Review of the Palaeozoic Stratigraphy of the Langkawi Islands, Malaysia

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INTRODUCTION

The Langkawi group of 99 islands off the northwest coast of Malaysian Peninsula is located some 30 km off the coast of Perlis and 112 km north of Penang. These islands are a paradise for geologists, including some of the best and most interesting exposures of Palaeozoic sedimentary rocks in Malaysia, ranging in age from Cambrian to Permian. These consist of both clastics and carbonates, deposited within a range of depositional and palaeoclimatic conditions ranging from shallow marine shoreface to turbidites with dropstones. In addition, these sedimentary rocks had been intruded by younger Mesozoic granites with considerable contact metamorphic effects.

Since the initial publication of the Geological Map of Langkawi and the subsequent Geology and Mineral Resources Memoir 17 on the States of Perlis, North Kedah and the Langkawi Islands, both by Jones (1966, 1981) many more recent studies had been carried out. These studies were particularly facilitated by the creation of new outcrops due to numerous recent development projects on the islands. A helpful compilation of published and unpublished geological researches on Langkawi was compiled by Sarman et al. (1997).

The spectacular geological heritage of the islands heralded the formation of the Langkawi Geoforestpark by the Kedah State Government, Malaysia in May 2006 to preserve and display its unique geological features. The Geoforestpark was endorsed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) under the Global Network of National Geoparks in June 2007 (Leman et al., 2007).

REGIONAL GEOLOGICAL SETTING

Langkawi is located within the Northwestern Domain of the Western Belt of Peninsular Malaysia (Figure 1) which is an integral part of Sundaland, the SE Asian extension of the Eurasian plate.

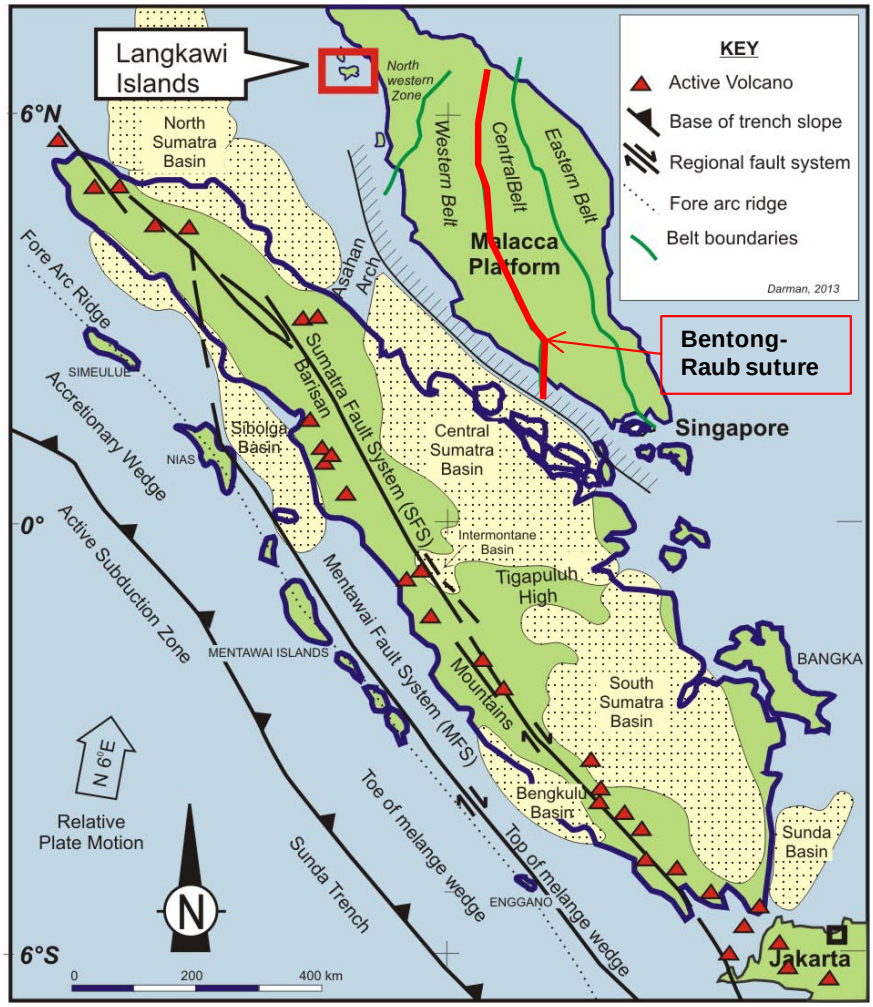


Figure 1. *Location map of Langkawi Islands. The three belts and northwestern domain within the Western Belt are after Lee (2009). Sumatra map is after Darman & Sidi (2000).*

The Paleozoic sedimentary rocks of Langkawi are mostly shallow-marine shelf type deposits that extend within a broad linear belt from South China, through Burma, Thailand, and northwest Peninsular Malaysia into northern Sumatra. These sediments form part of the Sibumasu Block which broke away from northwestern Australia at the northern edge of Gondwanaland, to subsequently collide with the Indochina or East Malaya block along the Bentong-Raub Suture during the Triassic (Metcalfe, 2000; Hutchison, 2009a). The above-mentioned Northwestern Domain is part of the Patani Metamorphic Terrane related to this plate tectonic suturing episode.

