Do, and Tak Bai town.

In north western Kelantan area, exposures at Kampung Bukit Lata, near Bukit Perdah area are generally hilly and are made up of highly to completely weathered volcanic rocks of the Perdah volcanics. The equivalent rock unit is also exposed at Ban Mu No, Thailand.

1.3 Climate

Generally, the climate of the mainland of the Malaysia-Thailand border is Tropical Rainforest type (Koppen`s: 'Af' climate). The mean annual rainfall for 30 years (from 1951 to 1980) was 2,618.8 mm. The hottest month is May (28.4°C in average) and the coldest month is December (25.9°C). The weather is normally warm and dry from January to April, whereas it is wetter from September to December. The annual temperature ranges from 21^{o}C to 32^{o}C and the rainfall ranges from 2,000 mm to 2,500 mm.

The characteristic features of the climate of Peninsular Malaysia and Thailand are uniform temperature, high humidity and copious rainfall. The area is having a fair amount of rain all year-round and it is common to have heavy downpour in the middle of period considered as dry season. The eastern part of the Malasia-Thailand border area having wetter conditions with more rain. Flood usually happened during the northeast monsoon in the month November to March.

2. PREVIOUS WORKS AND GEOLOGICAL SETTING

2.1. Previous works (Malaysia Side)

The study area consists of six transects which are had been mapped in detail and well correlated with Thailand by The Malaysian-Thai Border Joint Geological Survey Committee and published as the following; 1. The Langkawi-Tarutao Transect, 2. The Bukit Batu Puteh-Satun Transect, 3. The Gubir-Sadao Transect, 4. The Belum-Hala Transect, 5. The Pengkalan Hulu-Betong Transect Area and 6. The Batu Melintang-Sungai Kolok Transect. Four northern states of Peninsular Malaysia which are Perlis, Kedah (including Langkawi Islands), Perak and Kelantan are part of these transects (Figure 1).

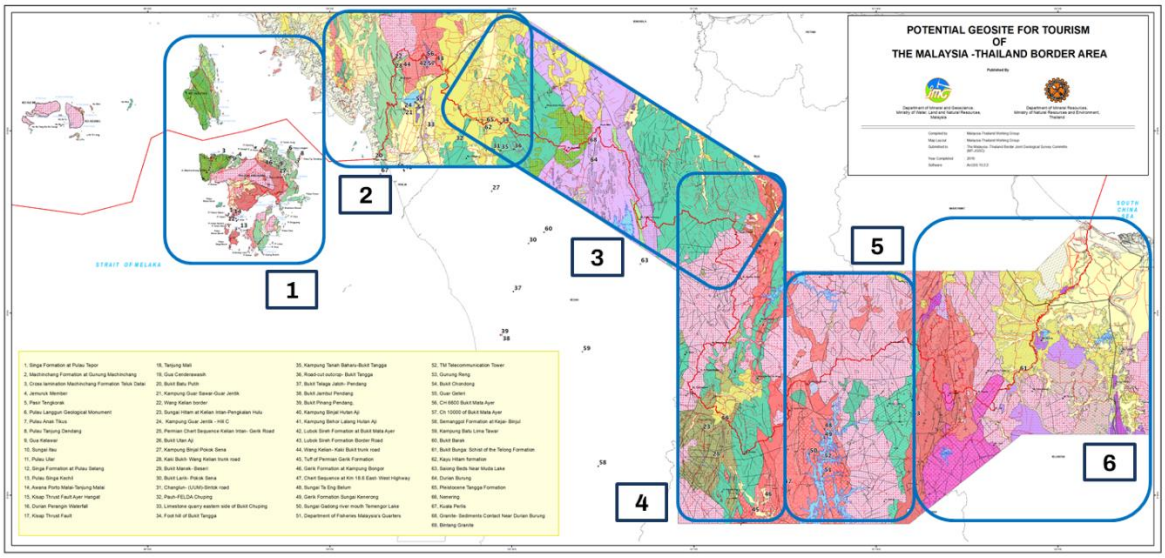

Figure 2: Geology map of the study area.

2.2. Geological setting (Malaysia Side)

Peninsular Malaysia is the South-East Asian part of Eurasian Plate, known as Sundaland. The rocks formations of North-West Peninsular Malaysia (where Perlis and Kedah lie) continue uninterrupted across the border into Peninsular Thailand (Hutchison & Tan, 2009) which explains the well correlated formations of Malaysia-Thailand particularly at the northern part. Part of Perak and Kelantan sections lie within East Malaya Block which is believed to be the separated extension of Indochina Block. Central Belt including Bentong-Raub Suture Zone was formed by the closing of an ancient ocean known as palaeo-tethys during Middle Triassic.

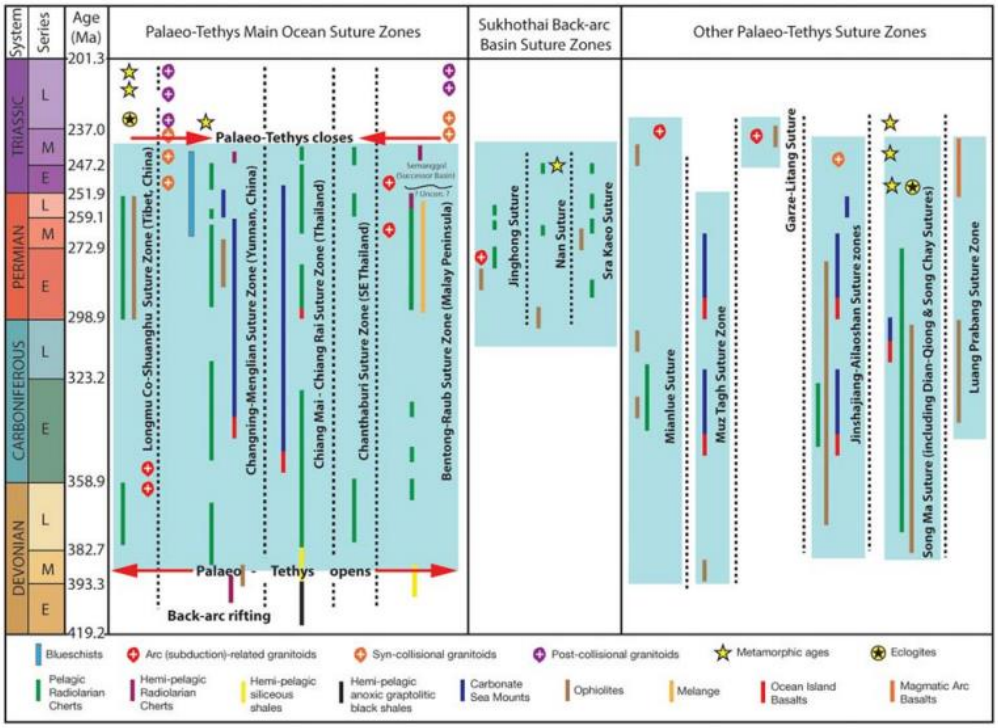

Figure 3: Ages of sedimentary rocks, ophiolites, melange, basalts, magmatic rocks and metamorphic rocks recorded from various suture-zone in Asia (after Metcalfe, 2021, 2017, 2013)

This regional geological evolution/history resulted in variety of lithology (sedimentary, metamorphic, and igneous) which vary in age from Cambrian to Cretaceous. Tertiary deposits are not observed in this study area but present to the south of Peninsular Malaysia. Quaternary deposits of clay sand originated from continental and marine environment typically formed flat plains. Diverse of lithology presents in Bentong-Raub Suture Zone and its proximity.

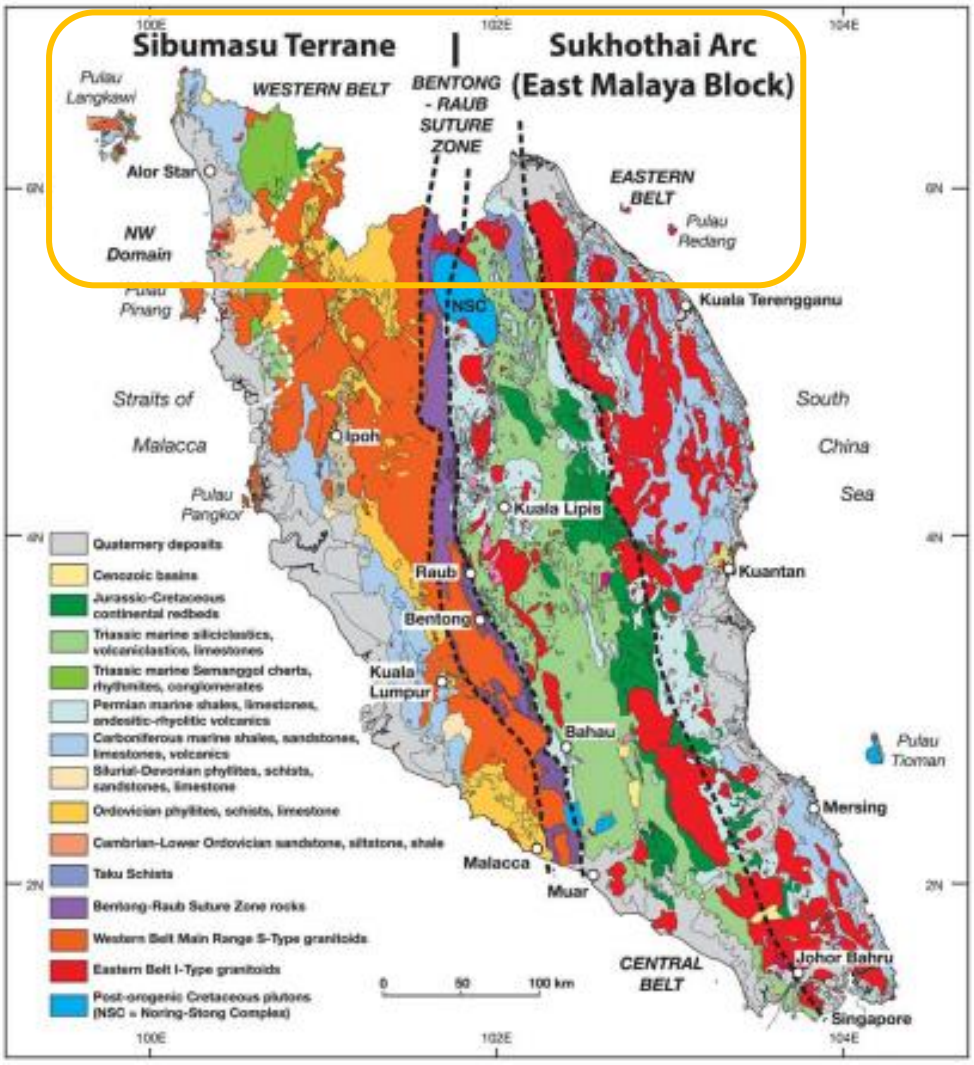

Figure 4: Geological map showing Western Belt, Central Belt, Easter Belt and Bentong Raub Suture Zone (after Metcalfe, 2009, 2013, 2017). The study area is marked in the yellow box.

<table>
<tr><th>Era</th><th>Period</th><th>Pulau Langkawi</th><th>West Kedah – Perlis</th><th colspan="2">Perlis – Central North Kedah</th><th>East Kedah (Baling)</th></tr>
<tr><td rowspan="2">CZC</td><td>QUATERNARY</td><td>Gula Formation</td><td></td><td colspan="2"></td><td></td></tr>
<tr><td>TERTIARY</td><td></td><td>Batu Arang beds</td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="3">MESOZOIC</td><td>CRETACEOUS</td><td></td><td></td><td colspan="2">Saiong Redbeds</td><td></td></tr>
<tr><td>JURASSIC</td><td></td><td></td><td colspan="2"></td><td></td></tr>
<tr><td>TRIASSIC</td><td rowspan="2">Chuping Formation</td><td rowspan="2">Kodiang Limestone</td><td colspan="2">Semanggol Formation</td><td>Semanggol Formation</td></tr>
<tr><td rowspan="6">PALAEOZOIC</td><td rowspan="2">PERMIAN</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Singa Formation</td><td>Chuping Limestone</td><td colspan="2">Cherty Unit</td><td>Cherty Unit</td></tr>
<tr><td>CARBONIFEROUS</td><td>Rebak Formation</td><td>Singa Formation</td><td>Singa Formation</td><td>Kubang Pasu Formation</td><td></td></tr>
<tr><td>DEVONIAN</td><td>Jentik Formation</td><td rowspan="3">Setul Formation</td><td colspan="2">Kampung Sena Formation</td><td rowspan="3">Baling Formation</td></tr>
<tr><td>SILURIAN</td><td rowspan="2">Setul Formation</td><td colspan="2" rowspan="2">Mahang Formation</td></tr>
<tr><td>ORDOVICIAN</td></tr>
<tr><td>LATE CAMBRIAN</td><td>Machincang Formation</td><td>Machincang Formation</td><td colspan="2">Jerai Formation</td><td></td></tr>
</table>

Figure 5: Stratigraphic correlation of formations in the study area (summarised after MTJGS Reports, 2016)

The oldest rock formation in Malaysia is the Cambrian Machinchang Formation which is characterized by Grey, brown, purple, green and red, coarse- to medium-grained quartzite, arkose and sub greywacke with subordinate beds of grit and conglomerate. Minor amounts of shale and mudstone occur alongside conglomerate (MT-JGSC, 2016). It covers an area of 52 kilometres square in the north-western part of Pulau Langkawi and extends to a small island nearby. This formation consists of four members, explain in ascending order;

Hulor Member: This oldest subunit comprises of grey fine clayey sandstone, fine sandstone and siltstone which is coarsening upwards. The lowermost consists of massive laminated greenish brown grey slate, phyllite and micaceous siltstone. Comprises grey to dark grey stylolitic limestone with irregular laminae and is variably dolomitic.

Anak Datai Member: Characterized by graded-bedded, cross-bedded pebbly sandstone and conglomerate and thin to thick beds of law angle, planar cross-bedded sandstone, with heavy mineral concentrations. Deposited within proximal to the eastward, prograding barrier beach complex.

Chinchin Member: 500 meters thick sequence of thick, grey and light purplish sandstone, fine-grained sandstone and siltstone with a few purple and green beds of fine acid tuffs and tuffaceous, and dark argillite. Divided into Temurun Beds (lower) and Tengkorak Beds (upper). Deposited in back barrier lagoons, connected to the open sea by channels.

Jemuruk Member: Comprises of well-bedded and well-foliated grey sandstone with fossiliferous beds containing fragmentary trilobite as well as trace fossil. Interpreted to be deposited in shallow marine environment due to the presence of cross-bedding and ripple marks.

Fossils are rare and limited to few trace fossils, brachiopods, fragmentary trilobites, and some tabular and unidentified remains. Fossils were only discovered Pulau Jemuruk, Tanjung Sabung, and Tanjung Buta. Generally, Machinchang Formation was interpreted to be deposited in offshore shelf, estuarine channel, barrier beach and lagoonal areas.

Early Ordovician to Silurian Setul Formation conformably overlying Machincang Formation and well exposed in the eastern part of Langkawi Islands. Also occurs in Perlis. Generally composed of hard, brittle, dark coloured, thickly-bedded, variably impure, crystalline limestone with stylolitic and bands of highly argillaceous content. The detrital unit of this formation usually consists of quartzite, limestone, phyllite, schist, gneiss and black cherty rocks (MT-JGSC, 2016). The Setul Formation are divided into three sub units which are in ascending order; Kaki Bukit Member, Tanjong Dendang Member, and Mempelam Member.

Kaki Bukit Member: The dominant member in Setul Formation. Comprises grey to dark grey stylolitic limestone with irregular laminae and is variably dolomitic.

Tanjong Dendang Member: Characterised by interbedded of dark grey to pink, very thin- to thin-bedded argillaceous limestones with occasional ripple cross-lamination and greenish grey, black and red shales. Contact of this unit with other units are conformable and gradational.

Mempelam Member: Characterized by thickly-bedded, dark grey, stylolitic limestone, less fossiliferous. Upper boundary of the Setul Formation.

Jones (1981) reported shelly fauna abundance from Early, Middle, and Late Ordovician in the Setul Formation. They include corals, brachiopods, gastropods, cephalopods, cystids and conodonts that sporadically occur within the formation in Langkawi and Perlis. Trilobite was also discovered and reported in Jones (1981). This Setul Formation is interpreted to be deposited mainly in the continental shelf (MT-JGSC, 2016) due to the occurrence of obvious stylolitic structures formed by bands of siliceous and carbonaceous impurities indicating deposition above the carbonate compensation depth (CDC).

Kubang Pasu Formation is well distributed from the western of Perlis until the north and northeastern part of Kedah. It is interpreted to be Early Carboniferous (Late Tournaisian) to Late Carboniferous based on discovered fossil assemblages. *Posidonomya* sp., ammonites and crinoid stem are occasionally found in the upper part and plant remains are abundant in argillaceous strata. Meanwhile, the middle part yield bivalve of *Posidonomya* sp. (Basir Jasin, 2015), Pygidium trilobite and crinoids. Chert

and siliceous shale yielded Tournaisian radiolarian in both middle and upper part of the formation (Basir Jasin & Zaiton Harun, 2001). Essentially comprises of thick interbedded of poorly sorted areno-argillaceous and minor siliceous rock (thin-bedded chert and siliceous shale), very thick sequence of argillaceous rock (dark grey and red mudstone and shale are most common) and very thick sequence of thick to massive beds of arenaceous rock (predominantly grey to white sandstone, greywacke, subordinate grit) with minor conglomerate (MT-JGSC, 2018). The Kubang Pasu formation are divided into three sub unit members, in ascending order; Jelutong Member, Jenun Member, and Papulut Member.

Jelutong Member: Comprises of interbeds of thin- to medium-bedded shale and sandstone with occasional fossiliferous beds and intercalated of chert beds. Overlies Mahang Formation in eastern Perlis and Kedah and overlies Kroh Formation in Upper Perak.

Jenun Member: Comprises very well laminated shale and well-bedded shale and mudstone intercalated with minor very thin bed of siltstone and very fine-grained sandstones (thick well-laminated argillaceous sequence).

Papulut Member: Comprises predominantly thick to massive beds of arenaceous rocks consisting of quartz arenite and minor arkosic sandstone interbedded with thin-bedded mudstone or siltstone. Underlying conformably the Permian Gerik Formation. Thick-bedded sandstone and feldspathic sandstone forms a prominent north-south ridge of Ulu Legong, Gunung Bayu in Baling, Kedah (among others that are mainly located in Upper Perak).

Stratigraphically, the outcrops in Kedah are part of the Jelutong and Jenun members of Kubang Pasu formation. The Jelutong Member is such outcrop in Bukit Telaga Jatoh, Pendang while the Jenun Member is well exposed in Bukit Jambul, Pendang. The Papulut Member is well exposed in eastern Kedah as well as Upper Part of Perak. This formation has been deposited in the intertidal environment to a continental shelf environment due to the presence of lenticular sandstone and thick-bedded mudstone. Presence of chert and siliceous shale may be due to the increase supply of silica from the underlying siliceous rocks (Mahang/Kroh/Betong Formations). Coarsening and thickening upward and fining and thinning upward sequence in parts of the sequences may represent fluctuation of sea level or tectonic activity or both during Carboniferous.

Cherty Unit was previously categorised as the Basal Member of Semanggol Formation). This unit crops out extensively in the Sungai Tiang and Kuala Nerang areas in Padang Terap, Kedah. It forms N-S strike ridges to the south of the Gubir-Sadao transect area, that are traceable up to Bukit Barak in Pokok Sena (MT-JGSC, 2006). Early Permian to Middle Triassic radiolarian faunas were found within the Cherty unit **in s**equence of light grey, buff and white, well-bedded pelagic chert grading upward into siliceous shale or mudstone with shale and sandstone. (Chert shale association with minor tuff beds). Lighter colored than the chert sequence in Kubang Pasu Formation. This unit

Underlain by Carboniferous Kubang Pasu Formation and overlain by the Rhythmite Member of Semanggol Formation. Deposited in the continental margin that is not far from volcanic activities, probably volcanic activities in the central belt of Peninsular Malaysia during the late Early Permian to Triassic (Basir Jasin, 2003).

Middle Triassic to Late Triassic Semanggol Formation is confined to the northeastern part of Kedah. In Malaysia, the Semanggol Formation is represented by two lithological units which are, in ascending order; Rhythmite Unit and Conglomeratic Unit.

Rhythmite Unit: Consists of rhythmic alternation of sandstone and shale or mudstone, and is the dominant rock of Semanggol Formation (MT-JGSC, 2006). Thick graded bedding sandstone shows sharp base grading upward to the thin overlying shale or mudstone. The prominent sandstone of this formation is classified as quartz arenite, litharenite, sublitharenite, graywacke and lithic graywacke.

Conglomeratic Unit: Forms N-S trending elongated hills along the western part of the Muda Dam in Pedu. Consist predominantly of pebble-szied clasts, normally rounded to subangular conglomerate, sandstone interbedded with mudstone and shale (showing fining upward sequence) (MT-JGSC, 2006). Semanggol Formation unconformably overlain the Kubang Pasu Formation (Permian hiatus?). Presence of Bivalves (*Halobia* species), ammonites *Paraceratites* sp. and *Paratrachyeras* sp. in Pokok Sena area, and presence of *Posidonia* sp., *Daonella* sp. and *Serpulites* sp. in Sungai Tiang area that indicates Triassic age. Conglomeratic Unit show a fining upward sequence, where the Rhythmite Unit was deposited in a deeper basin such the outer submarine fan environment while the Conglomeratic Unit deposited in the inner submarine fan environment.

Chuping Formatio is Permian to Triassic in age built prominent sporadic limestone hills in Central Perlis are built by this formation. In Langkawi Islands, Chuping Limestone can be observed at the western side of Pulau Dayang Bunting. This formation is equivalent of Kodiang Formation of northern Kedah. This formation is characterised by pure, light-coloured, thick-to very thick-bedded limestone sequence with predominated micstone and wackstone in which the individual crystal is rather indistinct (Batu Puteh- Satu Transect Report, 2016). Packstone is also common where the individual grain is much larger and sometimes developed into euhedral grains. Calcite veins vary in sizes whilst quartz veins are rarely occurred in this formation. Consist of three members which are Lower Limestone Member (Permian age), the Clastic Member (Early Triassic age), and the Upper Limestone Member (middle to late Triassic age).

Lower Limestone Member (Middle to Late Permian): Represented by Bukit Temiang, Bukit Tungku Lembu, Bukit Chondong, Bukit Semadong, Bukit wang Pisang, Bukit Manek, Bukit Chabang, and Bukit Mata Ayer. This member is characterised by fine-grained, light grey limestone with pure carbonate composed of calcite with presence of dolomite. Beddings are well developed with distinctive, sharp and planar contact at the

base. Brecciated limestone consists of angular limestone occurs in micrite and sandy matrix (can be observed at Bukit Chondong).

Clastic Member (Early Triassic): Formed isolated small hillocks and elongated undulating terrain striking N-S which can be observed just next to the railway line in the central part of Perlis). This member consists of thin-to medium-bedded sandstone-shale sequence. The sandstone is light grey, generally medium-grained, normally greywacke, feldspathic and poorly sorted with the occurrence of load structures (below the sandstone beds), minor folds and slump structures.

Upper Limestone Member (Middle to Late Triassic): The topmost member of Chuping Formation which formed the N-S limestone topography of Bukit Chuping, Bukit Keteri, Bukit Jerneh and Bukit Guar Sami. This member is fairly uniform deposit of thick- to very thick-bedded, fine-grained, light grey to whitish grey in colour. Coarse-grained marble occurs in certain localities. Jones (1981) reported shelly fauna abundance from some Permian faunas from Lower Limestone Member; the occurrences of the brachiopods in Bukit Tungku Lembu. Metcalfe (1990) reported the occurrence of Triassic conodonts from The Upper Limestone Member. This formation was deposited in from shelf relatively far from the shoreline to outer (distal) submarine fan deposits based on the transition from lower limestone to clastic member.

Early Devonian. Timah Tasoh Formation is localised to a very limited to a condensed section of 5 meter thick exposed at Kampung Guar Jentik, Guar Sanai of Perlis. Characterised by a thick bedded fossil rich black shale. It was previously part of Upper Detrital Member of Setul Formation, this clastic formation and divided into three units; Lower, Middle and Upper. Presence of Lochkovian conodonts in the basal bed, late Pragian/early Emsian dacryoconarid tentaculitoids and monograptids in the upper bed. Suggested to be deposited in a deep marine environment.

Early Silurian to Devonian Kroh Formation is extensively exposed in Pengkalan Hulu, Kelian Intan and Kerunai areas of North Perak (MTJSC, 2009). It extends along Sungai Ketil valley, nera Kampung Gubir (Kedah) and terminates at the intersect of Main Range Granite and Bintang Granite. Generally consists of well-bedded clastic rocks with the occurrence of fossiliferous calcareous portion and distinctive fossil-rich redbed. Hamada (1970) and Hamada et al. (1975) reported Devonian age fauna i.e graptolites and *Tentaculites* sp. with brachiopods and trilobites, Graptolites found in the valley of Sungai Rui appeared to be Middle-Upper Llandovery (Lower Silurian) according to Jones (1973). The Malaysia Working Group discovered a number of *Tentaculite*s, graptolites, brachiopods, and trilobites which indicate Lower Silurian and. Lower Devonian exist in Kroh Formation. The wide spread of argillaceous facies with considerable amount of carbonaceous content suggests the euxinic marine environment (MTJSC, 2009). The absence of benthos fossils and bioturbation suggests the deep marine depositional environment. Restricted occurrence of Calcareous Facies and Arenaceous Facies might be deposited in the slightly shallower shelf where still above the CCD.

Gerik Formation is Permian in age and exposed at the vicinity of Gerik Town and Lawin area including Kerunai and Belum areas. This formation can be well observed along the East-West Highway (also known as Gerik-Jeli Highway). Consist mainly tuffs, rhyolitic to rhyodacitic composition (MTJSC, 2009) which are the interbeds of tuffs, limestone, and calcareous shale. Tuffs exhibit grey to green, speckled bedded rocks composed of grains and fragments of quartz, potassic feldspar and plagioclase which set in fine matrix of quartz, mica, chlorite and siliceous matters and iron oxides under microscope. These tuffaceous rocks also contain various amount of clastic sediments of limestone and lenses of calcareous shale. Foliation results of regional metamorphism can be seen in the groundmass with the highest-grade presence as schistose structure. A weak lava flow structure which characterised by the alignment of prismatic K-fedspar phenocrysts was observed near Kuala Rui and Taman Klian Intan. Interbedded sedimentary rocks occurred in small amounts alongside with presence of dark grey impure limestone. Jones (1970) who firstly suggested the age of Gerik Formation (previously was Grik Tuff) as Late Ordovician whilst Burton (1986) suggested to be Middle Ordovician. According to Malaysian Working Group, the discovery of trilobites and brachiopods in calcareous shale strongly indicates Middle Permian age (of the clastic sediments). Thus, this suggests the Gerik Formation to be no older than Carboniferous hence made Jones (1970) and Burton (1986) hypothesis solely on lithological correlation to be redundant. Based on co-occurrence of well-bedded tuff, chilled magma, epiclastic materials and interbedded tuff with argillaceous, calcareous materials and shallow water fossils, likely Gerik Formation was deposited in the shallow marine environment with active volcanism.

Rocks of north Perak and Baling have similarly been metamorphosed to low grades (except for the Mahang fm) so the metamorphism here is not related to the Patani Metamorphics since Mahang Formation (early paleozoic age) is not metamorphosed. Youngest rock affected by the Patani Metamorphic are Singa Fm (probably metamorphism ended in mid-Permian on western mainland of Kedah). Sedimentary record in Baling area ends at early Paleozoic and little else is known except those late Triassic granitic intrusions have imposed contact metamorphic effects.

Late Triassic Bintang Granite is exposed around Baling and Gerik area and extends to Lenggong province. Bintang granite is the general name of granites in the area (there are Kupang, Inas and Damar Granite within Bintang Range). The granites are leucocratic, coarse grained with porphyritic texture. There are also quartz veins with tourmaline content intruding the granite (probably as seen in Lata Bayu.)

Mangga Formation is Carboniferous to Permian Age and well exposed in Jeli to Sungai Machang and extends to southeastwards to Kampung Gunong (MTJSC, 2016). Consist of low-grade metamorphic sequence that can be subdivided into four facies:

Argillaceous Facies: Mainly metamorphosed siliceous shale, slate, phyllite, metasiltstone and hornfels. This facies is divided to the upper part (hornfelsic rocks such as calc-silicate hornfels). The rocks are light grey in colour, very fine-grained, slightly foliated and recrystallised with both quartz and calcite veins. Chert unit is light

grey to grey and barren. Slate and phyllite are grey to dark grey and usually interbedded with metasiltstone.

Arenaceous Facies: Metasandstone and metagreywacke interbedded with minor metasiltstone and schist and quartz-mica-graphite schist.

Pyroclastic Facies: Mainly rhyolitic tuff. This facies do occur as lenses in argillaceous and arenaceous facies.

Calcareous Facies: Impure marble and pure white marble which co-occurred as lenses in other facies. This formation had been intruded by Triassic Kemahang Granite and Jurassic Cretaceous Stong Complex. Poorly preserved brachiopod and gastropod found by Macdonald (1955) in Mangga Formation at Kampung Belimbing, Batu Melintang area which may locally suggested Permian age.

The youngest granite intrusion in Peninsular Malaysia is Stong Migmatite Complex which formed during Jurassic - Cretaceous Age. Limited and localised distributed around North Kelantan, Jeli down to Dabong of Kuala Krai Province. This youngest plutonic intrusion in the Eastern Belt consists of three plutonic components:

Berangkat Tonalite: Dark grey partly strongly foliated megacrystic monzonite-tonalite-granodiorite. Hornblende presence as mafic portion.

Kenerong Leucogranite: Light grey to whitish aphaneritic granite. Consisted of of sequence of veins of fine- to medium-grained leucogranite and biotite granite, aplite and pegmatite. Three or more generations of leucogranite veins from unfoliated to intensely foliated can be observed at one place.
Noring Granite: The largest component which is characterised by distinctive pink K-feldspar, plagioclase, quartz, biotite, hornblende, sphene, apatite etc. Phaneritic.

2.3. Previous Work (Thai Side)

2.3.1. Sadao Area

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. Subsequently, Sashida *et al*. (2000) described that these radiolarians as *Entactinia variospina*, *E. vulgaris*, *Astroentactinia multispinosa*, *Spongentactinia* sp. and *Triaenospaera* sp. indicative of Early Carboniferous age (Tournaisian).

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) had been 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 granites of the Gubir-Sadao area on the Thai side were classified as Triassic Main Range Granite or Triassic Central Belt Granite (Hutchison, 1977; Cobbing *et al*., 1992).

2.3.2. Sungai Kolok Area

Sungai Kolok area was first mapped by the Geological Survey Division, Department of Mineral Resources (Muenlek *et al.*, 1979) on scale 1:250,000 of sheet NB 47-8,5 (Changwat Narathiwas and Takbai District; reprinted in 1985) and sheet NB 47-12 (Betong District;reprinted in 1985).

Muenlek *et al.* (1979) had introduced the Silurian-Devonian rocks as the Ban To and Betong Formations. The former consists of recrystallised limestones to marble, quartzite, phyllite, phyllitic schist and mica-schist, and the latter comprises shales with *Tentaculiteselegan*, cherts, siliceous shales, meta-tuff, carbonaceous shales, argillite, mudstones,sandstones and bedded recrystallised limestones.

Hastings (1983) investigated peat swamps in Narathiwat by means of palynology. Temporal and spatial changes of the vegetation were documented by analyzing the pollen and spores obtained from sediments in the swamps. It is postulated that peat development began under a herbaceous transitional to freshwater marsh, characterised by a relatively diverse arboreal component and notable amount of Gramineae and *Lycopodium*. This peat swamp has possibly mixed vegetation throughout its history. Based on the evidence, there would be a possible change in sea level during the development of the swamp.

Vijarnsorn and Liengsakul (1986) studied peat swamps in Narathiwat and mentioned that they occurred during the period 3,000 to 7,000 years BP. The old sand bar or mangrove clay is mainly underlain by stiff clay of the Pleistocene surface.

Dheeradilok *et al.* (1991) mentioned that the Holocene shallow marine clay and tidal flat deposits consisting of marine clay and peat were investigated along the Pattani coastal plain. The transgression began about 8,500 years BP, and rose up to about 5 m above the present mean sea level about 5,000 years BP. The last regressive phase began 2,500 years BP, and reached the present mean sea level about 1,500 years BP.

Sawata (1991) reported that fossil crabs and cuttlefish bones were found in marine sandy clays at Sungai Kolok, southern-most Thailand. The British Museum determined the cuttlefish as *Sepiabandensis adam* (identified by Dr. M.K. Howarth) and the crabs are *Macrophthalmus (Vetinus) latreillei* (Desmarest) (identified by Dr. S.F. Morris). Based on these fossils, the sediments range in age from Pleistocene to Recent and were deposited in estuaries or mangrove swamps.

GMT (1995) investigated the soil types and engineering properties of Phru To Daeng swamp in the vicinity of Sungai Kolok District (TD7, TD8, TD9), and the areas of Tak Bai District, Ban Khok It, Ban Khok Ni and Khlong Bang Toei, (TD1, TD2, TD3, TD4,

TD5 and TD6). According to drill-hole results, the succession of Phru To Daeng near Sungai Kolok District consists of 4 units: Residual deposits, Old alluvium Deposits (Terrace?), Nearshore Deposits and Mangrove Deposits, respectively in asccending order. The sequence of Quaternary geology at Tak Bai District can be divided into 6 units as follows: Old Alluvium Deposits (Terrace?), River Lag Deposits, Back Swamp Deposits, Nearshore Deposits, mangrove Deposits, and Overwash Deposits. The chemical analyses of clay minerals of Tak Bai District revealed that they consist of kaolinite, illite, quartz, smectite and siderite. The clay minerals at Sungai Kolok are composed of mainly kaolinite, illite, quartz, gibbsite, feldspars, pyrite and goethite.

Chaimanee (1999) reported that there are two types of peat in the coastal area of Thailand, i.e. topogeneous and ombrogeneous. These types of peat are usually associated with an undulating beach barrier and lagoonal deposits.

2.3.3. Betong Area

The Betong area on the Thai side was first mapped by the then Geological Survey Division, Department of Mineral Resources Thailand (Muenlek *et al.*, 1979) on scale 1:250,000 at Sheet NB 47-85 (Changwat Narathiwat and Takbai District; reprinted in 1985) and Sheet NB 47-12 (Betong District; reprinted in 1985).

Muenlek *et al.* (1979) introduced the Silurian-Devonian rocks as the Ban To and Betong Formations. The former consists of recrystallized limestones to marble, quartzite, phyllite, phyllitic schist and mica-schist, and the latter comprises shales with *Tentaculites elegans*, cherts, siliceous shales, meta-tuff, carbonaceous shales, argillite, mudstones, sandstones and bedded recrystallized limestones.

Hutchison and Taylor (1978) proposed three geographical granite belts in Malaysian peninsula based on lithology and petrochemistry of the granite. The Eastern belt granitoids are composed mostly of I-type, magnetite series granitoids. The Main Range granitoids in the central belt are composed mainly of S-type, ilmenite series granitoids with minor intrusion of I-type, magnetite series granitoids. The western belt granitoids consist of both I-type, magnetite series granitoids and S-type, ilmenite series granitoids.

Muenlek *et al.* (1982) published a regional geological map, Narathiwat sheet scale 1:250,000. The individual granite pluton was preliminarily studied petrographically, and subsequently three granite phases were classified as gneissic granite, coarse-grained porphyritic biotite granite and tourmaline-muscovite granite.

Cobbing *et al.* (1986) studied petrography, geochemistry, and Rb/Sr age determination of the granites of the South East Asian tin belt. They suggested that the granites in the east coast of Thai-Malay peninsula are mainly Triassic in age. The granite within the study area can be classified as a Triassic Main Range Granite or Triassic Central Belt Granite.

Nakapadungrat *et al*. (1988) introduced the Carboniferous rock sequences cropping out in Sabayoi Quadrangle, Thailand as the Yaha Formation, which can be correlated with the Kubang Pasu Formation on the Malaysian side.

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 Na Thawi District and Ban Kabang of Kabang District, Yala Province. These radiolarians are *Eutactinia varispina*, *E. vulgaris*, *Astroentactinia multispinosa*,*Spongentactinia* sp., and *Triaenospaera* sp. indicative of an Early Carboniferous age of Tournaisian stage (Sashida *et al*., 2000).

Charusiri, B & Charusiri, P. (1990) studied the geology and Sn-minineralization at Pin Yo mine in the Tham Talu mineralization zone. They concluded that the Sn- and Bamineralization could be classified as a metasomatic exoskarn in contact zone of Triassic granite and Permian limestone.

2.3.4. Hala Area

On the Thai side, the Belum-Hala Transect area was first mapped by the Geological Survey Division, Department of Mineral Resources Thailand (Muenlek *et al.*, 1979) on scale 1:250,000 of sheet NB 47-12 (Betong District; reprinted in 1985).

Cobbing *et al.* (1986) completed a Southeast Asian granite project including the geological map of individual granite plutons, petrography, geochemistry and Rb/Sr age determination studies. They suggested that the granites in the east coast of Malaysia-Thailand Peninsula are mainly of Triassic age.

Tonnayopas (1994) who studied the geology and stratigraphy of the Bang Lang Dam area in Yala Province suggested that the Bang Lang dam site could be mainly underlained by the Kanchanaburi Formation which consists of sandstone, shale, argillite and schist, with igneous intrusion to the west of the Dam site. The formation could be separated into the Bang Lang Formation consisting mainly of clastic sedimentary rocks and underlying the Hala Formation comprising metamorphic rocks with an angular unconformity contact.

Utha-aroon *et al*. (2000) reviewed the mineral resources near the Malaysia-Thailand border. They suggested that the mineralizations were related to granite intrusion and subsequent hydrothermal activities.

Chanrungrot (2003) studied the economic geology and mineral potential on scale 1:250,000 of sheet NB 47-12. He proposed the potential of Pb-Zn and Sn-W in the Belum-Hala area.

2.3.5. Satun Area

The Bukit Batu Puteh-Satun Transect area on the Thai side was first mapped by the then Geological Survey Division, Department of Mineral Resources (Tansuwan *et al.*, 1979) on scale 1:250,000 of sheet NB 47-7 (Changwat Satun).

Hutchison *et al.* (1978) proposed three geographical granite belts in the Malay Peninsula based on the lithology and petrochemistry of the granite. The Eastern belt granitoids are composed mostly of I-type, magnetite-series granitoids, which intruded the Palaeozoic host rocks during Permo-Triassic period. The Main Range granitoids (in the central belt area) are composed mainly of S-type, ilmenite-series granitoids with

minor intrusions of I-type, magnetite-series granitoids. They also intruded the Paleozoic-Mesozoic country rocks of Permo-Triassic age. The western belt granitoids consist of both I-type, magnetite-series granitoids and S-type, ilmenite-series granitoids of Cretaceous age.

Dheeradilok *et al.* (1991) mentioned that the Holocene shallow marine clay and tidal flat deposits consisting of marine clay and peat were investigated along the Pattani coastal plain. The transgression began about 8,500 *yrs. BP*, and rose up to about 5 m above the present mean sea level about 5,000 *yrs. BP*. The last regressive phase began 2,500 *yrs. BP*, and reached the present mean sea level about 1,500 *yrs. BP*.

Chaimanee (1999) reported that there are two types of peat in the coastal area of Thailand,i.e. topogeneous and ombrogeneous. These types of peat are usually associated with an undulating beach barrier and lagoonal deposits.

2.3.6. Tarutao Area

The systematic mapping on the scale of 1: 250,000 on the Thai side of the Langkawi-Tarutao area was started by Tansuwan *et al.* (1985). They published a regional geological map of the Changwat Satun sheet (NB47-7) at scale 1:250,000. They mentioned that the rock units in Tarutao Island and adjacent areas were subdivided into two units; the Cambrian Tarutao Group and Ordovician Thung Song Group. They also presented that the rock units in Adang-Rawi Islands are classified as Triassic granite and roof pendants of the Carboniferous-Permian Kaeng Krachan Group.

The systematic geological mapping on the scale of 1: 50,000 in Ko Tarutao (4922 II) sheet was done by Tansathien *et al.* (1999). They subdivided the succession of Tarutao Island into 5 units, namely, in ascending order, Tarutao Group, Thung Song Group, Colluvium deposits, Mangrove deposits, and Beach deposits**.**

The systematic geological mapping on the scale of 1: 50,000 in Ban Ko Adang (4822 II) Quadrangles was done by Tiyapairat *et al.* (2005). They subdivided the rock unit of Adang, Rawi, Batueng, Lipe and other islands into 4 units, namely: Triassic granite, Laem Mai Phai Formation, colluvium and beach deposits.

Kobayashi (1957) firstly discovered the Cambrian fossils from gently easterly dipping sandstone beds at Tarutao Island, where some Late Cambrian trilobites and brachiopods were described. An additional list of Cambrian fossils was given by Buravas (1961).

Javanaphet, (1969) introduced the Tarutao Formation to represent the sandstone sequence at Tarutao Island and correlated this rock unit with unfossiliferous Cambrian rocks distributed in the northern and western mountains of Thailand.

Bunopas (1974a) presented the first reconnaissance geological map of Tarutao Island and a possible northward extension of the Cambro-Ordovician rocks from this area to the mainland in the north.

Bunopas *et al.* (1980) also presented the geological sketch maps and some descriptions of the lower Paleozoic which shows three subdivisions for the Tarutao and Thung Song Formations. They also reported that these rocks were folded into a series of north-

northeasterly anticlines and synclines, and to a smaller degree into a series of northwesterly minor and less significant anticlines and synclines. The structural features are less common and are developed in the rocks at Tarutao Island.

Teraoka *et al.* (1982) carried out the studies of the Lower Paleozoic Formations of Tarutao Island. They divided the Tarutao Formation into 4 members, namely, in ascending order; T1, T2, T3, and T4, and the Thung Song Formation into 5 members, namely, in ascending order; S1, S2, S3, S4, and S5. Sketch geological map and composite stratigraphic column were also recorded. They also investigated the details of bedding, thickness, sedimentary structures, fossil assemblages, paleocurrent, petrography of rock units, and made correlation with the rock units in Langkawi, Malaysia.

Wongwanich *et al.* (1983) and Wongwanich (1990) subdivided the Thung Song Formation into seven members displaying a gradual deepening of the depositional environment from peritidal to open subtidal. The members, in ascending order, include Malaka, Talo Dang, La Nga, Panan, Lae Tong, Rang Nok and Pa Kae. He also studied the details of paleontology and age, petrography, micro facies, diagenesis of the formation.

Burrett and stait (1985) examined the Ordovician fauna in a paleobiogeographic context. The conclusion of this paper suggests that Tarutao Island was located adjacent to northern Australia during the Early Paleozoic.

Akarman (1986) studied the lithostratigraphy of the lower Paleozoic Tarutao Formation in Tarutao Island. He divided the formation into 3 members, namely, in ascending order, TF1, TF2 and TF3, and reported distribution of them on sketch geological map. He also studied the structure, fossil assemblages and depositional setting of this formation.

Mason (1986) studied the lithostratigraphy, sedimentology and structure of the Lower Paleozoic Thung Song limestone in Tarutao Island. He subdivided the formation into 7 units, namely, TS-1, TS-2, TS-3, TS-4, TS-5, TS-6, and TS-7, and reported distribution of them on sketch geological map. He also studied the structure, lithofacies, depositional setting, biostratigraphy and paleogeography of this formation.

Wongwanich *et al.* (1990) introduced the Tarutao and Thung Song Groups. He also summarized the stratigraphy, fossil assemblages and depositional environments of rock units in Tarutao Island. Structural geology of Tarutao Island was reviewed.

2.4. Geological Setting (Thai Side)

The oldest rocks is situated in the western part of the Malaysia-Thailand border area i.e. in Kedah State, Malaysia and in Satun Province, Thailand. The Cambrian–Ordovician Machinchang/Tarutao Group consists of well-bedded, brown to reddish brown as well as grey sandstones and minor interbedded shales. There are a lot of fossils such as trilobites (*Parakoldinioidia thaiensis* and *Eosaukia buravasi*) and brachiopods which indicate Late Cambrian- Early Ordovician age especially in the Thai side.

The Thung Song Group which is conformably overlying the Tarutao Group, consists of thin- to medium-bedded, argillaceous limestones, laminated limestones with intercalations of fine argillaceous bands and medium- to very thick -bedded dolomites, sparitic limestones with stylolite and thinly-bedded calcareous shales. Gastropods, nautiloids, polyplacophorans, monoplacophorans, trilobites, brachiopods bivalves, echinoderm

fragments are observed in this group. Based on fossil content, the rock unit in Thailand is Early to Middle Ordovician in age, whilst in Malaysia, palaeontological evidence indicates it is of Ordovician to Silurian age.

The Silurian–Devonian sedimentary rocks sequence are widely distributed in the central and western parts of the Malaysia-Thailand border. The Silurian-Devonian Kroh/Betong Formation consists mainly of very thin- to thinly-bedded shale, siltstone, slate, phyllite, lithic sandstone with subordinate chert and argillaceous limestone lenses in the middle to upper part. Many fossils such as *Tentaculites elegans, Tentaculites* sp. and graptolite occur in the shale and slate strata. Some interesting radiolarian assemblages occur in the chert.

The Silurian–Devonian Pa Samed Formation is exposed only in the Thai side. It comprises grey to light grey, massive to thin-bedded mudstone, chert and siliceous mudstone. Lithologically and palaeontologically, the upper part of the Pa Samed Formation is well correlatable with the Jentik Formation on the Malaysian side.

The Devonian succession is represented by the Jentik Formation, well exposed at Kampung Guar Jentik in central Perlis. It forms a condensed sequence representing a transitional sequence between the underlying Setul Formation and the overlying Rebak Formation. It comprises sequence of carbonaceous argillite, light coloured areno-argilite and red mudstone, and shale in ascending order. Fossil assemblages discovered in this rock unit imply the Devonian age. The Jentik Formation is well correlatable with the upper part of the Silurian–Devonian Pa Samed Formation of Thailand.

The Carboniferous succession is generally observed in the central and western parts of the Malaysia-Thailand border i.e. from Perlis/Kedah to Perak in Malaysia and from Satun to Yala Provinces in Thailand. In Western Perlis and Satun areas, the Carboniferaous succession is represented by the Rebak/Khuan Klang Formation. It consists of light grey, brown to reddish brown, thickly-bedded, laminated, fine- to very coarse-grained, mudstone intercalated with sandstone, poorly sorted conglomeratic sandstone and pebbly mudstone. It is assigned as Carboniferous in age based on the presence of abundant bivalves, trilobites, brachiopod, gastropod, and crinoid fossils. In Eastern Perlis-Kedah-Perak and Songkhla-Yala areas, the Carboniferous succession is represented by the Kubang Pasu/Yaha Formation. It consists predominantly of medium- to thickly-bedded areno-argilite sequence, consisting of light grey medium- to coarse-grained lithic sandstone with lesser amounts of shale. The sandstone is well sorted, well-cemented, medium- to very thick-bedded, and interbedded with light grey to yellowish brown shale, mudstone and radiolarian chert. Minor amounts of light grey to yellowish brown conglomerate is also present. *Posidonomya* (bivalve) is commonly found, followed by trilobites and radiolarians. In Perak area, the rocks of the Kubang Pasu Formation was metamorphosed due the granitic intrusion during the Triassic.

The Carboniferous Tiang/Ban Sa formation which are consist mainly of medium- to thickly-banded para-gneiss, augen gneiss with subordinate amphibolites schist, schist and hornfels. The high-grade regional metamorphism (amphibolite facies) is obviously recognised by the prograde of amphibole mineral group in terms of petrography. Tiang/Ban Sa formation only exposed on the Thai side.

Permian succession occurs in two geological terrains i.e. the cratonic area in the western and central part of the Malaysia-Thailand border and in the suture area in the eastern part. The Lubok Sireh/Khao Phra Formation consists of thickly- to very thickly-bedded, obviously laminated, sequence of dark grey, mudstone, shale, siltstone and pebbly mudstone. It grades upward into interbedded of thin- to medium-bedded sandstone and black shale, and mudstone. The sandstone is usually coarse-grained, poorly sorted, subrounded with poorly cemented pebbles of quarts, sandstone and shale. Bivalves, trilobites, brachiopod, gastropod and crinoid are present in abundance. Dropstone of glacial marine origin are present in parts. The presence of brachiopods i.e. *Spinomartinia* and *Brandoproductus* imply the Sakmarian (Early Permian) age to this rock unit.

In Thailand, the Kaeng Krachan Group comprises interbedding between dark grey to dark greenish grey slaty shales, mudstones and sandstones in the lower part, and white, medium- to thick-bedded, fine- to medium-grained, quartzitic sandstones with minor mudstones in occur the upper part. Based on lithology, the rock unit can be divided into two formations known as Khao Phra Formation and Khao Chao Formation. The Khao Phra Formation can be correlated with the Singa Formation in Langkawi Islands. The age of this rock unit which is deduced from stratigraphic correlation is supposed to be Early Permian.

The Sri Paen formation which is exposed only on the Thai side, comprising predominantly thin- to medium-bedded argillaceous limestone, shale, siltstone and chert with minor sandstone in the upper to middle part. Some successions are locally deformed and metamorphosed to phyllitic shale, schist and calc-silicate. The fossil assemblages, i.e. bivalves and brachiopods in siltstone strata, radiolarian assemblage in siliceous beds and brachiopod fragments indicates that the Sri Paen formation is Early Permian in age.

The Tham Krachaeng formation, also only exposed on the Thai side, is mostly consists of thickly-bedded to massive recrystallized limestone and marble with the presence of chert nodules. The thickness of the formation is indetermined. The occurrences of fusulinids in limestone layers revealed that the age of the Tham Krachaeng formation is Middle Permian.

The Mangga/Ka lu Bi formation is composed mainly of thin- to thickly-bedded, tuffaceous sandstones, quartzite, and metaconglomerates in the lower part. The upper part of the formation consists of cycles of thin- to medium-bedded shales, sandstones and conglomerates. Locallised deformation and low-grade metamorphism took place in the shear and contact zones resulting in the metamorphism of the original rocks to slate, phyllite, phyllitic shale and spotted slate. Radiolarian fauna discovered within the siliceous shale of the Mangga/Ka lu Bi formation on the Malaysian side indicates Permian age.

The Gerik formation distributed in the middle part of the Malaysia-Thailand border area, comprises predominantly pyroclatics rock with lenses of impure limestone. Trilobites and brachiopods discovered within the impure limestone gives Permian age to the rock unit. The Permian carbonate known as Jong formation expose only in Langkawi Islands on the Malaysian side, in the western part of the Malaysia-Thailand border area.

The Permian-Triassic succession is distributed in two geological terrains i.e. the cratonic area at the western and central part, and in the suture area at the eastern part of the Malaysia-Thailand border area. On the Malaysian side, it is represented by the Chuping Foramtion. It is divided into three members in ascending order; Chondong member, Panji member and

Keteri member. The clastic Panji member and carbonate Chondong member was deposited simultaneously with the Khao Rub Chang formation in Thailand, while Keteri member is corelatable with the Chaiburi Formation.

Exposed only on the Thai side, the Permian-Triassic succession of the Ai Ba Lo formation consists mainly of sharp, even, thin-bedded cherts with recrystalized radiolaria intercalated with thin shale beds and subordinate amounts of volcaniclastic sediments.

The Triassic succession is generally observed at the central and eastern parts of the Malaysia-Thailand border area. It consistsnof submarine fanglomerate of Bu Yong formation, exposed only on the Thai side. The sequence is made up of massive to thick-bedded conglomerates and conglomeratic sandstones, showing both matrix- and clast-supported types. Clasts are made up of sandstones, quartz, cherts, and volcanic rocks.

The Lampang Group consists of rhythmic alternation of sandstone and shale or mudstone in the lower part. The middle part is composed predominantly of conglomerate, sandstone interbedded with mudstone and shale which shows obvious cycles of fining upwards sequence. The upper part generally consists of pale grey, massive, oolitic limestones. The presence of the Triassic bivalve *Daonella* sp., *Halobia* sp., *Posidonia* sp. and ammonites in the lower and middle parts and Middle to Late Triassic foraminifera including *Malayspirina* cf. *fontainei* (Vachard) in the upper limestone indicates late Anisian to middle Norian age (late Middle to Late Triassic). It is correlatable with the Permian-Triassic of the Semanggol Group on the Malaysia side.

The Cretaceous red beds are located in the middle and eastern parts of the Malaysia-Thailand border area. The Cretaceous Kayu Hitam formation/Lam Thap Formation comprises reddish brown, thickly bedded, cross-bedded, well sorted, sub rounded, well cemented arkosic and lithic sandstones, siltstone, mudstone and conglomerate beds. The Cretaceous Saiong/Phun Phin formation consists of reddish clast-supported conglomerate with cycles of fining upwards sequences consisting of orthoconglomerate grading into paraconglomerate and then grading further into conglomeratic sandstone. Conglomerate, the dominant rock type in the formation, consists predominantly of semi-consolidated subangular to subrounded, multi-coloured (dominantly red) clasts sediments.

The Cretaceous Berapit Formation, Tan Hain formation and Panau Formation expose only on the Malaysia side. They were deposited in several isolated basins in Pengkalan Hulu area, Belum area, Upper Perak, and in Tanah Merah area, Kelantan.

The NeogeneArang/Sadao formation in Kedah/Songkhla area, consists of mudstone, siltstone and sandstone with minor occurences of conglomerate and occasional thin coal seams. The rocks are greyish brown to brown, thin- to medium-bedded, with plant fossils and freshwater gastropods. Thin coal seams occur occasionally.

The Quaternary deposits composed of the Pliestocene terrestrial deposits, and Holocene terrestrial and marine deposits. The Pleistocene Talo U Dang formation exposes in Tarutao Island. The Simpang Formation/Padangbesar formation exposes in Perlis/Satun areas, Bukit Tangga/Hat Yai Formation exposes in Kedah/Songkhla areas, and Nenering beds/Ai Yoe Boe Chang Gravel Beds exposes in Perak/Yala areas. The Gual Periok/Waeng formation, exposes in Kelantan/Narathiwat area, is a former flood plain/colluvium deposits

covering low lying areas. It consists of clay, silt and sand with some granules, and pebbles with the presence of iron concretions; red to reddish brown in colour.

The Pleistocene Hat Yai formation occupies high undulating terrains. It is made up of semiconsolidated deposits consisting of sand, gravel and boulder; light brown to reddish brown in colour. The Pleistocene gravel beds of Ai Yoe Boe Chang sediments are forming small hills around Betong District. They are composed of gravel, sand, silt, and laterite with abundant iron concretions. The size of the pebbles in the gravel beds is decreasing westwards, towards the Betong town.

The Holocene deposits comprises the marine Gula Formation/Tam Malang formation and terrestrial Nyior Chabang formation in Langkawi/Tarutao areas, marine Gula Formation/Tam Malang formation and terrestrial Beruas Formation/Chalun formation in Perlis/Satun areas, terrestrial Beruas Formation/Sungai Kolok formation in Kedah/Songkhla, Perak/Yala and Suture areas, and terrestrial Pasir Mas/Sungai Kolok formation and marine Pengkalan Kubor/Tak Bai formation in Kelantan/Narathiwat areas.

Volcanic rocks are distributed in the eastern part of the the Malaysia-Thailand border area. The Ku Mung Ophiolite Suite exposes in Ku Mung area on the Thai side. It comprises pillow lava basalt, serpentinite, relicts of ultramafic and mafic rocks. The Perdah/Muno Volcanic exposes in Jeram Perdah area, Kelantan on the Malaysian side and in Muno area, Narathiwat Province on the Thai side. It comprises mainly of pyroclastics with highly altered andesite andesitic tuff and agglomerate. Tanah Merah andesite is well-exposed in Tanah Merah area, Kelantan. It comprises predominantly of andesite flow. Temangan Ignimbrite distributed in Temangan area, Kelantan. It comprises mainly of massive ignimbrite with minor flow structure.

Granitic rocks are widely distributed in the western to eastern part of the Malaysia-Thailand border. These granitic rocks can be divided into two provinces which are separately by the Bentong-Raub Suture Zone in Malaysia and extended northwardly into the Thailand where it is known by Nan-Uttaradit Suture ZoneThese provinces named as Western Province Granite in Malaysia/Central Belt in Thailand and Eastern Province Granite in Malaysia/Eastern Belt in Thailand which is located within the western and eastern part of the Malaysia-Thailand border, respectively. On the Malaysian side, the granitic rocks expose predominantly in central and southeastern Langkawi Islands, northernmost Perlis, northern and northeastern Kedah, northeastern Perak and northwestern Kelantan.

The Western Province Granite in Malaysia/Central Belt in Thailand can be divided into seven major granitic bodies; namely from west to the east: Adang-Rawi Pluton, Langkawi Pluton, Bukit China /Khao Chin granite, Koh Mai Granite/Khuan Mai Pai granite, Rimba Telui/Si Nakhon Pluton and Belum-Hala pluton and Chantarat Granite. Whereas, the granitic rocks in Eastern Province Granite in Malaysia/Eastern Belt in Thailand is distributed mostly in Batu-Melintang-Sungai Kolok area. In this province, the rock can be divided into three major granitic bodies; namely from west to the east; Cretaceous Pluton, Kemahang /Sukhirin Granite and Boundary Range Granite. Generally, all the granitic body as mention above are Triassic in age accept the Cretaceous Pluton is Cretaceous in age.

Structurally, the Paleozoic succession in Batu Melintang-Sungai Kolok area is characterised by tightly folded isoclinal folds, especially in the Silurian-Devonian succession. The Triassic sequence normally exhibits open fold. Strike-slip, normal, reverse

and thrust faults are conspicuous with three main N-S, NW-SE and NE-SW directions. In Pengkalan Hulu-Betong area, the strata of the Palaeozoic succession are strongly folded (isoclinal folds) and, deformed producing repeated sequence, especially near the igneous pluton. The normal and strike-slip faults are conspicuous with three main N-S, NW-SE and NESW strike directions especially in the western part of the Bang Lang Dam site.

Generally, folds in the Ordovician – Devonian sedimentary and metamorphic successions in Bukit Batu Puteh-Satun area is striking in N-S direction, whilst folds in the Upper Palaeozoic rock sequence generally striking N-S. The strike-slip, normal, reverse, and thrust faults are trending in N-S, NW-SE and NE-SW directions. The Belum-Hala area had experienced series of deformations as shown byseries of faults and folds throughout the area. Most of the major faults interpreted from air-photographs and satellite imageries are generally NW-SE and NNE-SSW trending. Beddings are generally N-S striking with dominant eastwardly dipping. Folds can be observed locally.

In the Langkawi-Tarutao and adjacent areas, the sedimentary strata were openly folded forming a series of northwesterly plunging asymmetric anticlines and synclines with easterly dipping axial planes. The easterly dipping strata are much less tilted than the westerly dipping strata. Moderate to steep normal and reversed faults are almost parallel to the fold axes. Smaller scale transverse faults offset these major fold axes in places. The rocks are only slightly deformed and the folded cleavages are weakly developed in the less competent beds forming wavy beds especially in limestone sequences in the eastern of the island. The whole sequence was also intruded by the granites.

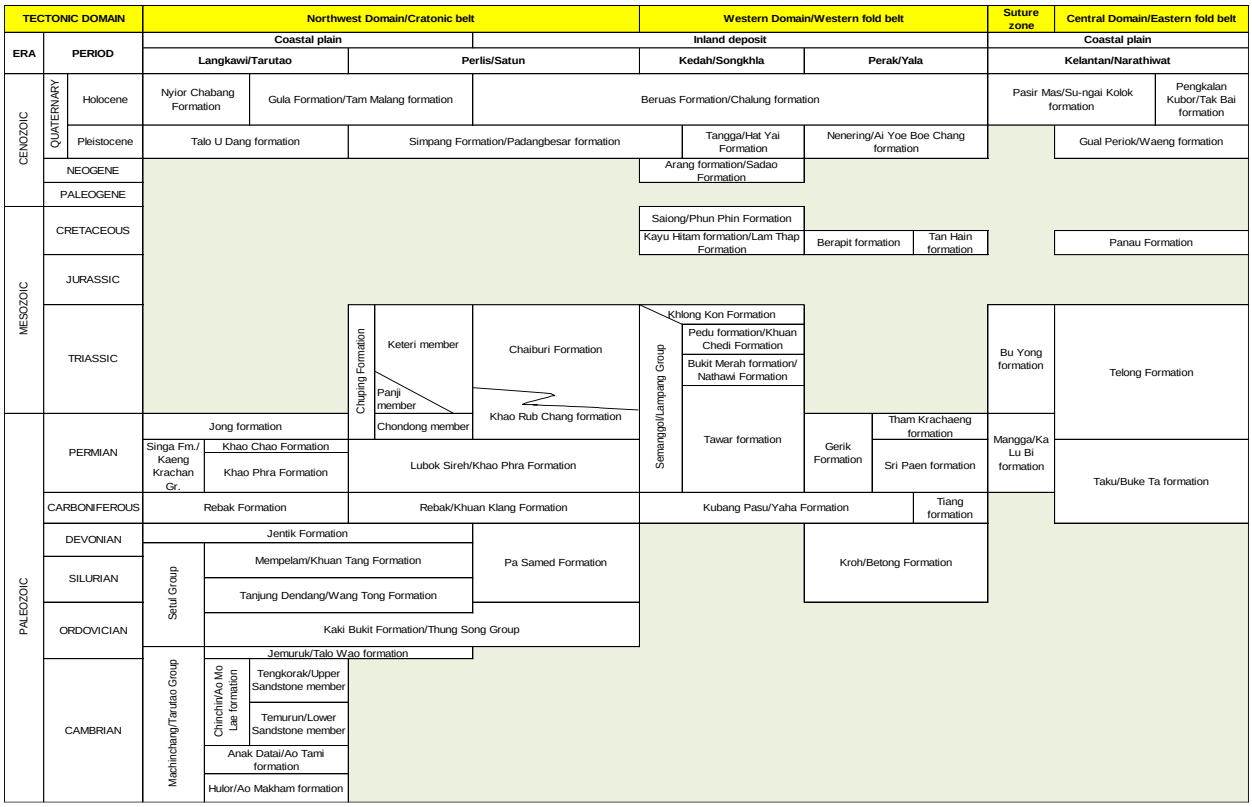

Figure 6: Stratigraphic column of formation in the study area.

3. GEOHERITAGE SITES POTENTIAL FOR GEOTOURISM (MALAYSIAN SIDE)

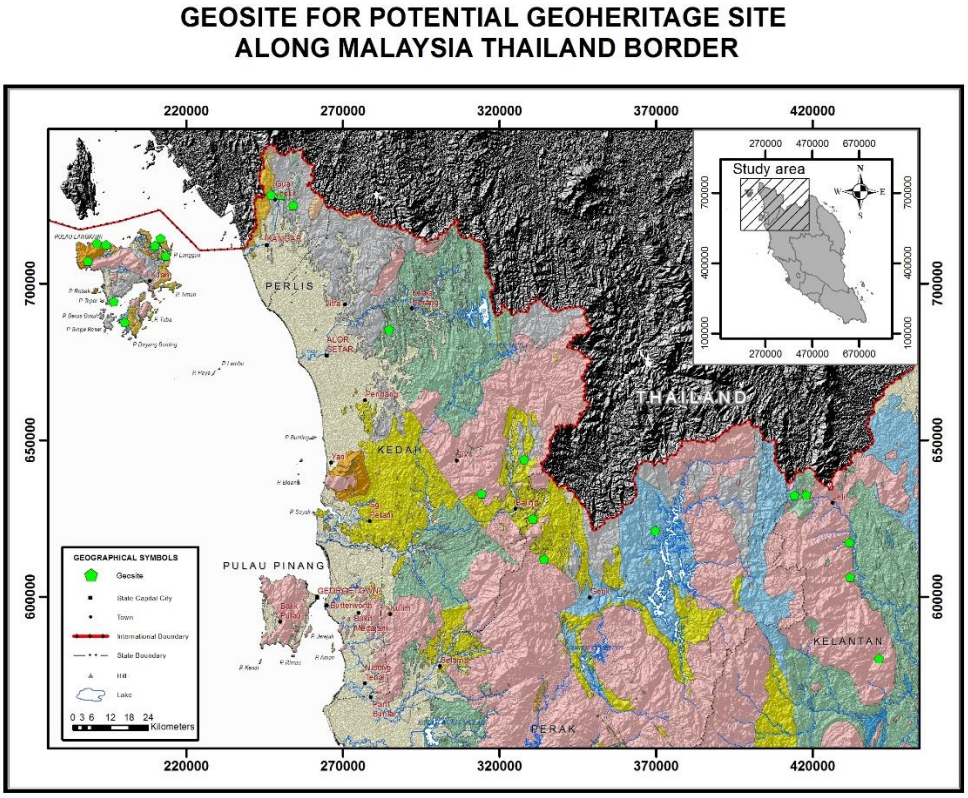

Figure 7: Map with location of potential geoheritage sites for Malaysian side.

3.1 KEDAH

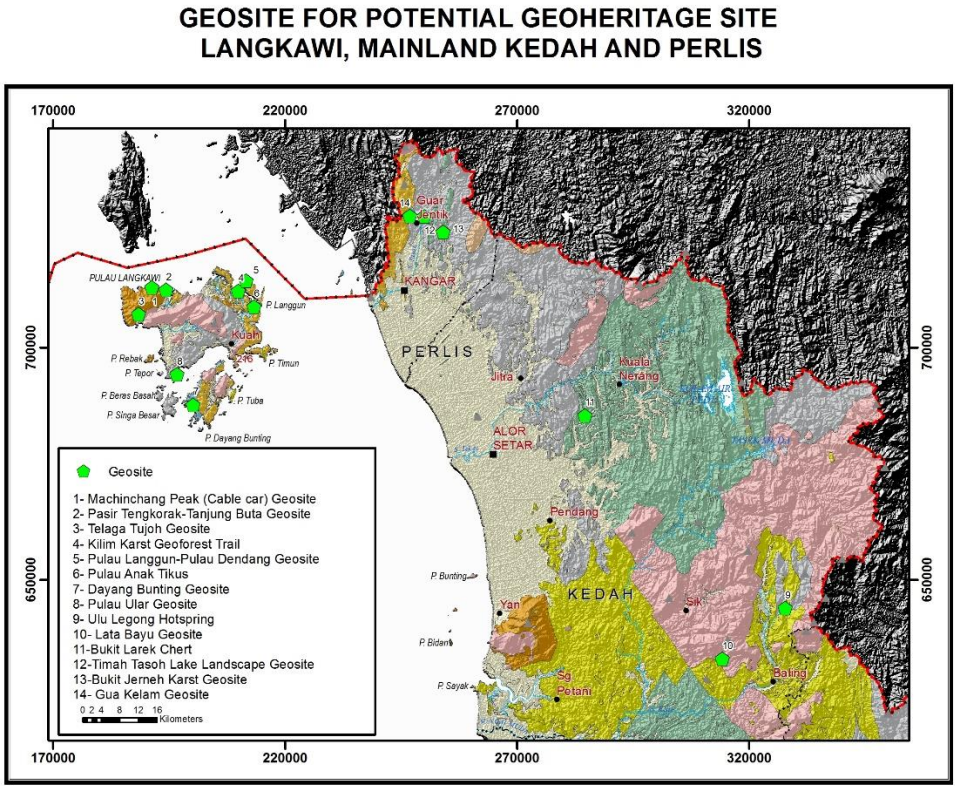

Figure 8: Map with location of potential geoheritage sites in Kedah.

3.1.1 LANGKAWI ISLANDS

General geology of Langkawi Islands

Geology of Langkawi Islands range from Cambrian Machinchang Formation (550 million years ago) to Perm-Triassic Chuping Formation (200-300 million years ago). The mountainous topography at the northwest part of this island was built up by sedimentary rocks and granite with presence of metasedimentary rocks within the proximity of the intrusion. Marble, which is the result of contact metamorphism is restricted in occurrence. The Ordovician limestone formation formed karst and islands topography in the north-eastern part. Younger Chuping Formation spreads at the southern part of Langkawi Islands. Fossils are diverse and abundance across the islands which provide good stratigraphic control for some sections.

3.1.1.1 Machinchang Peak (Cable Car) Geosite

Geographical Information: N 06° 23.158’ E 99° 39.740’
Location: Jalan Telaga Tujuh, Pulau Langkawi, Kedah.

Geological Information: Gunung Machinchang is located in the northwest side of Langkawi Island. Gunung Machinchang is the oldest mountain in Peninsular Malaysia Late Cambrian to Early Ordovician (450 million years – 510 million years ago). This formation has been deposited in deltaic up to shallow marine environments. Machinchang Formation is made up of mainly sandstone with subordinate amount of shale, siltstone, and conglomerate. Fossil distribution is restricted to the top of this formation. Landscape of Machinchang formed multi peaks ridge. The mountain is standing high at 708 metres above mean sea level.

Geological diversity:
Rock diversity: Massive size of cross-bed of thick bedded sandstone that can be seen above the mountain.
Fossil diversity: Late Cambrian trilobites and brachiopods occurred with trace fossils, which dominated the assemblages.
Structure diversity: Sedimentary structures

Heritage value:
Scientific value: The oldest rock formation in Malaysia.
Cultural value: The myth Mat Chinchang etc.
Aesthetic value: Look out point at the top of Gunung Machinchang.

Special features: The majestic blue vast Andaman Sea can be viewed from the platform at the Machinchang's peak. The occurrence of an outcrop with well-preserved sequence of topmost of Machinchang Formation and sedimentary structures (ripple mark, cross bedding).

Accessibility: Cable-car trail. Machinchang Trail also offers walking trail which covers short walk into the forest which is the habitat of several rare species of mountain plants and animals.

Status of conservation and development: Located in the Machinchang Reserve Forest.

Function: Recreational and education.

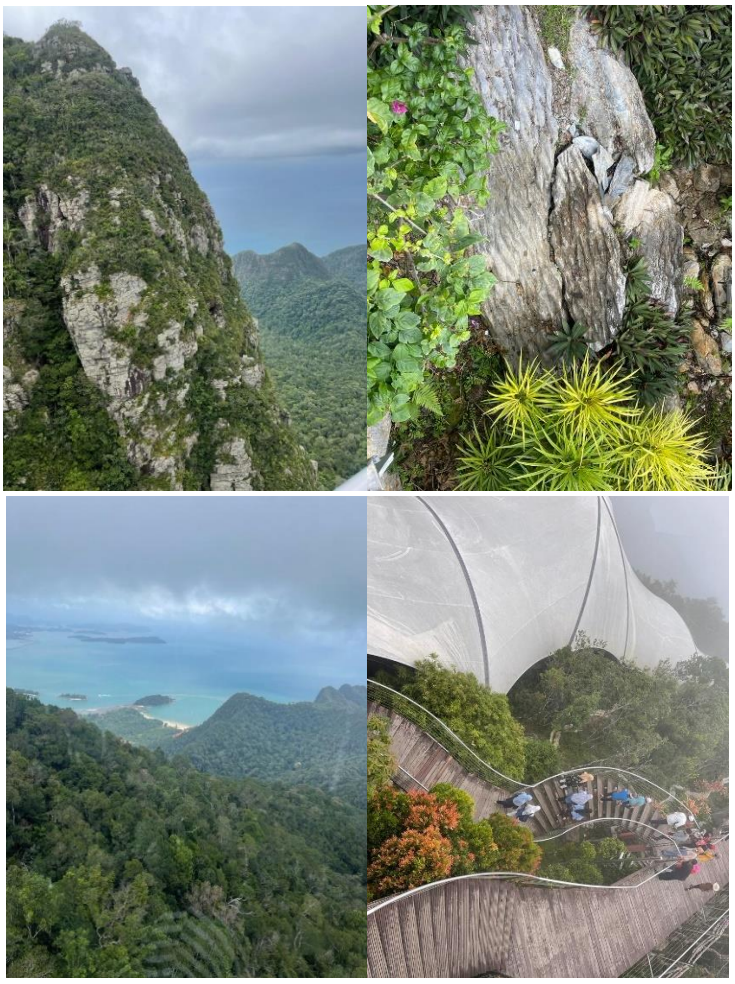

Figure 9: (Top left) Thick-bedded sandstone of Machinchang Formation is exposed at Gunung Machinchang; (Top right) Ripple mark structure can be observed at the top of the mountain; (Bottom left) Andaman Sea from the peak; (Bottom Right) Cable Car Station at the peak of Gunung Machinchang..

3.1.1.2 Pasir Tengkorak- Tanjung Buta Geosite

Geographical Information: N 06° 25.869’ E 099° 43.687’
Location: Jalan Datai, Pulau Langkawi, Kedah.

Geological Information: The exposed rock outcrop in Pantai Pasir Tengkorak consists of the interbedded of shale and sandstone of the upper part of Machinchang Formation. The rocks are a part of Chinchin members, and the beds are known as the Tengkorak beds. The outcrop in this area is trending (strike/dip) 10°/10°towards NW. The outstanding sedimentary structures observed at this geosite had suggested the depositional environment for Machinchang Formation.

Geological diversity:
Rock diversity: The lithology consists of a very thick light-coloured, whitish to orangish sandstone beds, with some dark mineral bands, followed by a greyish to brownish mudstone body.
Structure diversity: Syn-sedimentary structures such as load cast structure, flame structure, and ‘ball and pillow’ structure. Tafoni and fractures of secondary structures.

Heritage value:
Scientific value: Shallow marine sedimentary sequences with various sedimentary structures.
Cultural value: The story of Pasir Tengkorak
Aesthetic value: Beautiful sandy and rocky features.
Recreational value: Picnic and beach recreational spot.

Special features: This geosite is occasionally rich in significant fossil assemblages; Late Cambrian saukiid trilobites and orthid brachiopods.

Accessibility: This 1.5 kilometer trail on rocky coast and 600 meter of jungle and mangrove trail.

Status of conservation and developement: Machinchang Reserve Forest.

Function: Recreational, scientific

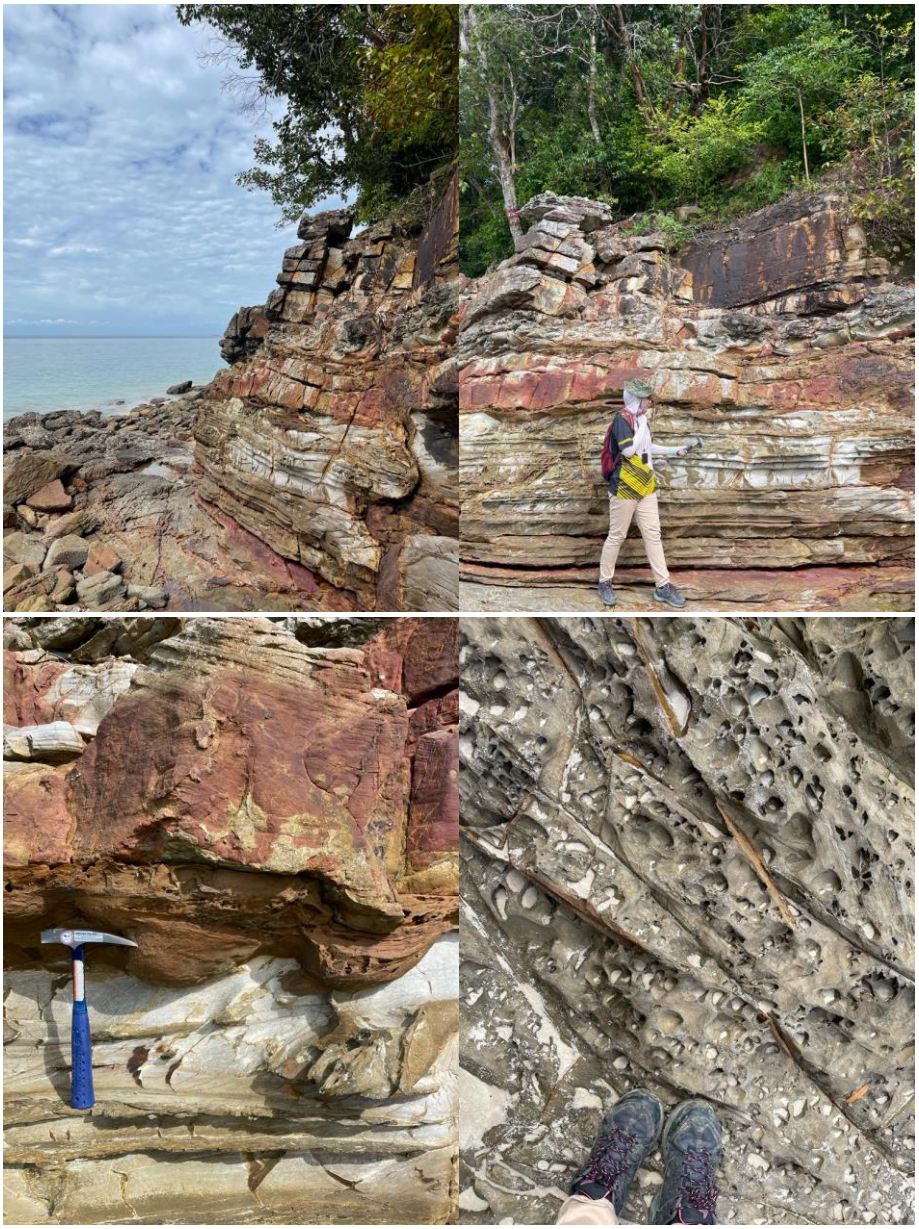

Figure 10: (Top) Well-bedded of Machinchang Formation exposes at Pantai Pasir Tengkorak. (Bottom left) Load cast structure. (Bottom right) Tafoni on the surface of the outcrop.

3.1.1.3 Telaga Tujoh Geosite

Geographical Information: N 6° 22’ 59.423’’ E 99° 40’ 27.027’’
Location: Jalan Telaga Tujuh, Pulau Langkawi, Kedah.

Geological Information: This geosite consists of massive phaneritic granite with large size phenocryst (3 cm to 8 cm) and dominated by feldspar mineral. The large grain and crystal sizes indicate a slow

magma cooling process. The pothole structures around this geosite seven of huge in size were formed due to whirling cobbles and pebbles that are trapped in grooves on the river floor. The rapid river flow forces the rock to spin and erode the grooves until becoming potholes. The Telaga Tujuh waterfall preserves the evidence of Gunung Raya granitic intrusion on the Machinchang formation. The river flows from the top of a granitic body and carries sedimentary rocks along (cobbles and pebbles).

Geological diversity:
Rock diversity: Quartzite and granite.
Geomorphology diversity: There are two distinctive levels of waterfall flows from Sungai Perangin, the highest waterfall is 30 metres. There is a viewing platform on the top of waterfall which can overlook the cable car and Gunung Machinchang.
*Structure diversity***:** Potholes. Fault and fractures.

Heritage value:
Scientific value: Contact between Machinchang Formation and Gunung Raya granite.
Cultural value: The infamous legend of seven princesses.
Aesthetic value: Scenic waterfall and natural gigantic pools.
Recreational value: Picnic and river recreational spot.

Special features: Telaga Tujoh had gotten its name from the occurrence of numbers of potholes varying in size around this waterfall, Telaga Tujuh can be translated as Seven Wells (potholes). These potholes were formed by abrasion process of the granite body.

Accessibility: Accessible via well pathed road. Basic infrastructure is available at the foothill (entrance).

Status of conservation and development: Machinchang Reserve Forest.

Function: Recreational

Figure 11: (Left) View of Machinchang Cable Car from Telaga Tujoh Waterfall. (Right) Massive potholes become the natural pool and attraction at Telaga Tujoh.

3.1.1.4 Sungai Kilim Karst Geosite

Geographical Information: N 6° 22’ 59.423’’ E 99° 40’ 27.027’’
Location: Mukim Kampung Kilim, Pulau Langkawi, Kedah.

Geological Information: This geotrail is characterised by a magnificient karst landscape of hills with rugged topography, islands and caves was formed by the oldest limestone formation in Malaysia, known as Setul Formation which is Ordovician – Devonian (505 million years to 309 million years ago. This limestone which has been deposited in shallow marine (neritic) settings later exposed to the surface as seen recent days. Rugged topography was formed due to prolonged differential erosion and the caves were formed due to geological process of weathering and sea level changes. Mangrove ecosystem spreads across this geotrail is the habitat of important flora and fauna. This geotrail consists of Gua Kelawar, Gua Langsir, and Gua Buaya and fauna sighting of many species of eagles and bats. Gua Kelawar consists of two main chambers, with the eastern cave is the larger. Both caves have openings facing south and north and rich with cave features like stalactite, stalagmite, flowstone, and rim pools. Gua Langsir meanwhile, has a small underground tunnel that connects a large lake to the sea and rich in fossils. It has a lake which formed by a doline filled by saline water and surrounded by vertical limestone cliff. Ancient encrusting oysters and barnacles 110 years old were found attached on the cave wall and roof, showing the sea level during time of deposition was two meter higher than the present day. Gua Buaya Geosite is a natural tunnel

developed in limestone formation that turns into a cave with ascending chamber flanked by walls of limestone with minimal stalactites and stalagmites. Ancient shells of rock oysters were soon sticking on the wall and roof of the cave at a few meters above the present day highest tidal level. The tunnel in Gua Buaya was developed by an underground stream that once flowed in the area during low sea-level.

Geological diversity:
Rock diversity: Limestone.
Fossil diversity: Gastropods, bivalves, corals and crinoids
Geomorphology diversity: Cave, pinnacles, doline, lake and islands.

Heritage value:
Scientific value: The oldest limestone formation in Malaysia.
Cultural value: -
Aesthetic value: Karst landscape.
Recreational value: Boat tour trip for landscape sightseeing.

Special features: The outstanding limestone karsts (pinnacles) is the landmark of Kilim Geoforest Park.

Accessibility: Access via boat ride from Kilim Jetty.

Status of conservation: Kilim Geoforest Park.

Function: Recreational, scientific.

Figure 12: (Top Left) Island in Kilim Geoforest Park formed by limestone formation. (Top Right) The peak of limestone hill formed 'Gorilla' like structure. (Bottom Left) Formation in Gua Kelawar. (Bottom Right) Entrance to Kilim Geoforest Park is filled with mangrove plants.

3.1.1.5 Langgun Karst Geosite

Geographical Information: N 6° 27.03 E 99° 53.07
Location: Mukim Kilim, Pulau Langkawi, Kedah.
Geological Information: This geosite is consisted of Pulau Langgun, and Pulau Tanjung Dendang. Type section of Setul Formation such as abrasion platform and sea notch are exposed at Teluk Mempelam, Pulau Langgun alongside with the detrital member of Setul Formation and the highly fossiliferous redbeds. In addition, Tasik Langgun which is the second largest fresh water lake in Langkawi that occurs within the Lower Limestone Member of Setul Formation exists in Pulau Langgun. The lake is positioned along a major fault that cut across Pulau Langgun and was part of a bowl-shaped depression called sinkhole or doline that were formed when water dissolves the limestone walls. Teluk China Mati which located on Pulau Tanjung Dendang (an elongated island which orients in roughly N-S direction, with older Setul Limestone on the northern part and Lower Silurian age Setul limestone on the southern part). These different sequence of limestone in the island are separated by a narrow belt of Lower Silurian detrital rocks that are exposed in Teluk China Mati. A wave cut notch, 23m above present sea level was developed at the base of a limestone cliff. Rock oysters were also found encrusting on hard rocks within the intertidal zone, and age around 7000 years old.

Geological diversity:
Rock diversity: Limestone, sandstone-siltstone, shale and red mudstone.
Fossil diversity: Gastropods, cephalopods, crinoids, corals, conodonts, bivalves and brachiopods.
Geomorphology diversity: Cave, islands, lake, abrasion platform and sea notch.

Heritage value:
Scientific value: Type section for Setul Limestone and the Langgun Redbeds.
Cultural value: -
Aesthetic value: The abrasion platform and sea stacks formed splendid beach landscape.
Recreational value: Picnic spot.

Special features: Pulau Langgun – Pulau Dendang Geosite possess an important scientific geosite due to the occurrence of well-preserved fossils, geological features, and sea-karst landscape.

Accessibility: Access via boat from Kilim Jetty and Tanjung Rhu Jetty.

Status of conservation and development: Kilim Karst Geoforest Park.

Function: Recreational and scientific.

Figure 13: (Top) Sea notch at Teluk Mempelam, Pulau Langgun.
(Below) Fosiliferous redbeds of Pulau Langgun.

3.1.1.6 Pulau Anak Tikus Fossil Geosite

Geographical Information: N 6° 24' 46.953", E 99° 54' 22.190"
Location: Mukim Kilim, Pulau Langkawi, Kedah.

Geological Information: Pulau Anak Tikus and part of Pulau Langgun is made up by dark coloured, moderately to thickly layered limestone of the Setul Formation's Lower Limestone Member of and is very rich in Ordovician (400 million years) fossils, particularly gastropod and cephalopod. Pulau Anak Tikus was formed due to prolonged erosion and solution along weaker zone on the neck of an ancient headland.

This geosite is characterised by a freshwater lake within an island that is surrounded by the ocean. The rocks formations at this geosite are the Ordovician- Silurian (450 mya to 400 mya) of Setul Formation and Permian-Triassic (300 mya to 200 mya) of Chuping Formation. This freshwater lake had been formed due to geological process, the dissolution of limestone bedrock of underground cave ceiling. The depth of this lake which occurred at the boundary of Setul and Chuping Formation is estimated to be 14 metres.

Geological diversity:
Rock diversity: Limestone
Fossil diversity: Gastropods and cephalopods.

Geomorphology diversity: Karst and island landscape.

Heritage value:
Scientific value: The existence of key Ordovician fossils in The Lower Setul Limestone particularly *Malayaspira rugosa*.
Cultural value: -
Aesthetic value: Karst island.
Recreational value:-

Special features: Pulau Anak Tikus Geosite is a well known place to learn about the Ordovician fossil assemblages occur in Lower Setul Limestone i.e: *Malayaspira rugosa*, *Teichispira kobayashii*, *Helicotoma jonesi*, *Palaeomphalus giganteus*, *Lesuerilla zonata* and *Hormotoma* sp.

Accessibility: Access via boat ride from Kilim Jetty and Tanjung Rhu Jetty.

Status of conservation and development: Part of Kilim Karst Geoforest Park.

Function: Scientific.

Figure 14: (Top) Pulau Anak Tikus. (Below) Gastropod fossils at Pulau Anak Tikus.

3.1.1.7 Dayang Bunting Geosite

Geographical Information: N 6 12' 28" , E 99 46' 58"
Location: Pulau Dayang Bunting, Pulau Langkawi, Kedah.

Geological Information: This geosite is characterised by a freshwater lake within an island that is surrounded by the ocean. The rocks formations at this geosite are the Ordovician- Silurian (450 mya to 400 mya) of Setul Formation and Permian-Triassic (300 mya to 200 mya) of Chuping Formation. This freshwater lake had been formed due to geological process, the dissolution of limestone bedrock of underground cave ceiling. The depth of this lake which occurred at the boundary of Setul and Chuping Formation is estimated to be 14 metres.

Geological diversity:
Rock diversity: Limestone
Structure diversity: Fault
Geomorphology diversity: Lake and doline.

Heritage value:
Scientific value: The contact between Setul and Jong Formations.
Cultural value: The myth pregnant maiden.
Aesthetic value: Lake landscape
Recreational value:

Special features: Apart from geological significance, this place is visited for its mystical element. Locals believe that by dipping or drinking water from this lake can increase women fertility which live up to its name; The Pregnant Maiden Lake (Tasik Dayang Bunting).

Accessibility: Access via boat ride from Kuah Jetty.

Status of conservation and development: Dayang Bunting Reserve Forest?

Function: Tasik Dayang Bunting which is popular for recreational activities is the largest freshwater lake in Langkawi.

Figure 15: (Top) The entrance to Dayang Bunting Marble Geoforest.
(Bottom) Landscape of limestone formation at Tasik Dayang Bunting.

3.1.1.8 Pulau Ular Geosite

Geographical Information: N 6° 15.595' , E 99° 44.524'
Location: Pulau Dayang Bunting, Pulau Langkawi, Kedah.

Geological Information: Pulau Ular Geosite is located to the northeast of Tasik Dayang Bunting and was formed due to the geological process of wave erosion. Pulau Ular lithology was made up by Ular Member of Singa Formation. This small island consists of multiple landforms of small-separated hills, broad abrasional platforms, rocky beach, coquina beach, and cave. The glacial dropstones which are observed at this geosite is significant in paleoenvironment history relating Langkawi to the cold Gondwanaland. This event had taken place during the most extensive glacial period in the history of earth.

Geological diversity:
Rock diversity: Sandstone, siltstone and pebbly mudstone.
Fossil diversity: Trace fossils indicating shallow marine environment occurred in abundance in this island.
Geomorphology diversity: Abrasional platforms, sea notches, rocky beach, coquina beach and cave.
Structure diversity: Beddings, cross laminations, quaternary fault, slumps, tafoni.

Heritage value:
Scientific value: The pebbly mudstone is the evidence of paleogeography of cold-water environment. Trace fossils -----
Cultural value: -
Aesthetic value: Island landscape and abrasion platform.
Recreational value:-

Special features: The occurrence of drop stones vary in types and sizes can be observed particularly from argillaceous lithology are important in understanding the palaeogeography of this region.

Accessibility: Access via boat ride from Kuah Jetty.

Status of conservation and development: LADA territory.

Function: Scientific (public education).

Figure 16: Abrasion platform at Pulau Ular.

Figure 17: (Left) Cross lamination structure. (Right) Drop stone in pebbly mudstone of Pulau Ular.

3.1.2 NORTHEAST OF KEDAH

General geology of Northeast Kedah

The oldest rock formation in this area is Ordovician-Silurian Kroh Formation which is the adjacent to North Perak. The limestone hills and caves around Baling Town including the infamous Baling Hill are mainly the calcareous facies of Kroh Formation. This formation is overlain by clastic rocks of Carboniferous Kubang Pasu Formation and Permian Gerik Formation. Late Triassic granite intrusion in this area resulted in mountainous topography. Major fault, Bok Bak cut across this area.

3.1.2.1 Ulu Legong Hotspring Geosite, Baling

Geographical Information: N 05° 49’ 00.986’’ , E 100° 56’ 08.72057’’
Location: Kampung Keda Ulu Legong, Baling, Kedah.

Geological Information: This geosite is located within metamorphosed Kroh Formation of Silurian – Devonian age (440 million years to 350 million years ago). The lithology consists of dominantly slate, pelitic hornfels and minor unit of sandstone. The contact of this formation and the granite body had occurred in the subsurface. Major fault, Bok Bak occurred at this geosite. These hot springs are located along a NNW-SSE direction which represents the main tectonic trend of the Peninsula.

Geological diversity:

Rock diversity: Dominantly slate, pelitic hornfels and minor unit of sandstone.
Structure diversity: Major fault and lineaments

Heritage value:
Scientific value: Contact between Kroh Formation and Bintang Granite.
Cultural value: -
Aesthetic value:-
Recreational value: Recreational destination for hot spring.

Special features: Several natural hot spring pools.

Accessibility: Well-developed amenities; there are chalet, restaurants and toilets nearby.

Status of conservation and development: Baling District Council territory. The geosite lies within FELCRA management, thus it is not conserved by any acts but has been developed as tourism site.

Function: Recreational.

Figure 18: Ulu Legong Hotspring had been developed by local authority as local tourist attraction.

3.1.1.1 Lata Bayu Geosite, Baling

Geographical Information: N 05° 43’ 05.071’’, E 100° 48’ 51.074’’
Location: Lata Bayu, Baling, Kedah.

Geological Information: This geosite is the exposed outcrop of Bintang Granite. The main rock observed with angular quartz crystallization. A vein striking 284 and 102 was observed cross cutting the main rock. The vein is slightly darker in colour. Evidence of conjugate faults from Bok Bak Major Fault is observed here. The direction of vein was similar to the direction of the conjugate fault. The rock has a smooth surface due to weathering from the flowing water. The upper side of the waterfall has a different rock type where the rocks are generally more pinkish, less quartz minerals, and many plagioclases due to visible holes on the rock

indicating a less resistant mineral. The upper rock however is much coarser than the previous one. Faulting predates the intrusion as fractures were filled with veins that are in similar orientation with the fault.

Geological diversity:
Rock diversity: Phaneritic granite
Structure diversity: Conjugate fault, fractures, and veins

Heritage value:
Scientific value: Conjugate faults of Bok Bak Fault
Cultural value: -
Aesthetic value: Scenic waterfall landscape
Recreational value: River recreation spot

Special features: Tall, multilevel waterfalls consist of Bintang Granite outcrop exhibits secondary structures that can clearly observed at this locality.

Accessibility: Travel via road. Basic amenities are provided and managed by Kedah Forestry Department.

Status of conservation and development: Rimba Teloi Reserve Forest. This geosite had been developed as recreational forest.

Function: Recreational.

Figure 19: Waterfall formed by Bintang Granite at Lata Bayu, Baling.

3.1.1.2 Bukit Larek Chert Geosite, Pokok Sena

Geographical Information: N 6° 22’ 59.42379’’ E 99° 40’ 27.02750’’
Location: Kampung Bukit Lapek, Pokok Sena, Kedah.

Geological Information: This geosite exposes light coloured, interbedded chert with siliceous shale, and highly fossiliferous outcrop. Chert beds two to 10 centimetres thick interbed with thinner siliceous shale layers (less than 1 centimeter). The chert bed is resistant to weathering thus it protrudes more than the shale layers. Folding was also observed in the outcrop, and on the left limb of the fold, the layers strike at 284 and dips at 50º. The pelagic chert is indicative of the Cherty Unit (previously the Chert Member of Semanggol Formation). Findings of radiolarian in the chert bed are consistent with the depositional environment of Cherty Unit at deep marine (open ocean environment, Basir & Zaiton 2007). Marker species of radiolarians had been extracted from this site indicating 290-230 million years ago (Early Permian).

Geological diversity:
Rock diversity: Chert and siliceous shale.
Fossil diversity: Biomarker radiolarians.
Structure diversity: Folds.

Heritage value:
Scientific value: Biomarker radiolarians indicating Early Permian of Cherty Unit.
Cultural value: -
Aesthetic value: -
Recreational value:-

Special features: The occurrence of biomarker radiolarians of Early Permian biozone.

Accessibility: Close to main road connecting Alor Setar- Kuala Nerang.

Status of conservation and development: Private owned.

Function: Scientific (education). This geosite is a locality for local geology university students. Knowledge-based tourism.

Figure 20: Interbedded of chert and siliceous shale at Bukit Larek, Pokok Sena.

3.2 PERLIS

General geology of Perlis

Geology of Perlis is mainly the extension of formations in Langkawi Islands with the oldest, dolomitic formation of Setul formed magnificient topography at the northern part function as border of Malaysia and Thailand. Younger and lighter grey limestone formation of PermoTriassic Chuping occurred mostly as isolated hills and sporadic throughout the southern part of Perlis. The dissolution process of limestone had formed the unique landscape of Perlis and made it suitable for paddy plantation. Abundance of fossil assemblages discovered from clastic deposits of Utan Aji, Jentik and Timah Tasoh Formation whilst occasional occurrence in Kubang Pasu Formation, mainly within the localised redbeds.

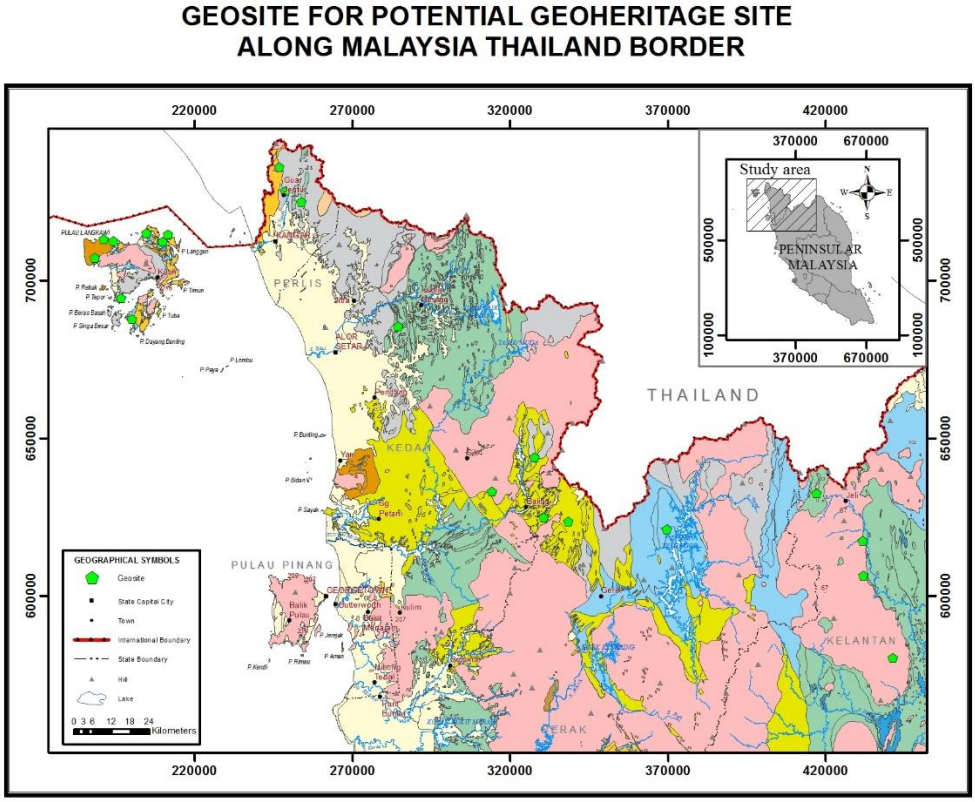

Figure 21: Map with location of potential geoheritage sites in Perlis, Malaysia.

3.2.1 Timah Tasoh Lake Landscape Geosite

Geographical Information: N 6° 34' 38" , E 100° 13' 52"
Location: Kampung Bukit Manek, Kangar, Perlis.

Geological Information: The geology of this geosite consists of Timah Tasoh Formation of Early Devonian to Early Carboniferous (420 million years to 350 million years ago). This clastic formation (calcareous sandstone and mudstone) had been deposited in shallow marine and cold environment. Palaeogeography of this geosite is interpreted to be at the near southern hemisphere, close to south pole.

Geological diversity:
Rock diversity: Calcareous sandstone and mudstone.
Fossil diversity: The discovery of the cold-water index fossil *Monodiexodina Shiptoni*, indicated Kungurian age.

Heritage value:
Scientific value: Passage bed of Kubang Pasu Formation and Chuping Formation.
Cultural value: -

Aesthetic value: Lake and mountainous landscape
Recreational value: Look out point. Camping and water sport activities.

Special features: Man-made lake landscape with the Setul Range in the background.

Accessibility: Access via road.

Status of conservation and development: The main reservoir for Perlis State and managed by Department of Irrigation and Drainage (JPS) Perlis.

Function: Recreational and scientific.

Figure 22: Landscape of Timah Tasoh Lake with the range built by Setul Limestone at the background.

Figure 23: Mini display section had been built to exhibit rock formation of Timah Tasoh Formation.

Figure 24: The anti-tropic index fossil *Monodiexodina Shiptoni* discovered from Timah Tasoh Formation.

3.2.2 Bukit Jerneh Karst Geosite

Geographical Information: N 6° 32' 50" , E 100° 16' 05"
Location: Bukit Jerneh, Kangar, Perlis.

Geological Information: This geosite is one of the sporadic isolated limestone hills of Chuping Formation in Perlis, surrounded by paddy fields. This light grey coloured limestone is Lower Triassic (240 million years old). Mogote and cave system of this hill were formed due to dissolution process. This limestone was deposited in shallow marine environment.

Geological diversity:
Rock diversity: Limestone and dolomitic limestone.
Fossil diversity: Foraminifera, nautiloids, crinoids and trace fossils.

Heritage value:
Scientific value: Karst morphology and fossil assemblages.
Cultural value: -
Aesthetic value: Karst landscape.
Recreational value: River recreational spot and rock-climbing activity.

Special features: Karst landscape such as mogote, cave and underground river. One of distinct features can be found at this geosite is the notches that indicate the ancient water level.

Accessibility: Access via road.

Status of conservation and development: Managed and developed as a recreational site by Kangar City Council.

Function: Bukit Jerneh is a popular recreational destination for local visitors and climbers. This geosite is well known for climbers for rock climbing as the magnificent view of Perlis's landscape. Cavers come here for caving exploration activities.

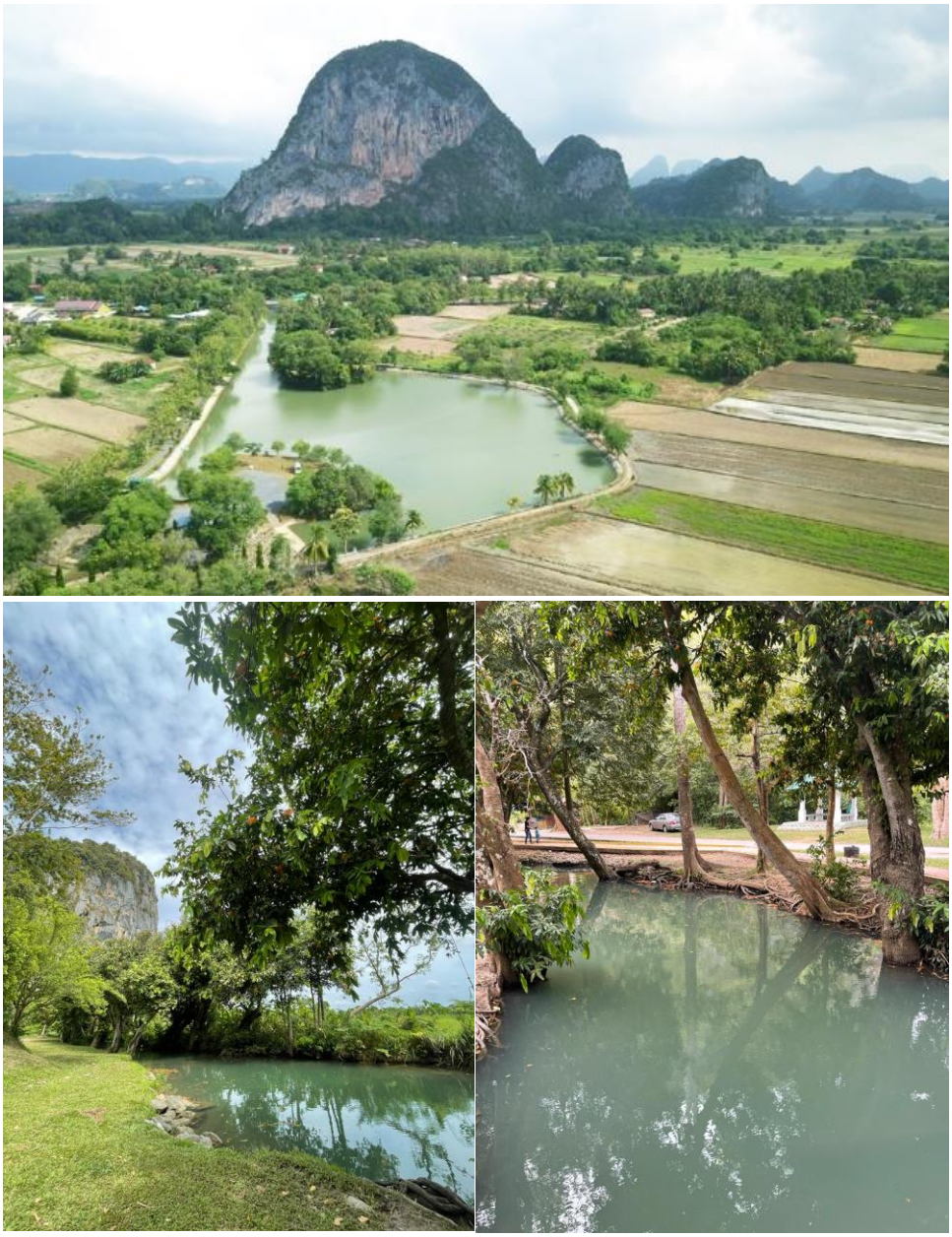

Figure 25: (Top) Bukit Jerneh is surrounded by paddy field. (Bottom): The river flows through Bukit Jerneh had become the attraction for local people.

3.2.3 Gua Kelam Geosite

Geographical Information: N 6 34' 41" , E 100 12' 11"
Location: Kaki Bukit, Perlis.

Geological Information: Gua Kelam Geosite is an important site for Setul Formation. Setul Limestone is characterised by dark grey, dolomitised, and fossiliferous limestone. This Early Ordovician- Silurian formation. This geosite is characterised by the subterranean river flows through the cave of Gua Kelam. Cave features such as stalactite, stalagmite, and rim pools can be seen observed at this location for cave tin mining then. Occurrence of Ordovician – Silurian shallow water.

Geological diversity:
Rock diversity: Limestone
Fossil Diversity: Gastropods, brachiopods, and nautiloids.
Geomorphological diversity: Stalactite, stalagmite, rim pools and doline.

Heritage value:
Scientific value: Karst morphology and fossil assemblages.
Cultural value: Ex-tin mine
Aesthetic value: Beautiful cave formation.
Recreational value: Cave exploration.

Special features: Cave and cave formation.

Accessibility: This geosite has been developed with basic amenities by Perlis Forestry Department.

Status of conservation and development: Perlis State Park.

Function: Recreational and education.

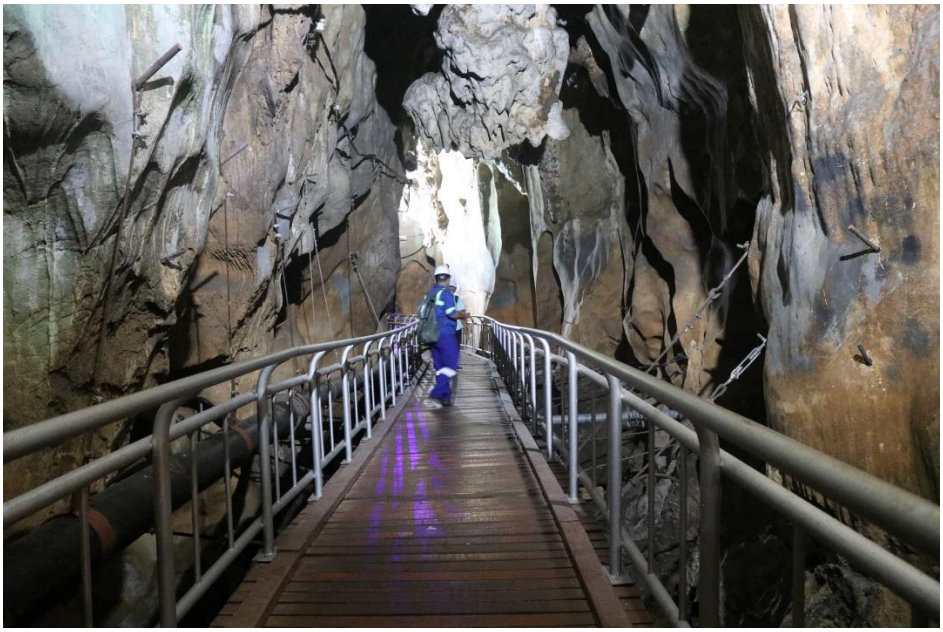

Figure 26: Cave formation inside Gua Kelam Geosite.

Figure 27: River flows out of Gua Kelam where limestone formation can be observed around.

3.3 NORTH PERAK

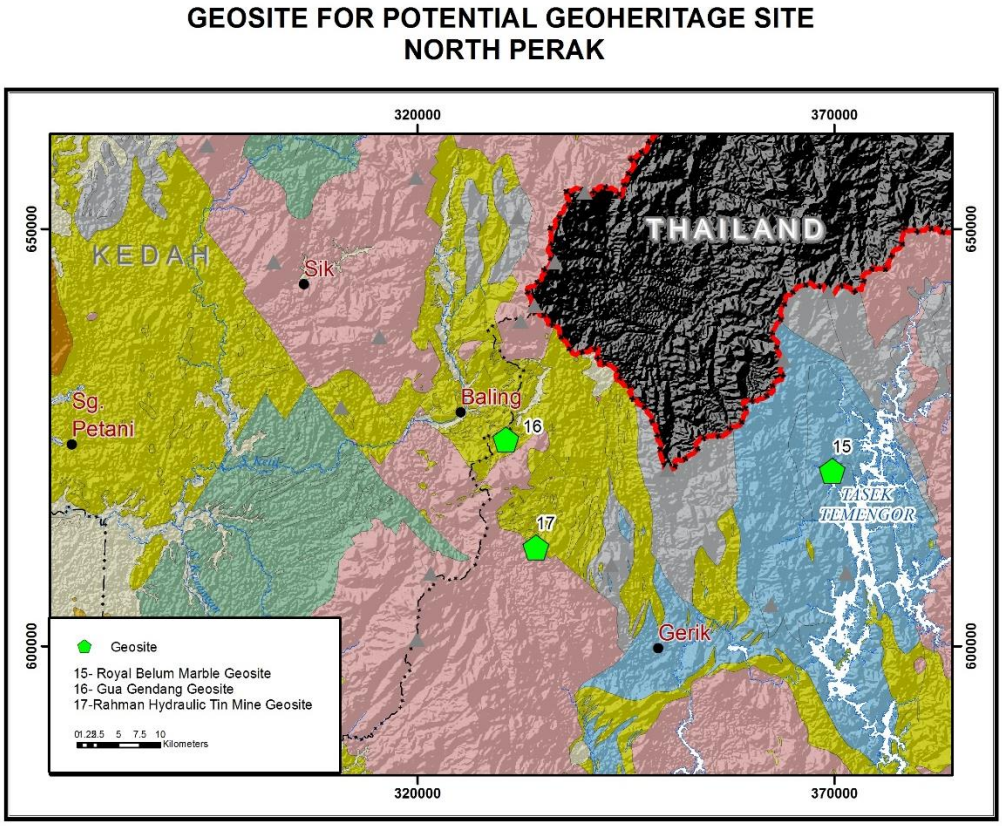

Figure 28: Map with location of potential geoheritage sites in North Perak, Malaysia.

General geology of North Perak

North Perak area consists of the extensive rock formations of East Kedah. The Silurian-Ordovician Kroh Formation is the oldest formation in this area. It is overlain by Carboniferous Kubang Pasu and conformably underlain by Permian Gerik Formation. Late Triassic Main Range Granite and Bintang Granite occurred in this area. Younger Cretacous Berapit Formation and Nenering Bed of Quartenary occurrence are localised and very restricted to certain part.

3.3.1 Belum Marble Geosite

Geographical Information: N 5° 36.759' , E 101°18.997'
Location: Sungai Gadong, Belum Reserve Forest, Gerik, Perak.

Geological Information: This geosite is a part of Gerik Formation of Permian (290 million years to 250 million years ago). It consists of calcareous unit (lenses) of Gerik Formation can be observed in this state park, light grey in coloured with presence of folded darker layers at certain outcrop. This unit had been turned into banded marble by the massive Late Triassic granite intrusion.

Geological diversity:
Rock diversity: Marble
Structure diversity: Folds

Heritage value:
Scientific value: The contact between calcareous facies of Gerik Formation and main range granite.
Cultural value: -
Aesthetic value: Lake landscape and tropical forest.
Recreational value: Jungle trekking.

Special features: Banded marble was formed by the contact metamorphism of Gerik Formation's calcareous unit and main range granite body. This geosite is also rich in flora and fauna. Few species of Rafflesia, amongst the biggest flower in world had been discovered here; *Rafflesia kerii, R. cantleyi* and *R. azlanii*. This forest is also the habitat of fauna such as hornbills, tigers, elephants, seladang, tapirs, and a lot more endangered species.

Accessibility: Access via boat ride from Royal Belum Jetty.

Status of conservation and development: Conservation area in Belum Reserve Forest and undeveloped.

Function: Scientific, recreational.

Figure 29: (Left) Belum Marble surrounded by Temenggor Lake. (Right) Banded marble.

Figure 30: (Left) *Rafflesia azlan*ii of Belum Forest. (Right) *Rafflesia cantleyii* of Belum Forest.

3.3.2 Gua Gendang Geosite

Geographical Information: N 05° 38’ 42.745’’, E 100° 57’ 43.936’’
Location: Pengkalan Hulu, Perak.

Geological Information: This geosite is the calcareous unit of Kroh Formation, Silurian-Devonian age. Thick bedded, dark grey limestone is exposed here. Calcite veins and small folds can be observed in the limestone beds. An underground chamber (cave system) formed by dissolution process of an underground river.

Geological diversity:
Rock diversity: Rock
Geomorphological diversity: Cave and underground stream
Structure diversity: Veins and folds

Heritage value:
Scientific value:
Cultural value:
Aesthetic value:
Recreational value: Cave exploration.

Special features: Cave tunnel with two entrances. *Cycas clivicola* grows at this geosite. This cave tunnel had been used as a hiding place by the communists during insurgency period.

Accessibility: Access via road.

Status of conservation and development: Within a private owned resort.

Function: Recreational, historical, and cave exploration.

Figure 31: (Left) Cave tunnel of Gua Gendang. (Right) Thick bedded limestone of Kroh Formation in Gua Gendang.

3.3.3 Rahman Hydraulic Tin Mine Geosite

Geographical Information: N 05° 31’ 42.21587’’, E 100° 59’ 41.24673’’
Location: Kampung Bukit Buloh, Pengkalan Hulu, Perak

Geological Information: This geosite is located in Rahman Hydraulic Tin Mine, Klian Intan. Rahman Tin Mining is the oldest mining activities recorded in Peninsular Malaysia since 1907 and still active until now. Mineralisation of tin in the Kroh Formation (Silurian to Devonian) occurred during the intrusion of Bintang Granite (Late Triassic) that uplifted Peninsular Malaysia and formed the landscape that can be seen nowadays.

The dam structure had been built in 1920 on Bintang Granite to generate power supply for tin mining downstream of Sungai Pong. Bintang Granite consists of grey coloured phaneritic granite with euhedral plagioclase phenocrysts. The age of Bintang Granite is Late Triassic (220 million years ago).

Geological diversity:
Rock diversity: Phaneritic granite
Mineral diversity: Cassiterite, Pyrite, Stannite, Tourmaline, Quartz
Structure diversity: Veins

Heritage value:
Scientific value: Tin mineralisation.

Cultural value: The oldest operating tin mine in Malaysia (more than 100 years)
Aesthetic value: -
Recreational value:-

Special features: Tin mineralisation.

Accessibility: Access via road with four-by-four vehicle.

Status of conservation: Private owned properties.

Function: This geosite has potential to be a public educational site about tin mineralisation and tin mining activities in Malaysia.

Figure 32: (Top) Dam and hydroelectric station at the upstream of Sungai Pong provide flow for mining activity downstream. (Below) Rahman Hydraulic Tin Mine, Klian Intan.

3.4 NORTH KELANTAN

General geology of North Kelantan

The mountainous landscape of northern Kelantan is mainly built up by Cretaceous intrusion of Stong Complex. This intrusion occurred in series knowing as Berangkat Tonalite, Kenerong Leucogranite, and Noring Granite. Older metamorphosed Mangga Formation consisted of argillaceous, calcareous, and arenaceous members exposed well particularly at the north eastern part of Jeli. Granite intrusion process had turned Mangga Formation into gold enriched area.

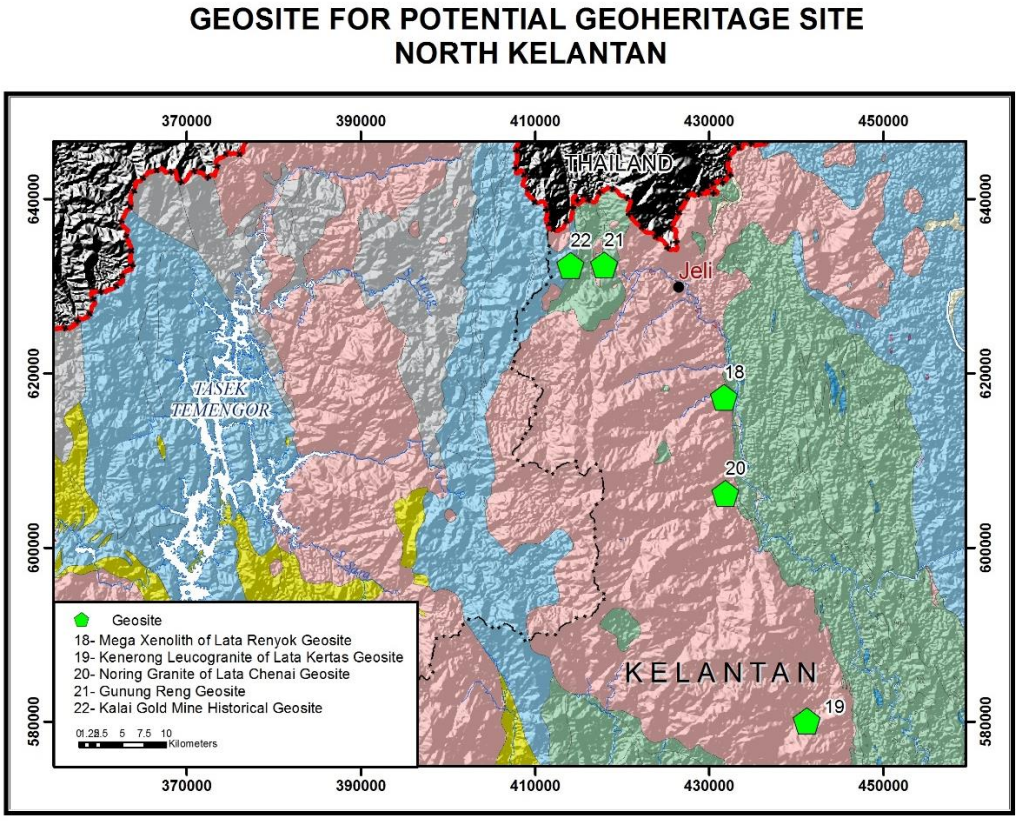

Figure 33: Map with location of potential geoheritage sites in North Kelantan Malaysia.

3.4.1 Mega Xenolith of Lata Renyok Geosite

Geographical Information: N 5°39'39.98'' , E 101°41'27.98''
Location: Gunung Basor Reserve Forest, Mukim Kuala Balah, Jeli, Kelantan.

Geological Information: This geosite comprises of a one-kilometer size of metamorphic rocks that is actually a mega size xenolith in Kenerong Leucogranite unit of Stong Complex. It is characterised by layers of very

dark grey interbedded (hornblend schist) with light grey unit (biotite muscovite schist). It is highly deformed; folded, faulted and structure as boudinage, pinch and swell, lenses can be observed at this geosite. 'Textbook' structures (deformation) formed by series of intrusion of Stong Complex. Key geosite to understand the mechanism of the intrusion.

Geological diversity:
Rock diversity: Hornblend schist, biotite muscovite schist, aphaneritic granite and pegmatite.
Structure diversity: Folds, boudinage, pinch and swell, veins, faults, fractures.

Heritage value:
Scientific value: Structures of mega xenolith.
Cultural value: -
Aesthetic value: Scenic cascading waterfall
Recreational value: River recreation.

Special features: This xenolith, part of Gua Musang Formation had formed multiple stage of waterfalls and pools at Sungai Renyok with one of them is the intake for a mini hydroelectric station.

Accessibility: Lata Renyok is a popular recreational spot for locals and equips with basic facilities.

Status of conservation and development: Gunung Basor Reserve Forest

Function: Recreational, scientific. Due to the diversity and enrichment of structures present here, this geosite is a popular locality for geological students from universities for a fieldwork.

Figure 34: (Left) Boudinage structure of Lata Renyok. (Right) Folds at Lata Renyok.

Figure 35: (Top) Cascading waterfall of Sungai Renyok. (Below) Hydroelectric station powered by Sungai Renyok.

3.4.2 Kenerong Leucogranite of Lata Kertas Geosite

Geographical Information: N 5°14'40.73'' , E 101°57'39.18''
Location: Jalan Jelawang- Gua Musang, Dabong, Kuala Krai, Kelantan.

Geological Information: Kenerong Leucogranite is the second series of Stong Complex. It can be recognised by a very light grey to whitish grey lithology with microfolds (at the vicinity of younger series). Lata Kertas is consisted of fine-grained light-coloured granite of Cretaceous Kenerong Leucogranite (about 60 million years ago). Xenoliths and veins of older Gua Musang Formation occur in vary of geometry, colours and sizes.

Geological diversity:
Rock diversity: Aphaneritic granite, quartz and metasediment (xenolith).
Structure diversity: Xenolith, veins, and folds.
Geomorphology diversity: Waterfall

Heritage value:
Scientific value: Kenerong Leucogranite Unit of Stong Complex and xenolith of Gua Musang Formation.
Cultural value: -

Aesthetic value: Rapid waterfall
Recreational value: River recreation spot.

Special features: There are two levels of waterfall at Lata Kertas, with the main formed ‘door-like’ openings, effect of geological processes. Xenoliths of metasediment can be observed in vary sizes, one of it is similar to a phoenix (flying).

Accessibility: Access via small road less than 200 metres from main road Dabong-Gua Musang. Limited infrasctructure is available.

Status of conservation and development: Gunung Stong State Park

Function: Recreational, scientific

Figure 36: Door-like openings of Lata Kertas.

Figure 37:(Left) Xenolith vary in geometry and sizes (Right): Flying Phoenix shaped xenolith.

3.4.3 Noring Granite of Lata Chenai Geosite

Geographical Information: N 5°28'48.1'', E 101°52'33.8''
Location: Gunung Basor Reserve Forest, Mukim Kuala Balah, Jeli, Kelantan.

Geological Information: This Lata Chenai Geosite is located at Sungai Terang, 25 kilometer from main roads connecting Jeli and Gua Musang (via Kuala Balah). This geosite is the best location to observe the Noring Granite unit, the latest intrusion series of Stong Complex. Porphoritic biotite granite with K-feldpsar phenocryst (pink color) exhibits mineral arrangements of biotite with subordinate of metasediment xenolith and aplite, pegmatite and quartz veins. Cretaceous Noring Granite had intruded into older Gua Musang Formation to form schlieren and assimilation of magma and country rocks.

Geological diversity:
Rock diversity: Phaneritic granite, pegmatite and metasediment (xenolith).
Structure diversity: Xenolith, aplite, and veins.
Geomorphology diversity: Cascading waterfalls, pools, and potholes.

Heritage value:
Scientific value: Youngest intrusion of The Stong Complex.

Cultural value: -
Aesthetic value: Waterfall and river landscape.
Recreational value: River recreation spot.

Special features: Sungai Terang flows in between the fractures of pink coloured Noring Granite makes a unique view at this geosite.

Accessibility: Access via small road connecting orchards.

Status of conservation and development: Gunung Basor Reserve Forest.

Function: Recreational and scientific.

Figure 38: (Top) Waterfall of Lata Noring (Below) Phaneritic Noring Granite.

3.4.4 Gunung Reng Karst Geosite

Geographical Information: N 5°42'54.47" , E 101°44'42.87"
Location: Gunung Basor Reserve Forest, Mukim Kuala Balah, Jeli, Kelantan.

Geological Information: Gunung Reng Karst Geosite has an outstanding landscape as this isolated limestone hill (mogote) about 200 meter in height and 100 width is the only high topography around that area. This metamorphosed limestone hill consists of several caves (chambers), the mains are Gua Payong and Gua Badak. This limestone hill can be seen from afar, as it is surrounded by low plain area consist of river alluvium. Gunung Reng is the calcareous member of Carboniferous-Permian Mangga Formation which had been intruded by Triassic Kemahang Granite and Creataceous-Triassic Stong Complex. This geosite is believed to be a part of Bentong-Raub Suture Zone.

Geological diversity:
Rock diversity: Metamorphosed limestone.
Geomorphological diversity: Cave and mogote.

Heritage value:
Scientific value: The chaotic limestone block in Bentong-Raub Suture Zone.
Cultural value: The myth of Puteri Saadong.
Aesthetic value: Mogote landscape and cave formations.
Recreational value: Cave exploration and wall climbing.

Special features: Interesting features such as mogote, caves, and ancient water levels can be seen at this geosite. In addition, this geosite is also famous for Puteri Saadong's myth where locals believe that Puteri Saadong used to reside in one of the caves.

Accessibility: Access via road. Less than one kilometer from Jeli-Gerik Main Road. Basic amenities such as toilets, stalls, hall, recreational area and a mini gallery had been built up by Jeli District Council.

Status of conservation and development: Territory of Jeli District Council.

Function: Recreational, scientific and culture.

Figure 39: (Left) Mogote of Gunung Reng. .(Right): Alluvial deposit surrounding Gunung Reng.

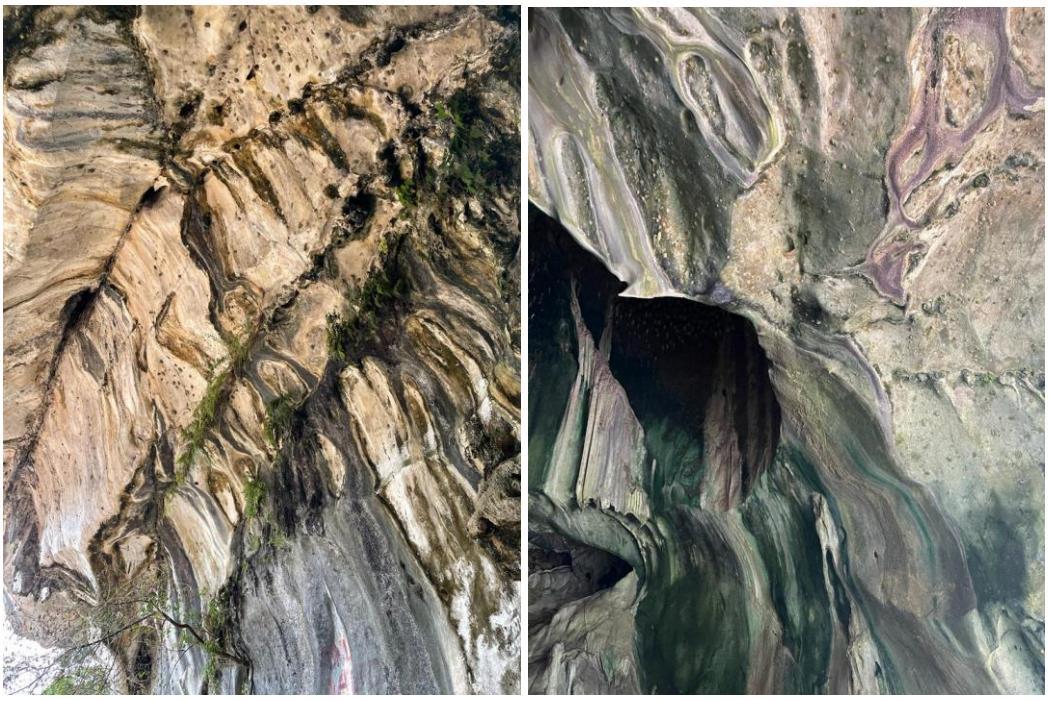

Figure 40: Speleothem inside the cave of Gunung Reng.

3.4.5 Kalai Ex-Gold Mine Geosite

Geographical Information: N 5° 47' 3.518" , E 101° 43' 1.986"
Location: Kampung Kalai, Mukim Hutan Melintang, Jeli, Kelantan.

Geological Information: This Kalai Ex-Gold Mine Geosite is situated on rocks of Carboniferous to Permian Mangga Formation within proximity of granite intrusion. Intrusions of Stong Complex followed by the formation of quartz veins had led to the occurrence of gold in this area. There are several tunnels at this geosite with some almost 100 metres long, two metres height, and two metres width; still in sturdy condition. These tunnels were excavated in schist. Batu Melintang area is the high potential gold mineralisation zone. This area is well known as enriched with gold placer in the alluvium and had been mined traditionally across Sungai Pergau and abandon mine site.

Geological diversity:
Rock diversity: Schist and metasediment.
Mineral diversity: Gold, quartz and iron minerals.

Heritage value:
Scientific value: Gold mineralisation
Cultural value: The oldest gold mine in Kelantan (since 1930)
Aesthetic value: -
Recreational value: -

Special features: The gold mining activities in Kelantan had begun as early as 1920, including in Sungai Pergau and extended to Kampung Kalai (north of Kelantan). This geosite is unique as it combines geological and historical of this area and offers the same route of mining activities were in 1931-1946.

Accessibility: Access via four-by-four vehicle and traverse by foot. Located about 25 kilometer to the north of Gunung Reng Geosite in Batu Melintang and only 200 metres from Malaysia-Thailand Border.

Status of conservation and development: Gunung Basor Reserve Forest

Function: History and scientific.

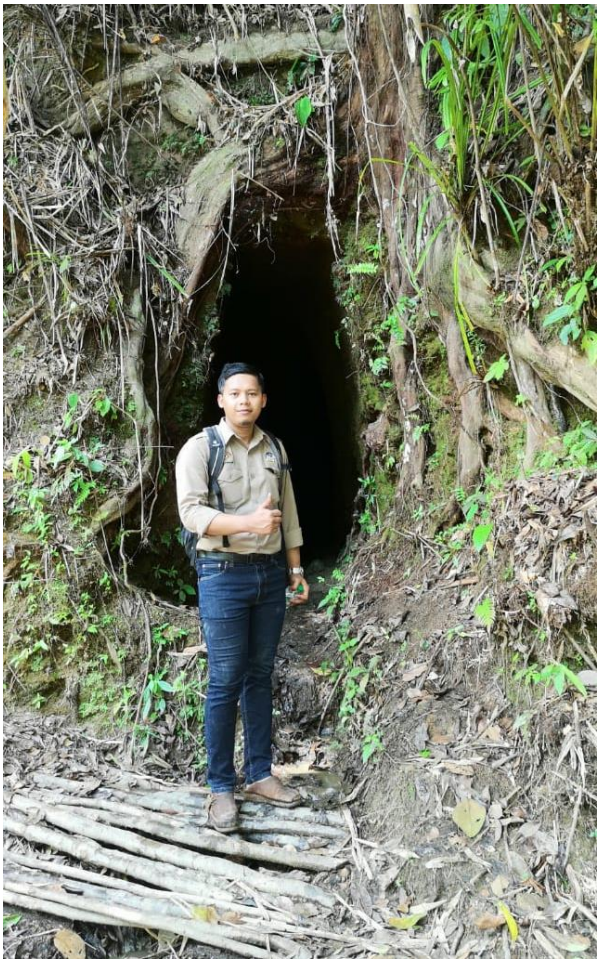

Figure 41: Abandoned gold exploration tunnel in Kampung Kalai.

4. GEOHERITAGE SITES POTENTIAL FOR GEOTOURISM

4.1 TARUTAO – KHAI - ADANG – RAWI – LIPE ISLANDS AREA

4.1.1 Chorakhe Cape

Location: Chorakae Cape, Tarutao Island,
Tarutao National Park, Satun province
Latitude: 6.706663, Longitude: 99.642572
Zone: 47N Easting: 571018 Northing: 741368

Geological Information: The rock sequence is exposed in a large embayment (more than 150 m long) located opposite to the Pante Malaka port. General attitude of beds is approximately NNW-SSE trending with low angle (20^o – 25^o) to the east. A NE-SW trending sinistal fault is observed in the northern part of the section. It is remarkable to be a fault boundary between this rock unit and the Thung Song Group. This sequence, 110 m thick, constitutes reddish brown to purplish red, well-bedded, sharp, parallel, thin-bedded, fine-grained, laminated, some micaceous sandstones interbedded with reddish brown to greenish grey siltstones to mudstones, very thin- to thin-bedded. Cross-bedding, load casts and ball and pillow structures are common sedimentary structures found in this sequence. Trilobite and brachiopod fragments have also been found in this sequence. Several pale yellowish brown, thin to medium bedded (10 cm – 30 cm), friable and porous bioturbation rich strata are observed in the lower part of this sequence. In the upper part, calcareous sandstones with limestone lenses are more common. These form as a transitional zone between the Tarutao Group and the overlying Thung Song Group.

Geological diversity:

Rock diversity: 110 meters thick, constitutes reddish brown to purplish red, well-bedded, sharp, parallel, thin-bedded, fine-grained, laminated, some micaceous sandstones interbedded with reddish brown to greenish grey siltstones to mudstones, very thin- to thin-bedded. Cross bedding, load casts and ball and pillow structures.

Fossil diversity: Trilobites
Structure diversity: Sedimentary rock structures

Heritage value:

Scientific value: The oldest rock in Thailand.
Cultural value: History of imprisoned on the island of Koh Tarutao
Aesthetic value: Beautiful sedimentary rock strata and cliff

Special features: Transitional zone between the Tarutao Group and the overlying Thung Song Group.

Accessibility: By speed boat and kayaking.

Status of conservation and development: Located in the Tarutao National Park

Function: Recreational and education.

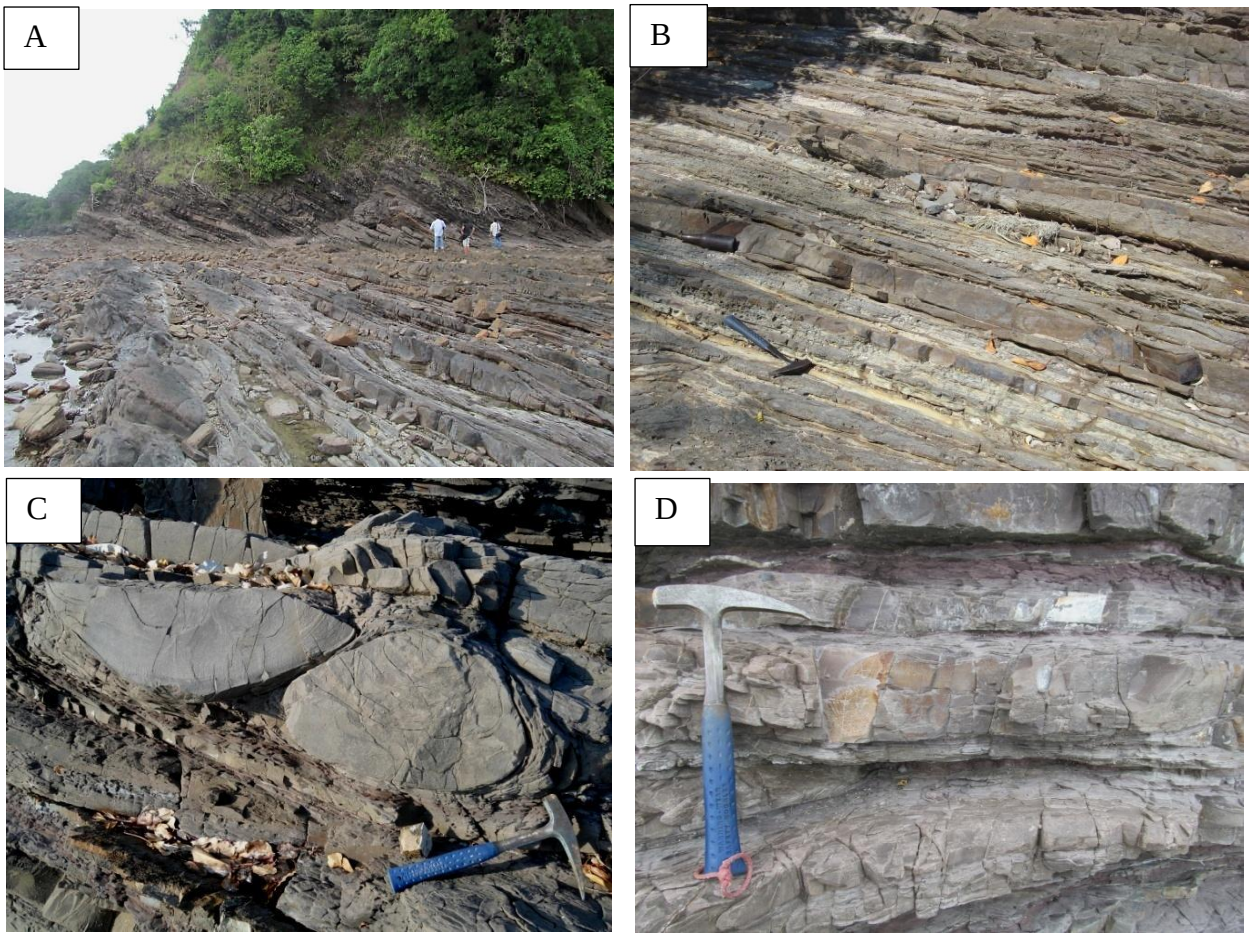

Figure 42: General views of the Chorakae Cape: (A)-(C) The rock sequence of Tarutao Group sandstone at Chorakae Cape. (D) Pillow structures in Tarutao Group sandstone.

4.1.2 Ao Mo Lae Bay

Location: Ao Mo Lae, Tarutao Island
Tarutao National Park, Satun province
Latitude: 6.672498, Longitude: 99.639233
Zone: 47N Easting: 570653 Northing: 737591

Geological Information: In the Ao Mo Lae section, the upper part of the sequence is well exposed. The sequence, NW-SE to E-W trending, has low to moderate angle dipping (25 degree-30 degree) northeastwardly and northwardly. The unit reveals the fault boundary with argillaceous and oolitic limestones of the lower Thung Song Group. The rock unit consists mainly of sandstones with some micaceous, pale greenish grey siltstones interbedded. Sandstones are characterized by fine- to medium-grained with reddish brown to purplish in colour. Thickness of beds varies from 5 to 60 cm. Planar cross-bedding, lamination and hummocky cross-bedding are

common. In the upper part of the sequence, honeycomb structures, sand dykes and erosional surfaces are usually observed. It should be noted here that in several beds (0.5-5.0 cm), trilobites and brachiopods have been remarkably found. Most of them are rather incomplete consisting of broken pieces. The trilobites have been identified as *Thailandium solum* Kobayashi, *Eosaukia buravasi* Kobayashi and *Coreanocephalus planulatum.*

Geological diversity:

Rock diversity: Sandstones with some micaceous, pale greenish grey siltstones interbedded.

Fossil diversity: new species of trilobites such as *Thailandium solum* Kobayashi, *Eosaukia buravasi* Kobayashi and *Coreanocephalus planulatum.*

Structure diversity: Sedimentary rock structures such as planar cross-bedding, lamination and hummocky cross-bedding.

Heritage value:

Scientific value: The oldest rock formation in Thailand and new species of trilobites.

Cultural value: History of imprisoned on the island of Koh Tarutao.

Aesthetic value: Beautiful white beach contrast with red color rock strata

Special features: Beautiful wide white beach contrast with red rock strata and blue color of Andaman Sea.

Accessibility: National park car and short walk to the beach.

Status of conservation and development: Located in the Tarutao National Park.

Function: Recreational and education.

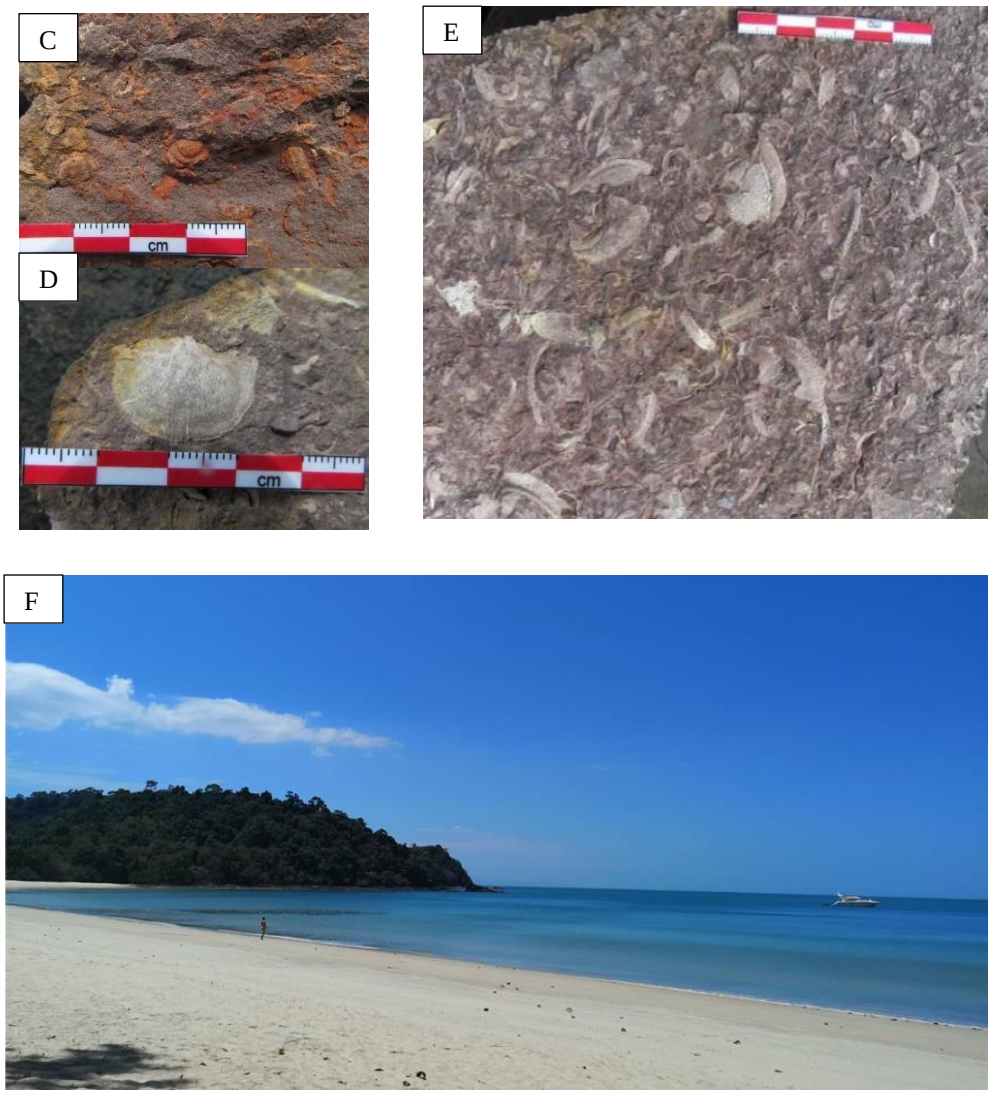

Figure 43: Rock and fossil at Ao Mo Lae bay: (A)-(B) Cambrian rock at Southern part of Ao Mo Lae bay; (C)-(E) Many kinds of Cambrian fossils were found in Ao Mo Lae bay; (F) General views of the white beach.

4.1.3 Ao Son Gravel Beach

Location: Ao Son, Tarutao Island Tarutao National Park, Satun province
Latitude: 6.686445, Longitude: 99.642685
Zone: 47N Easting: 571033 Northing: 739133

Geological Information: The succession is interbeds of purplish red to red, medium- to thick-bedded, some micaceous sandstone and reddish and green, thin-bedded shales. Sandstones are characterized by fine- to medium-grained and well-sorted. Planar and tabular cross-beddings and load casts are common and ripple marks can be observed. Quarzitic sandstones strata, about 60 cm thick, are intercalated in the lower unit. Some fossiliferous beds have been recorded in the lower part of the horizon whose thickness of bed varies from 0.5 to 1 cm. Incomplete fossils of the oldest trilobites, brachiopods and traces of graptolites can be observed in this locality.

Geological diversity:
Rock diversity: Micaceous sandstone.
Fossil diversity: New species of trilobites such as *Thailandium solum* Kobayashi, *Eosaukia buravasi* Kobayashi and *Coreanocephalus planulatum.*
Structure diversity: Sedimentary structure such as planar and tabular cross-beddings and load casts are common and ripple marks can be observed.

Heritage value:
Scientific value: The oldest rock formation in Thailand and gravel beach.
Cultural value: History of imprisoned on the island of Koh Tarutao.
Aesthetic value: Sound of wave and gravel beach and blue color of Andaman Sea.

Special features: Sound of wave and wide gravel beach and blue color of Andaman Sea.

Accessibility: National park car and short walk to the beach.

Status of conservation and development: Located in the Tarutao national park

Function: Recreational and education.

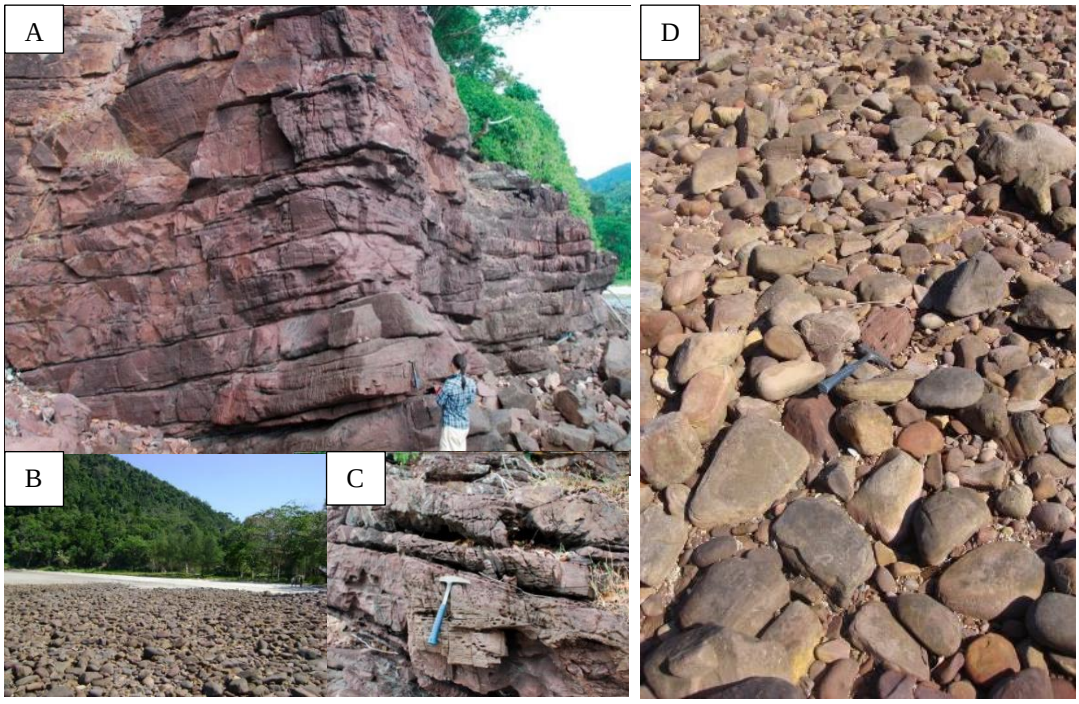

Figure 44: Rock cliff and Gravel beach at Ao Son Beach: (A)-(B) Cambrian rock cliff at Ao Son Beach shows rock sequent and outstanding red colour; (C)-(D) Cobbles gravel beach.

4.1.4 Ao Makham Gravel Beach

Location: Ao Makham, Tarutao Island Tarutao National Park,
Satun Province.
Latitude: Longitude:
Zone: 47N Easting: Northing:

Geological Information: The Site is identified from amount of talus loose blocks or floats on Makham gravel beach near the local forest office. Large blocks (1.5x3 – 4 m) of coarse-grained, quartz pebble conglomerates interbedded with trough cross stratification and planar lamination, coarse sandstones are observed. The estimated thickness of this unit is about 100 meters. Detailed study of these talus blocks by the Thai Working Group indicates three types of rocks are observed as follows;

1) Sandstones; white and reddish brown on weathered, medium- to coarse-grained, moderate sorted, medium- to thick-bedded. Planar and trough cross lamination is common. Small rounded pebbles (0.2 – 1 cm in diameter) of white and colorless quartz and chert are locally found.

2) Conglomeratic sandstones; white to pale brown, coarse-to very coarse – grained, poorly sorted, thin- to medium-bedded. Layer of rounded pebbles (0.2 – 1.5 cm) of white and colorless quartz is common in the lower part of each bed. Cross stratification and lamination are also recorded.

3) Pebbly sandstone; white to reddish brown, matrix varies from medium- to very coarse-grained, poorly to moderate sorted, thin- to very thick-bedded. Pebbles, 15 – 25% by volume are subangular white quartz grains, felsic volcanics, and smoky quartz dikes with average 1x3 cm in diameter up to 3x5 cm. Cross stratification and trough cross-bedding are also observed. Makham gravel beach form the weathering and erosional process from sandstones and conglomerate of the Tarutao Group. Well-roundness gravels are result from transportation by longshore wave current around Island.

Geological diversity:
Rock diversity: Sandstones, Conglomeratic sandstones, Pebbly sandstone
Fossil diversity: -
Structure diversity: planar lamination

Heritage value:
Scientific value: Gravel beach that source from erosion of the oldest rock formation in Thailand.
Cultural value: History of imprisoned on the island of Koh Tarutao.
Aesthetic value: Wide gravel beach.

Special features: Sound of wave and wide gravel beach and blue color of Andaman Sea.

Accessibility: Rental longtail boat.

Status of conservation and development: Located in the Tarutao National Park.

Function: Recreational and education.

Figure 45: General views of the Ao Makham stop; (Top left) Talus loose blocks from the lower part of the Ao Tami Formation at Ao Ma Kham area, southwestern part of the Tarutao Island; (Top right) Talus loose block of pebbly sandstone showing subangular, white quartz grains, felsic volcanics, and smoky quartz dykes in conglomerate layers. (Bottom left) Talus loose block of sandstone present cross-bedding. (Bottom right) Makham Gravel beach.

4.1.5 Ao Talo Wow Bay

Location: Ao Talo Wow, East of Tarutao Island,
Tarutao National Park, Satun province
Latitude: - Longitude: -
Zone: 47 N Easting: Northing:

Geological Information: Exposures of the Kaki Bukit/Pante Malaka Formation on the Ao Talo Wao jetty is showing by isolated sea stack with at about 30 m high. The sequence is in the N-S trending with moderate dipping angle (40o) eastwardly. The unit is recognized as the lower part of the formation which are conformably overlying the reddish-brown sandstones and siltstones of the Talo Wao Formation. The rocks, 40 m thick are dark grey to grey, well-bedded, medium-bedded, discontinuous laminated, stylolitic limestones. Grey argillaceous limestones, greenish grey shale layers are usually found. Rock cliff and collapse at the southern part of this stack resulting from E-W fracturing movement are observed.

Geological diversity:

Rock diversity: sandstones, siltstones and argillaceous limestones.

Fossil diversity: -

Structure diversity: sea stack and sedimentary rock strata.

Heritage value:

Scientific value: Boundary between Pante Malaka Formation and Talo Wao Formation.

Cultural value: History of imprisoned on the island of Koh Tarutao.

Aesthetic value: Talo Wao viewpoint.

Special features: 30 meters high of the iconic limestone sea stack at the end of Talo Wao pier and blue sea and learn about evidence of History of imprisoned on the island of Koh Tarutao.

Status of conservation and development: Located in the Tarutao national park.

Function: Recreational and education.

Figure 46: General views of Ao Talo Wow bay; (Top) 30 m. high of the iconic limestone sea stack at the end of Talo Wao pier; (Bottom) sandstones and siltstones of the Talo Wao Formation.

4.1.6 Koh Hin Son Granite Island

Location: Hin Son Island in Batueng Island, Tarutao National Park, Satun province
Latitude: - Longitude:-
Zone: 47N Easting: Northing:

Geological Information: It is an island with a large granite cube is standing over the base rock in balance with peculiar scenery. This granite complex is similar to the Rokloi Island. The good exposure is observed in the southern part of the island. The oldest granite phase is represented by cognate-like within the younger granite phase. It is characterized by non-foliated, light grey to grey, medium- to coarse-grained, sparsely porphyritic (10 – 20%), biotite granite. Lath shapes of low An-content plagioclase and quartz megacrysts are common with 0.5 cm to 2 cm long. Carlsbad twin are common in the feldspar megacrysts. Mineral composition of groundmass is quartz (35 – 40%), K-feldspar and plagioclase (45 – 50%) and biotite; flakes and elongated cluster (10%). Generally, texture of this granite phase is homogeneous and good primary textures. The younger granite phase, the main granite type, is characterized by white to light grey, heterogeneous, fine-grained, leucocratic granite with tourmaline-rich pegmatite. The mineral composition consists of feldspar (45 – 50%), biotite, muscovite and tourmaline (10 – 15%). Biotite-tourmaline patches (3 cm – 4 cm) in their granitic texture are sometime found. Late stage granite phase consists mainly of minor intrusions of tourmaline pegmatite veinlets, trending E-W. They cross-cut on various granites and filled in the fracture zone. The younger granite phase is characterized by white to light grey, heterogeneous and fine-grained of leucocratic granite or aplite with tourmaline-rich pegmatite. The mineral composition consists of 50% quartz, 40 – 45% feldspar and 5%-10% biotite and tourmaline. Biotite-tourmaline patchs (3 cm – 4 cm) in their granite texture are occasionally found.

Geological diversity:
Rock diversity: biotite granite.
Fossil diversity: -
Structure diversity: Joints and

Heritage value:
Scientific value: Composition of biotite granite and weather process.
Cultural value: relate to lifestyle of indigenous people call "Urak Lawoi"
Aesthetic value: Iconic shape of granite rock Island.

Special features: the island with a large granite cube is standing ove the base rock in balance with strange scenery. It is a famous scenic viewpoint of tourists who visit Lipe Island.

Accessibility: take speed boat from Pakpara pier to Lipe Island and longtail boat trip around Lipe Island.

Status of conservation and development: Located in the Tarutao national park.

Function: Recreational and education.

Figure 47: Hin Son Island; (Left) Texture of granite rock at Hin Son Island; (Right) Large granite cube, the outstanding scenic viewpoint of Hin Son Island.

4.1.7 Ko Hin Ngam Gravel Beach

Location: Ko Tarutao, Mueang Satun District, Satun Province
Latitude: 6.515057, Longitude: 99.262416
Zone: 47N Easting: 529013 Northing: 720148

Geological Information: The site is a small, elongated islet about 600 meters long and about 150 meters wide. It is made of hornfels, a low-grade metamorphic rock, with a spectacular gravel beach at the northeast tip covering an area about 200×40 square meters. The source of the gravel is a hornfels outcrop on the east of the islet that has been broken up by sea waves into rock fragments then transported along the seashore to accumulate as a

gravel beach at the northeast tip. Waves have also acted on the western coast providing the growth of the beach toward the northeast direction. The stratigraphic sequence, more than 90 m thick, comprises well-bedded, sharp, wavy, non-parallel, mudstones to slaty shales and mudstones interbedded with siltstones and sandstones. Mudstones to slaty shales are usually characterized by dark grey to black, dense, massive to laminated, very thin- to thick-bedded. Each bed has convoluted layering of pale brown colour of siltstones intercalated. Lamination, load cast and graded bedding are commonly found. Cleavages are well developed as slates. Pebbly mudstones are dark grey, thick-bedded. Pebbles, 10 – 20% by volume, consist of sandstones, limestones and quartzs with approximately 40 cm in diameter. Siltstone is usually characterized by homogeneous, dark to black colour, thin- to thick-bedded. Sandstones are greenish grey, thin- to thick-bedded, fine- to coarse-grained, lithic and wacke. Discontinuous lamination and graded bedding are very common.

Geological diversity:
Rock diversity: Mudstones, siltstone and hornfels
Fossil diversity: -
Structure diversity: Lamination, load cast and graded bedding

Heritage value:
Scientific value: hornfels outcrop on the east of the islet that has been broken up by sea waves into rock fragments then transported along the seashore.
Cultural value: relate to lifestyle of indigenous people call “Urak Lawoi”
Aesthetic value: wide beautiful dark colour gravel beach

Special features: unique beautiful dark shine gravel beach surround by deep blue colour of Andaman Sea.

Accessibility: take speed boat from Pakpara pier to Lipe Island and longtail boat trip around Lipe Island.

Status of conservation and development: Located in the Tarutao national park.

Function: Recreational and education.

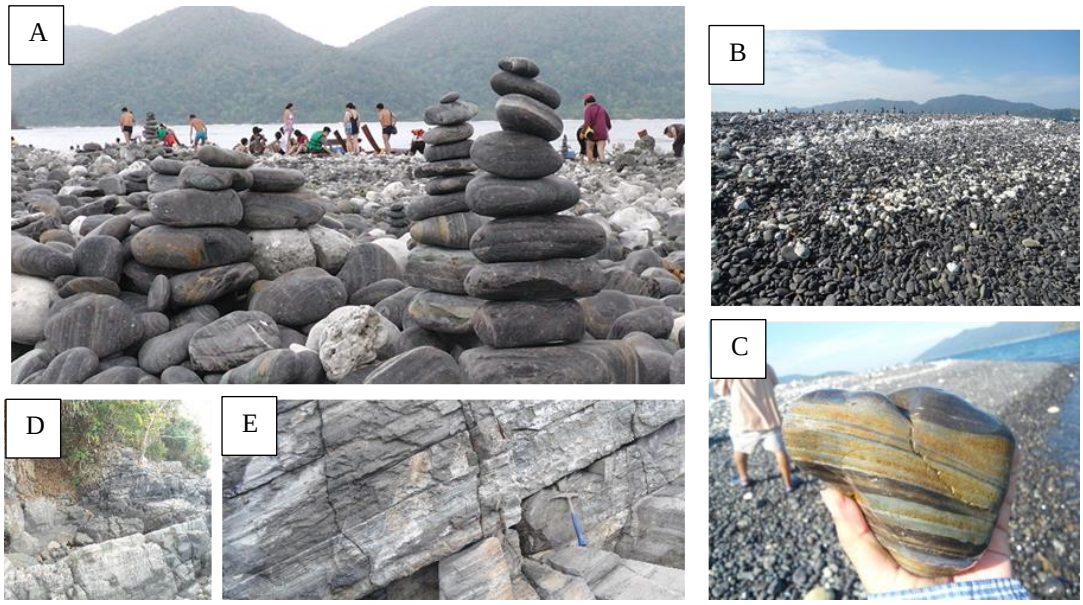

Figure 48: General views of Ko Hin Ngam Black Gravel Beach; (A)-(C) Unique beautiful dark shine gravel beach; (D)-(E) Hornfels outcrop on the east of the Hin Ngam islet.

4.1.8 Haad Pramong Aad Pramong Beach (Sunset Viewpoint in Lipe)

Location: Koh Lipe, Mueang Satun District, Satun Province
Latitude: 6.485614, Longitude: 99.297507
Zone: 47N Easting: 532895 Northing: 716896

Geological Information: The site has granite covering an area of about 30 x 50 square meters. Stay away from the Pakbara harbor to the southwest for approximately 82 kilometers in distance. Beach area or so-call sunset beach is a high slope down to the sand beach. There is porphyritic granite emerged as small nods along the beach. It consists of quartz and feldspar minerals with perfect crystals of biotite and tourmaline are small scales scattered around. White sand with tourmaline crystals in this beach were derived from that granite.

Geological diversity:
Rock diversity: porphyritic granite
Fossil diversity: -
Structure diversity: -

Heritage value:
Scientific value: white sand with tourmaline crystals weather from granite.
Cultural value: Relate to lifestyle of indigenous people call "Urak Lawoi".
Aesthetic value: Beautiful long white sand beach.

Special features: The best viewpoint beach in Lipe Island.

Accessibility: Take speed boat from Pakpara pier to Lipe Island and take the van to the beach.

Status of conservation and development: Located in the Tarutao National Park.

Function: Recreational and education.

Figure 49: General views of Pramong Beach; (Left) Pramong Beach; (Right) white sand with tourmaline crystals at Pramong Beach.

4.1.9 Khai Island

Location: Ko Tarutao, Mueang Satun District, Satun Province
Latitude: 6.571045, Longitude: 99.467990
Zone: 47N Easting: 551736 Northing: 726354

Geological Information: Khai Islet is about 300 meters long and 100 meters wide consisting of two rocky islets connected by a sand deposit, tombolo. The rock is made of softer sandstone with joints in different intervals with harder iron oxide deposited in the joint spaces generated boxworks in some places. A sea arch has been developed in the north islet with a stunning pose in the intertidal zone and has been regarded as a tourism symbol of Satun Province

Geological diversity:
Rock diversity: Sandstone and sand beach
Fossil diversity: -
Structure diversity: Iconic sea arch in Thailand

Heritage value:
Scientific value: Coastal erosion process
Cultural value: -
Aesthetic value: Beautiful morphology and white shell beach

Special features: Beautiful sea arch that has been regarded as a tourism symbol of Satun Province

Status of conservation and development: Located in the Tarutao national park.

Function: Recreational and education.

Figure 50: General views of Khai Island; (Top) beautiful sea arch that has been regarded as a tourism symbol of Satun Province; (Bottom) Photo from top view of Khai Islet show very beautiful white sand beach and deep blue sea.

4.2 SATUN - LA NGU - THUNGWA – MANANG AREA

4.2.1 Khao Thanan Isolated Karst Mountain

Location: Thung Bu Lang, Thung Wa District, Satun Province
Latitude: 7.061771, Longitude: 99.695192
Zone: 47N Easting: 576776 Northing: 780635

Geological Information: The site is a small, isolated limestone mountain as steep side cliff tower. It is in a public area with a water pond in the north and west. The southern side is a decorated landscape surrounded by four meters wide concrete road. It covers an area about 20 acres. Khao Thanan is characterized as a karst topography with sea caves and sea notch indicating it was an islet off the coast. After that the sea level has been

regressed leaving the islet as a small, isolated mountain. The limestone is massive, pale grey, and fossiliferous. The fossils include bivalves, brachiopods, bryozoans, corals, sponges, gastropods and crinoids. The limestone was formed under shallow sea as a coral reef during probable Permian.

Geological diversity:
Rock diversity: limestone.
Fossil diversity: bivalves, brachiopods, bryozoans, corals, sponges, gastropods and crinoids.
Structure diversity: sea caves, sea notch, isolated karst mountain.

Heritage value:
Scientific value: fossiliferous limestone, karst topography and 5,500 years ago sea level rise evidence.
Cultural value: -
Aesthetic value: Beautiful karst morphology

Special features: Beautiful karst morphology and evidence of 5,500 year ago sea level rise.

Accessibility: travel by car 10 km. from Thungwa district.

Status of conservation and development: Protected by Forest Act and managed by Subdistrict Administrative Organization

Function: Recreational and education

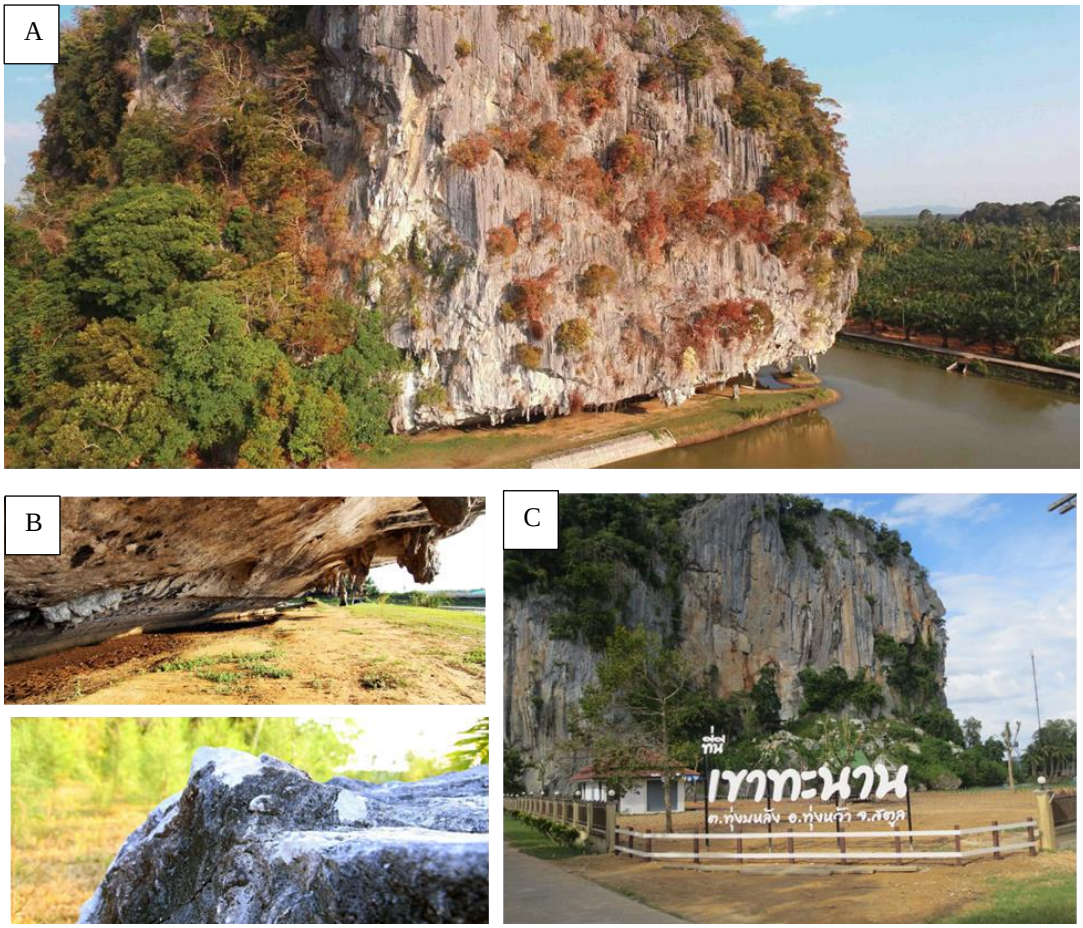

Figure 51: General views of Khao Thanan Mountain; (A) Bird Eyes view photo shows isolated karst mountain feature of Khao Thanan Mountain; (B) – (C) Evidence of 5,500 year ago sea level rise. (B) paleo sea notch and (C) paleo sea cave.

4.2.2 Le Stegodon Sea Cave

Location: Thung Wa, Thung Wa District, Satun Province
Latitude: 7.123441, Longitude: 99.798671
Zone: 47N Easting: 588193 Northing: 787471

Geological Information: Tham Le Stegodon is a sea cave in the N-S elongated cliff limestone mountain ranges. Its two stream inlets are in the eastern side of the mountain and a stream outlet in the western side. It is characterized as three crooked tunnels extending to join together in the mountain. The tunnels are 10 – 20 meters wide and 10 – 20 meters high with a total length approximately 3-4 kilometers. The stream outlet in the western side is connected with a brackish stream run through a thicket of mangrove forest that needs to sailing boat about four kilometers to get on the land at Ban Tha Oil pier. The former name of the Tham Le Stegodon is Wang Kluai cave characterized by a sea cave with seawater intrusions on the western outlet. The two stream inlets in the eastern side are joined together in the cave into a single tunnel and flow out the stream outlet in the western side. The water level in the cave is affected by water from streams and daily sea tides from the western outlet. The kayaking in the cave has to therefore consider the water level in the cave. Discoveries of

Pleistocene rhinos and particularly the Stegodon the name “Tham Le Stegodon” or “Stegodon sea cave” is renowned.

Geological diversity:
Rock diversity: Massive Limestone of Rangnok Formation.
Fossil diversity: Nautiloids, Stegodon and many kind mammal fossils.
Structure diversity: Karst mountain and sea cave.

Heritage value:
Scientific value: Longest sea cave in Thailand and many kind of fossil animal.
Aesthetic value: Look out point at the top of Gunung Machinchang.

Special features: Beautiful cave, features mammal fossils and many kind of cave and brackish water animal.

Accessibility: Accessible via well pathed road and kayaking into the cave.

Status of conservation and development: Protected by Forest Act and managed by Subdistrict Administrative Organization

Function: Recreational and education.

Figure 52: General views of Tham Le Stegodon Cave; (Top) Bird Eyes view photo shows karst topography and the N-S elongated cliff limestone mountain ranges above Tham Le Stegodon Cave. (Bottom) Beautiful cave features in Tham Le Stegodon Cave.

4.2.3 Wang Klang Cave

Location: Pa Kae Bo Hin, Thung Wa District, Satun Province
Latitude: 7.126543, Longitude: 99.997046
Zone: 47N Easting: 610100 Northing: 787857

Geological Information: Tham Wang Klang is a long stream cross cave over 1 kilometer with stream outlet as the Lam Yae Nae. A weir with 7,200 square meter reservoir were built. An area in front of the cave is similar to the large sinkhole with cliff morphology on the western, northern, and eastern sides. The cave inside is a long tunnel with stream flow out at the outlet onto the Lam Yak Nae Reservoir. The stream inlet is on the other side of the mountain.

Geological diversity:
Rock diversity: Massive limestone
Fossil diversity: -
Structure diversity: cave features and sinkhole.

Heritage value:
Scientific value: long stream cave
Cultural value: -
Aesthetic value: beautiful cave features along the cave.

Special features: long stream cross cave over 1 kilometre

Accessibility: Accessible via well pathed road and kayaking into the cave.

Status of conservation and development: Protected by Forest Act and managed by Subdistrict Administrative Organization.

Function: Recreational and education

Figure 53: Beautiful cave features in Tham Wang Klang cave.

4.2.4 Phu Pha Phet Cave

Location: Palm Phatthana, Manang District, Satun Province
Latitude: 7.126543, Longitude: 99.997046
Zone: 47N Easting: 610100 Northing: 787857

Geological Information: The site is a large limestone cave with about 20,000 square meters size located above the down below area about 50 meters. An outside service area is consisted of car parking lot, souvenir and food shops, rest rooms, meeting room, tourist service center, walking tracks, ticket booth, and other landscapes under a tropical rainforest tree canopy. The area is characterized by a rugged terrain of karst topography mostly consisting of Ordovician limestone. The cave contains diversified spectacular speleothems such as stalactites, stalagmites, columns, soda straws, sinter pools, sinter terraces, calcite crystals, cave pearls, flowstones, etc. Air ventilation in the cave can be taken place via a karst window. This karst window also lets a sunbeam radiating into the cave and lighting up a large stone surface to be a green carpet by such kinds of green microorganisms. There are some prehistoric archeological artifacts found in the cave. Ancient humans used to inhabit the cave as a shelter leaving with some potteries and sea mollusk shells.

Geological diversity:
Rock diversity: Massive limestone
Fossil diversity: Nautiloids
Structure diversity: Karst topography and many kinds of speleothems such as stalactites, stalagmites, columns, soda straws, sinter pools, sinter terraces, calcite crystals, cave pearls, flowstones, etc.

Heritage value:
Scientific value: The oldest rock formation in Malaysia.
Cultural value: relate to living style of indigenous people called “Mani”
Aesthetic value: Biggest cave in Satun that contains iversified spectacular speleothems

Special features: at the end of the cave, there are karst window that lets a sunbeam radiating into the cave and lighting up a large stone surface to be a green carpet by such kinds of green microorganisms.

Accessibility: Accessible via pathed road and short walk to the waterfall.

Status of conservation and development: Located in Khao Banthat Wildlife Sanctuary.

Function: Recreational and education

Figure 54: (Left) Large columns and walkway in Phu Pha Phet cave. (Right) Karst window lets a sunbeam radiating into the cave.

4.2.5 Tharn Pliew Karst Waterfall

Location Thung Wa, Thung Wa District, Satun Province
Latitude: 7.112103, Longitude: 99.841817
Zone: 47N Easting: 592960 Northing: 786226

Geological Information: The site is a mountain valley with a stream and its tributaries covering an area about 200 x 400 square meters. It is the limestone mountainous area in the north with five meters high waterfall and smaller waterfalls down below. Source of the water is from cavities or caves in the dark grey Ordovician limestone mountains with calcium carbonate dissolution. The tufa is formed on the rock surfaces when water evaporates from the lime-rich waters, leaving calcite to crystallize. The tufa-coated rock surface with running water is not slippery. Water from the main waterfall is diverged into many creeks falling onto many levels of terraces and finally converged into a single stream.

Geological diversity:
Rock diversity: limestone and tufa.
Fossil diversity: -
Structure diversity: cave and limestone mountain.

Heritage value:
Scientific value: Karst system and ground water.
Cultural value: -
Aesthetic value: beautiful limestone waterfall.

Special features: This waterfall is the main attraction of Satun province with 5 meters high and beautiful cascades formed by rimstone pools. It is surrounded by the deep green rain forest.

Accessibility: Accessible via pathed road and short walk to the waterfall.

Status of conservation and development: Located in Khao Banthat Wildlife Sanctuary.

Function: Recreational and education.

Figure 55: (Left) Source of water flow out from cave in limestone mountain.
(Right) Spectacular view of Tharn Pliew waterfall front that made from tufa.

4.2.6 Lan Hin Pa Phon Stromatolite

Location: Palm Phatthana, Manang District, Satun Province
Latitude: 7.085610, Longitude: 99.973505
Zone: 47N Easting: 607510 Northing: 783325

Geological Information: The site is an area about 40×40 square meters in the school as a natural rockscape with man-made decoration. It is composed of many rock stacks of outcrops with some floated rocks of thin-bedded limestone under some tree canopies, walking tracks, and a pool. The rock beds are about 10-45 centimeters thick dipped toward the south. The rocks show stromatolitic structure and are regarded as a part of the Pa Kae Formation of the Ordovician Thung Song Group.

Geological diversity:
Rock diversity: Type section of the upper part of the Thung Song Group.
Fossil diversity: -
Structure diversity: stromatolitic structure

Heritage value:
Scientific value: evidence of environment in Ordovician period
Cultural value: -
Aesthetic value: beautiful rock garden.

Special features: Good place for learning about the origin of life.

Accessibility: Accessible via pathed road.

Status of conservation and development: Located in Khao Banthat Wildlife Sanctuary and take responsibility by Ban Pa Phon school

Function: Recreational and education.

Figure 56: General view of Lan Hin Pa Phon Stromatilite rock garden that shows clearly layers of stromatolitic structure on the rock.

4.2.7 Chet Khot Cave

Location: Thung Wa, Thung Wa District, Satun Province
Latitude: 7.111711, Longitude: 99.933765
Zone: 47N Easting: 603115 Northing: 786202

Geological Information: The site is a stream cross cave with an inlet on the east and an outlet on the west about 600 meters long, 70-80 meters wide and 40-50 meters high. There is a car park with service pavilions and restrooms on the east with a small pier for getting about 300 meters kayaking along a stream to the stream inlet spot. Kayaking can be made further along a dark cave with a karst window then get out the cave on the western side to join the La-ngu River. The Chet Khot Cave is made of an Ordovician thin-bedded limestone surrounded by rugged mountains consisting of stream valleys and cliffs, waterfalls and sinkholes under a dense thicket of tropical rainforest.

Geological diversity:
Rock diversity: limestone
Fossil diversity: Nautiloids
Structure diversity: cave and *:* thin-bedded limestone

Heritage value:
Scientific value: Karst topography
Cultural value: -
Aesthetic value: Beautiful cave

Special features: travel along the beautiful cave by kayaking and enjoy with various shape of cave feature.

Accessibility: Accessible via pathed road and kayaking

Status of conservation and development: Located in Khao Banthat Wildlife Sanctuary

Function: Recreational and education.

Figure 57: (Top) Stream of La-Ngu canal in front of Chet Khot Cave. (Bottom) Cave features in Chet Khot Cave.

4.2.8 Khao Noi Rock Succession

Location: Kamphaeng, La-ngu District, Satun Province
Latitude: 6.975064, Longitude: 99.772157
Zone: 47N Easting: 585293 Northing: 771062

Geological Information: The site is a small hill on the east of the route no. 416. It is an abandon quarry as a type area for the Pa Kae Formation and Wang Tong Formation. The Pa Kae Formation is 66 meters thick with a red thin-bedded limestone characterized as a mud crack-like stromatolitic structure consisting of 10 – 15-centimeter-thick beds. The cracks are filled with higher resistant dark brown material. Fragmentary fossils found from this rock formation are Late Ordovician trilobites, nautiloids, crinoids, and brachiopods. The Pa Kae Formation is conformably overlain by the Wang Tong Formation. The Wang Tong Formation is a succession of black shale with graptolites and trilobites and intercalation of chert in the upper part.

The fossils indicate Late Ordovician – Early Silurian in ages. Graptolites are extinct marine animals that lived in the seas about 370 million years ago. Like corals they were colonial – each graptolite was made up of many tiny individual animals which linked together into a single colony. As fossil, they have a shiny look as though they had been drawn onto the rock with a pencil.

Geological diversity:
Rock diversity: limestone, sandstone, shale.
Fossil diversity: stromatolite, trilobites, nautiloids, crinoids, graptolite, and brachiopods.
Structure diversity: stromatolitic structure, fault, bed rock

Heritage value:
Scientific value: type area for the Pa Kae Formation and Wang Tong Formation.
Cultural value: -
Aesthetic value: -

Special features: Time boundary of Ordovician – Silurian Period and UNESCO protection site

Accessibility: Longtail Boat and Speed Boat

Status of conservation and development: Protected by Fossil Act.

Function: Education.

Figure 58: (A)-(C) General view of Khao Noi Rock Succession. (D)-(E) Trilobite and Graptolite found in sedimentary rock at Khao Noi.

4.2.9 Urai Thong Cave

Location: Kamphaeng, La-ngu District, Satun Province
Latitude: 6.937578, Longitude: 99.764489
Zone: 47N Easting: 584452 Northing: 766916

Geological Information: Tham Urai Thong is a cross limestone cave in an isolated north-south elongated cliff mountain about 40 meters long and 25 meters wide. There are three caves in the mountain, but the Urai Cave is the largest with both stream inlet and outlet at the eastern and western sides respectively. A joint system can be observed that might be the ways the cave has been developed. The south wall of the cave reveals three sea notches suggesting that the cave was affected by the sea incursions as well as the presence of some sea mollusk shells on the cave floor such as Anadara spp., Polymesoda proxima, Nerita spp. and oysters. The mollusk shells are mostly in the upside positions. There are some ancient human and animal bones found in the cave including rhinos, zebras, bovines, and boars. The animal bones are generally fragmentary pieces suggesting that they had been made by the ancient humans.

Geological diversity:
Rock diversity: imestone
Fossil diversity: -
Structure diversity: Karst topography

Heritage value:
Scientific value: Development of karst topography.
Cultural value: Evidence of an ancient human.
Aesthetic value: Beautiful viewpoint and karst features.

Special features: Three level of cave and beautiful viewpoint and discovery of the evidence of the ancient human.

Accessibility: Longtail Boat and Speed Boat.

Status of conservation and development: Protected by Forest Act.

Figure 59: (A) – (C) General view and cave features in Tham Urai Thong Cave.

4.2.10 Wang Sai Thong Karst Waterfall

Location: Nam Phut, La-ngu District, Satun Province
Latitude: 7.089966, Longitude: 99.909796
Zone: 47N Easting: 600473 Northing: 783793

Geological Information: The site is a waterfall where water is originated from a water body in cavities of the karst limestone mountain by outflow down below along the hill slope into the La-ngu River. It is regarded as a tufa waterfall formed when water running over carbonate rock absorbs calcium. Aquatic plants which grow on the rocks in the stream and air in the atmosphere provide carbon dioxide during photosynthesis and water running which precipitates the calcium from the water to deposit it as layer of tufa on the surface of the waterfall – a process that takes millions of years. This tufa precipitation forms many curtain dams in form of many levels of terraces with spectacular water ponds and water curtains under shades of tree canopies. Forest Protection Unit of the Khao Bunthad Wildlife Sanctuary provides the parking lot, information panels, walking tracks and bridges for easy accession of the tourists.

Geological diversity:
Rock diversity: limestone and tufa.
Fossil diversity: -
Structure diversity: cave and limestone mountain.

Heritage value:
Scientific value: Karst system and ground water.
Cultural value: -
Aesthetic value: Beautiful limestone waterfall.

Special features: This waterfall is famous tourism site of Satun province with several beautiful cascades formed by rimstone pools. It is surrounded by the deep green rainforest.

Accessibility: Accessible via pathed road and short walk to the waterfall.

Status of conservation and development: Located in Khao Banthat Wildlife Sanctuary.

Function: Recreational and education.

Figure 60: General View of Wang Sai Thong waterfall and multi-level of rim stone pool.

4.2.11 Khao To Ngai Geological Time Boundary

Location: Nam Phut, La-ngu District, Satun Province
Latitude: 6.833017, Longitude: 99.754060
Zone: 47N Easting: 583318 Northing: 755355

Geological Information: A fault plane is on the south of a small isolated Khao To Ngai mountain about 7 kilometers from La-ngu District. It can be seen on a cliff at the seafront accessible by a walking bridge from the national park office. This fault plane site is an important geological structure of the Satun Global Geopark. Cambrian red sandstone (Tarutao Group) which is overlain by Ordovician limestone (Thung Song Group) as a normal fault contact boundary between the two rock groups with different ages located on the high cliff with the seafront spanned up to the sea horizon far away. A walking bridge built by the Mu Ko Petra National Park is paved encircling the mountain along the seafront named the "Time-bounded crossing bridge". The Satun Geopark together with Mu Ko Pethra National Park and Satun Province have launched a concept of group wedding ceremony across the time-bounded location. This is to make a story for local people in learning about the geological site with

tourism industry stimulation. The site is thus a tourist spot with inheriting the group wedding tradition.

Geological diversity:
Rock diversity: Sandstone and limestone
Fossil diversity: Nautiloid
Structure diversity: Sedimentary bed and fault

Heritage value:
Scientific value: Sandstone and limestone Cambrian red sandstone of Tarutao Group and Ordovician limestone of Thung Song Group.
Cultural value: The myth Mat Chinchang etc.
Aesthetic value: different colour cliff and beautiful viewpoint.

Special features: tourists can see beautiful cliff at the seafront accessible by a bridge and walk across geological period.

Accessibility: Longtail Boat and Speed Boat

Status of conservation and development: Located in Mu Ko Phetra national park

Function: Recreational and education

Figure 61: Bird eyes view picture of Khao To Ngai Geological Time Boundary shows walking bridge and fault contract between Cambrian red sandstone of Tarutao Group and Ordovician limestone of Thung Song Group.

4.2.12 Prasat Hin Pun Yod Pinnacle Karst

Location: Pak Num, La-ngu District, Satun province
Latitude: 6.853082, Longitude: 99.695323
Zone: 47N Easting: 576825 Northing: 757563

Geological Information: Khao Yai Island is 3 kilometers far from Pak Bara Port and located in the area of Mu Koh Phetra National Park. Koh Khao Yai is essentially a sculptural work of nature, similar to rock castle which has a natural bridge protruding into the sea, whereby, during the low tide, boats can be rowed through. There is also a bay on this island called Kam Pu Bay with small falls and creeks. Kam Pu Bay is rather calm with no waves all year round and during the lowest tide, coral reefs and marine life will be very visible along the coastline. Moreover, sea turtles often come ashore and lay their eggs around Kam Pu Bay as well. Prasat Hin Panyod was formed by collapsed sinkhole of limestone. One of the important characteristics of limestone. It can be dissolved by rainwater. The less resistant part of limestone will be dissolved quickly showing groove and hole structures while the more resistant part is difficult to dissolve leaving the remain which look like sharp knife.

Geological diversity:
Rock diversity: Limestone
Fossil diversity: Nautiloid
Structure diversity: Pinnacle, sinkhole, beach, joint, sea cave

Heritage value:
Scientific value: Karst topography
Cultural value: -
Aesthetic value: beautiful karst topography and beach

Special features: The beaches and the emerald waters that hide in the rock face look like a castle with thousands of peaks.

Accessibility: Accessible by Longtail Boat

Status of conservation and development: Located in Mu Ko Phetra national park

Function: Recreational and education

Figure 62: (Top) Photo from top view of Prasat Hin Pun Yod show sinkhold and beautiful hidden beach in center. (Below) Spectacular pinnacle karst, view from inside sinkhole.

4.2.13 Khuan Klang Type Section

Location: Khuan Sung, Si-ngam village, Khuan Kat Urban, Muang District, Satun Province
Latitude: Longitude:
Zone: 47N Easting: 615658 Northing: 0731857

Geological Information: The type section has continuous exposure (500 m) currently mined in the eastern part of the hill. Good exposures of fresh rocks and continuous sequence without break are superb for studying characteristics of the rock units
Generally, rock units at the type section show E-W trending with southward dipping. Azimuth of beds varies from 25/155 to 50/225. Characteristics of strata are very smooth having a continuous sequence without movement of beds by faulting. However, in the northern part of the main, this sequence is affected by a thrust fault (85/250 in azimuth) with close and tight folds.

Faulting and jointing occurred in the area is characterized by the two directions of oblique strike-slip faults trending NE-SW and NW-SE directions. Cleavages are well developed particularlly in argillite strata with general 45/165 and 60/220 directions. Three formations of rock units, approximately 213 m thick, recognized in this type section are described in detail, in ascending order, as follows;

a. Devonian Pa Samed Formation

The exposures of this formation are represented by natural outcrops at the lower level located in the northeastern part of the main quarry. The sequence is measured to be more than 33.5 m thick. The rock units comprise two lithofacies. Lithofacies 1 is represented by shales interbedded with mudstones. Shales are light brown and fissile. Mudstones are reddish brown, pale reddish brown and white, laminated, thin-bedded (5-10 cm). Tentaculites elegans, Nowakia sp., trilobites and bioturbation are abundant in mudstone. Lithofacies 2 is carbonaceous shale, lenses, sharp, wavy, dark grey to black, thin- to medium-bedded (5-20cm) intercalated with light brown, very thin-bedded, laminated claystone. Tentaculites elegans, Nowakia sp. and graptolites are abundant in carbonaceous shale. It is recognized that the Tentaculites was filled with pyrite.

b. Lower to Middle? Carboniferous Khuan Klang Formation

The exposures of this formation are represented by natural outcrops, road cuts and quarries in the northern and central parts of the main quarry. The sequence was measured to be more than 150.65 m thick. The Khuan Klang Formation at the type section can be divided into 5 subunits.
(i) Lower clastic member the lowest member is continuously underlain by the carbonaceous shale of the Pa Samed Formation. The member A is generally characterized by the presence of interbeds of sandstones, mudstones and claystones with 64.95 m in thickness. *Posidonomya* sp. and fossil assemblages are occasionally found. Sandy siltstones and sandy mudstones are light brown and yellowish brown, dirty, thin-bedded with abundant Posidonomya sp
(ii)Siliceous rocks member: The member shows tight and recumbent folds chert within the mudstones and claystones in the upper portion of the member
(iii)Middle mudstone and claystone member: The rock sequences are characterized by light colour, thick to massive mudstones and claystones, and some lenses of sandstones beds with 38.50 m thick. Fossilifeous beds of *Posidonomya* sp are occasionally found.
(iv)Upper lithic sandstone member: The member sequences are characterized by cycles of conglomerates-pebbly sandstones-sandstones-mudstones with 6 m thick
(v)Upper mudstone member: The member E is generally characterized by the presence of mudstones intercalated with sandy siltstone and sandstones with 37.00 m in thickness. Well preserved *Posidonomya* sp., ammonites, bivalves, crinoid stems and lignite jet are usually found. *Posidonomya* sp., pygidiums of trilobites, ammonite and plant remains are very abundant. Sandstones are white, loose, lenticular bed, medium-bedded (20-30 cm). Cross lamination, flaser lamination, mud cracks, ripple structures and iron hard pans are also associated.

c. Lower Permian Kaeng Krachan Group

The exposures of this formation are represented by natural outcrops and quarries located in the southern part of the main quarry. Thickness of this group in the type section area exceeds to 26.5 meter. The sequence consists of interbeds of slaty shales, sandstones, and para-conglomerates. Generally,

beds of rock are well-bedded, sharp, wavy, non-parallel. Slaty shales are dark grey to dark greenish grey, very thin- to very thick-bedded. Lamination, load cast and graded bedding are commonly found (Figure 33 and 34). It is remarked that the developed cleavages are strongly affected in these argillites. Sandstones are greenish grey, fine- to coarse-grained, lithic, wacke and thin- to thick-bedded. Discontinuous lamination and graded bedding are very common. Para-conglomerates are occasionally found and characterized by greenish grey, medium-bedded, poorly sorted. Clasts are quartz, chert, and pebbles of rock fragments.

Geological diversity:
Rock diversity: shale, sandstone, para-conglomerate, siltstone, mudstone and claystone
Fossil diversity: Tentaculites, trilobites, ammonites, bivalves, crinoid stems and Bivalve (*Posidonomya* sp.)
Structure diversity: Faulting, jointing, sedimentary bed

Heritage value:
Scientific value: type section of Khuan Klang Formation
Cultural value: -
Aesthetic value: Old quarry

Special features: Good exposures of fresh rocks and continuous sequence without break are superb for studying characteristics of the rock units

Accessibility: Accessible via pathed road

Status of conservation and development: Located in private area

Figure 63: (Left) Outcrop of Pa Samed Formation (Right): Fossil assemblages in Pa Samed Formation *Tentaculites elegans, Nowakia* sp.

Figure 64: Exposure and outcrop of Khuan Klang Formation

Figure 65: (Left) Interbeds of sandstone and slaty shale of kaeng Krachan Group (Right) Dark grey to black, slaty shale with well-developed cleavages of the Kaeng Krachan Group.

4.3 SADAO AREA

4.3.1 C-TR Boundary

Location: Road cut from Sadao - Khao Nam Kang road, Na Thawi District, Songkhla Province
Latitude: Longitude: 6º 34.580'N, 100º 33.752'E to 6º 37.165'N, 100º 36.755'E
Zone: 47N Easting: Northing:

Geological Information: The reference section has 50% exposure as 7 km long and 5-10 m high along the road cut in the mountainous terrain. Good exposures of rocks with index fossil assemblages having superb for studying characteristics of the rock units.

Rock units in the reference section have generally N-S to NNW-SSE trending with both eastward and westward dipping. Tight and closed folds are commonly found in this area. Generally, azimuth of beds varies from 35/070 to 50/085 and 25/265 to 30/270. Main faulting and jointing occurred in the area is characterized by the normal and oblique strike-slip faults trending NW-SE and NNW-SSE directions. Steep dipping of beds and repeated sequence on the Yaha Formation are locally observed near the fault zone. Two Formations of rock units which bounded by NW-SE

oblique strike slip fault are recognized in this reference section. Described rock unit, in detail, can be explained in ascending order:
1. Early Carboniferous Yaha Formation is characterized by the presence of thick sequence of mudstone intercalated with thin- to medium-bedded, laminated, sandstone. Bivalve of Posidonomya sp., ammonites, trilobites and crinoids are observed. Above the sequence, unit is consisted of shale and tuffaceous shale intercalated with sandstone followed by well-bedded cherts or siliceous shale and sequence of thick-bedded sandstone. The upper part of the formation comprises grey to greenish-grey, laminated mudstones with the bivalve Posidonomya sp. and crinoids. The Yaha Formation in this area was measured to be more than 380m in thickness.
2. Triassic Na Thawi Formation consisting of rhythmic alternation of sandstone and shale or mudstone. The rock is light grey in color, parallel bedded ranges from 10 to 50 cm in thickness. 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.

Geological diversity:
Rock diversity: sandstone, shale, and mudstone
Fossil diversity: Bivalve of *Posidonomya* sp., ammonites, trilobites and crinoids
Structure diversity: bed, ripple marks and load

Heritage value:

Scientific value: contact between Early Carboniferous Yaha Formation and Triassic Na Thawi Formation
Cultural value: -
Aesthetic value: -

Special features: Time boundary of the Carboniferous and Triassic succession.

Accessibility: Accessible via pathed road

Status of conservation and development: Located in Public area

Function: Recreational and education

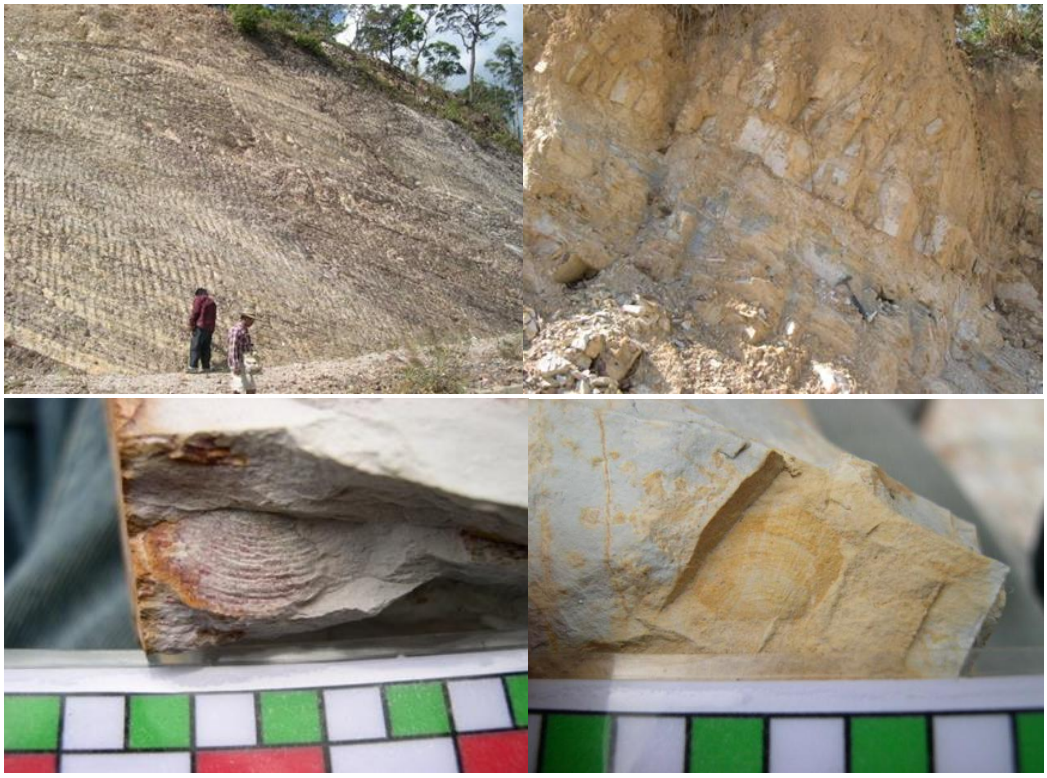

Figure 66: Exposures of the Yaha Formation along the road cut from Sadao- Khao Nam Kang road, Na Thawi District, Songkhla Province a) well-bedded sandstone and mudstone b) medium-thick-bedded sandstone and thin-bedded mudstone c) and d) fossil assemblages at the Upper member.

4.4 BETONG AREA

4.4.1 Piyamit Tunnel And Granite

Location: Ban Phiyamit 1, Ai Yoe Weng area, Betong district, Yala province
Latitude: Longitude:
Zone: 47N Easting: Northing:

Geological Information: This tunnel winds through a mountain for approximately 1 kilometer and is nearly 20 meters wide at certain points, with multiple entrances. It was built in 1976, taking three months to complete. Though the area is presently part of a village belonging to the Thai National Development Front, it was once a stronghold of the Communist Party of Malaya. It was once used as an air raid shelter and food storage area. At present there is an exhibition about the history of Piyamit Tunnel, including the way of life in the forest. The tunnel located in granite area. The granite is medium- to coarse grained, light grey in colour with good primary granitic texture. K-feldspar can be observed as large megacrysts of light grey to chalky white colour with elongate to tabular, euhedral to subhedral habits. Their population varies from sparsely megacrysts to locally concentrated megacrysts. Weakly foliated K-feldspar megacrysts are locally observed. Biotite groundmass is observed as euhedral book crystals and subhedral to anhedral flaky

crystals with single to clusters habits. Plagioclase is present in the groundmass as chalky white colour, euhedral to subhedral crystals with tabular to equant habits. K-feldspar groundmass forms subhedral to euhedral crystals with tabular habit.

Geological diversity:
Rock diversity: granite
Fossil diversity: -
Structure diversity: joint

Heritage value:
Scientific value: composition of granite.
Cultural value: history of Communist Party in the most southern Thailand.
Aesthetic value: exhibition about the history of Piyamit Tunnel

Special features: exhibition about the history of Piyamit Tunnel

Accessibility: Accessible via pathed road

Status of conservation and development: Located in private area.

Figure 67: (Left) Characteristic of Porphyritic granite around Piyamit tunnel.
(Right) The front of Piyamit tunnel shows that it has been decorated relate to history of Communist Party.

4.5 SUNGAI KOLOK

4.5.1 To Mo Gold Mine

Location: Abandon To Mo gold Mine, To Mo, Sukhirin District, Narathiwat Province
Latitude: Longitude:
Zone: 47N Easting: Northing:

Geological Information: 61 years ago, it was the location of the To Mo gold mining with the French as the operator of the concession and later in 1931, the Great Eastern War broke out. The To Mo gold mining was shut down and the concession owner fled the war to return to France. Currently,

there are still structures such as the residence, the original office, 4 main tunnels and many sub-tunnels. The mine is a historical and cultural attraction that has been built by human beings. Gold in To Mo gold mine was found in granite that are exposed in the southern part of Licho-Balu mountain range, extending southward across the border to Malaysia. They are composed of granodiorite, granite, dolerite, pegmatite and aplite, which are exposed as dykes, veins and veinlets. The granitic rocks are also well exposed along the stream at the electric power plant in Ai Ka Po village. The general characteristic of granite is characterized by light grey, fine-grained, equigranular biotite-hornblende granite which is partly sheared and modified. It is also noticeable that the intrusions of aplite, pegmatite and leucocratic granite as dykes and sills has initiated contact metamorphism of the country rocks (schist phyllite and other low-grade metamorphic rocks) and subsequently gold mineralization has been introduced within the contact aureole.

Geological diversity:
Rock diversity: granodiorite, granite, dolerite, pegmatite, aplite, biotite-hornblende granite
Fossil diversity: -
Structure diversity: dykes, veins and veinlets

Heritage value:
Scientific value: gold mineralisation has
Cultural value: History of ancient gold mine in Thailand.
Aesthetic value: structures of gold mine tunnels.

Special features: Tourist can see lifestyle of ancient miners and structures of gold mine tunnels.

Accessibility: Accessible via pathed road.

Status of conservation and development: Located in private area.

4.5.2 I-Type Sirindhone Waterfall

Location: Sirindhone waterfall, Hala-Bala National Park, Waeng District, Narathiwat Province
Latitude: Longitude:
Zone: 47N Easting: Northing:

Geological Information: The Kenerong Granite/Ba La granite (Kgrkn/bl) typically shows various types of granite, which forms a granite complex body. They intrude as subordinate late-stage granite intrusions, which occur as dykes and veins including leucocratic granite and pegmatite into the Kemahang Granite/Sukhirin granite (Trgrkg/su). The Ba La granite unit can be lithologically subdivided into four phases:

1. The first granite phase is represented by the NNW-SSE foliated, dark grey, mediumgrained (1-3 mm), equigranular to porphyritic biotite granite. K-feldspar phenocrysts are up to 3-5% by volume and are mainly of 1-3 cm in diameter equant crystals. The mineral composition of groundmass including 30% quartz, 50-60% K-feldspar and plagioclase and 15-20% flakes and elongated cluster biotite.

2. The second granite phase is characterised by N-S trending foliation, pale grey to light grey, equigranular, fine-grained, leucocratic granite including feldspar-rich pegmatite. The mineral composition consists of 30-40% quartz, 50-65% feldspar and 3-5% biotite, whereas red garnet is the only accessory mineral found in this rock.

3. The third granite phase is composed mainly of dark greenish grey fine-grained equigranular granodiorite, slightly-moderately foliated in N-S direction. The mineral composition consists of quartz, feldspar and biotite. This phase generally occurs as dykes and veins trending WSW-ENE to NW-SE. The xenoliths of two-phase variants granites are locally included in this granite phase.

4. The fourth granite phase consists mainly of minor intrusions of pegmatite and aplite veinlets, trending N-S, NE-SW and E-W. Cross-cutting relationship can be observed clearly along the road cut at the top of the mountain and also at the Sirindhorn waterfall.

Bignell (1972) reported that the western part of the Eastern Belt Granite in Malaysia that lies immediately east of the Bentong-Raub Suture gave the age of 64-69 Ma, which indicates granite intrusion during the Cretaceous. According to field observation as mentioned earlier by Cobbing et al. (1992), it can be concluded that the age of intrusion of Ba La granite is Cretaceous.

Geological diversity:
Rock diversity: leucocratic granite and pegmatite
Fossil diversity: -
Structure diversity: dykes, veins. joint

Heritage value:
Scientific value: Four phases of Ba La granite
Cultural value: -
Aesthetic value: Beautiful waterfall

Special features: Beautiful morphology and white shell beach.

Accessibility: Accessible via pathed road.

Status of conservation and development: Located in Hala-Bala National park.

Figure 68: General views of To Mo Gold Mine

5. DISCUSSION AND CONCLUSION

Geotourism has become more visible as one of potential economic income which benefits directly to the communities. This revives the conventional preservation by developing the potential geoheritage sites sustainably through integrated effort including continuous educational and awareness activities. Systematic assessment and data inventory of potential geoheritage sites along Malaysia and Thailand Border is essential in facilitating next step to geotourism. Langkawi UNESCO Global Geopark and Saturn UNESCO Global Geopark are the best example on how these geoheritage sites had been developed successfully and benefiting the local communities while preserving these sites.

Geotourism activities can support the geoheritage site conservation in Thailand – Malaysia Border. It can increase socio-economy in the area by creating a new income to local people. Geo-guides play an important role in geotourism by linking "geoscience knowledge" with "tourism activities". Therefore, an intensive and expensive high quality training course of geoscience, local history, culture, and tourism should be provided to geo-guides to ensure a well understanding of these key aspects. Geo-guides act as 'the eyes and ears' to spread the awareness and education about sustainable natural resources and protection to public. Field guide handbooks and info panels are useful materials to assist geo-guides in explaining scientific information to tourists.

Developing these potential geoheritage sites requires collective and cooperative effort from local authority to local community.

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