Cenozoic uplift of the Langkawi chain of islands is related to the peripheral effects of later Neogene collision of India with Tibet creating the Himalayas as well extrusion of Sundaland to the southeast (Tapponier et al., 1982). In addition, the Langkawi islands, being geographically located on the northern cratonic margin of the North Sumatra Basin, have been affected by Neogene block faulting caused by back arc extension associated with the continuous northwards push of the Australian Plate under the Eurasian Plate (Raj et al., 2009).

STRATIGRAPHY OF LANGKAWI

The Palaeozoic sedimentary rocks in Langkawi are traditionally subdivided into four formations (Jones, 1981), although newer more detailed stratigraphic subdivisions have been proposed (Cocks et al. 2004; Meor and Lee, 2004; Lee, 2009). These units are, from the oldest to the youngest, the Machinchang, Setul, Singa and Chuping Formations. Their geographical distribution and stratigraphic relationships are given in Figures 2, 3 and Figure 4, respectively. They are mostly shallow marine shelf type deposits and are discussed as follows:

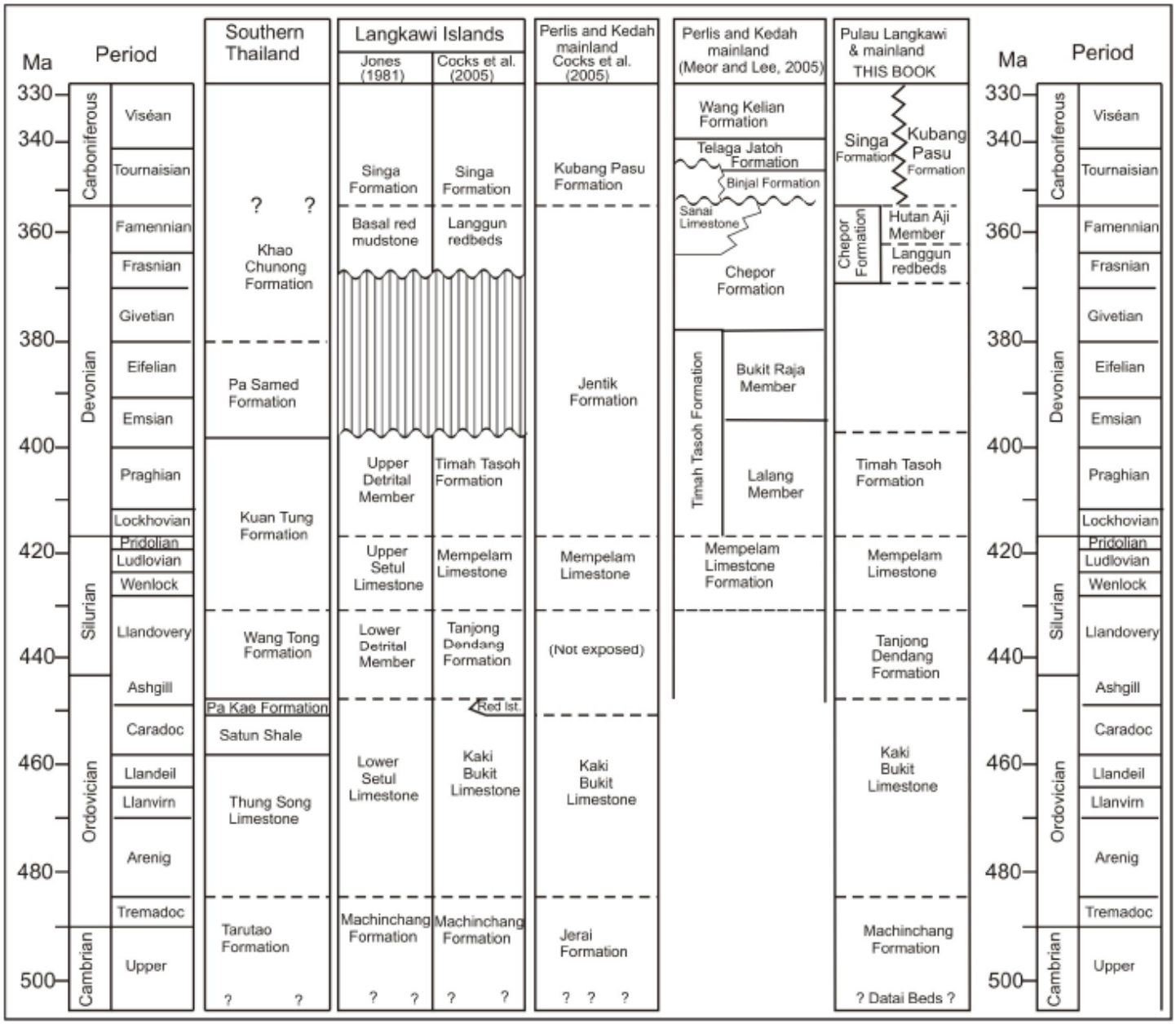


Figure 2. *Revised stratigraphy of Palaeozoic rocks up to the Singa Formation in the Northwestern Zone of Peninsular Malaysia (after Lee, 2009).*

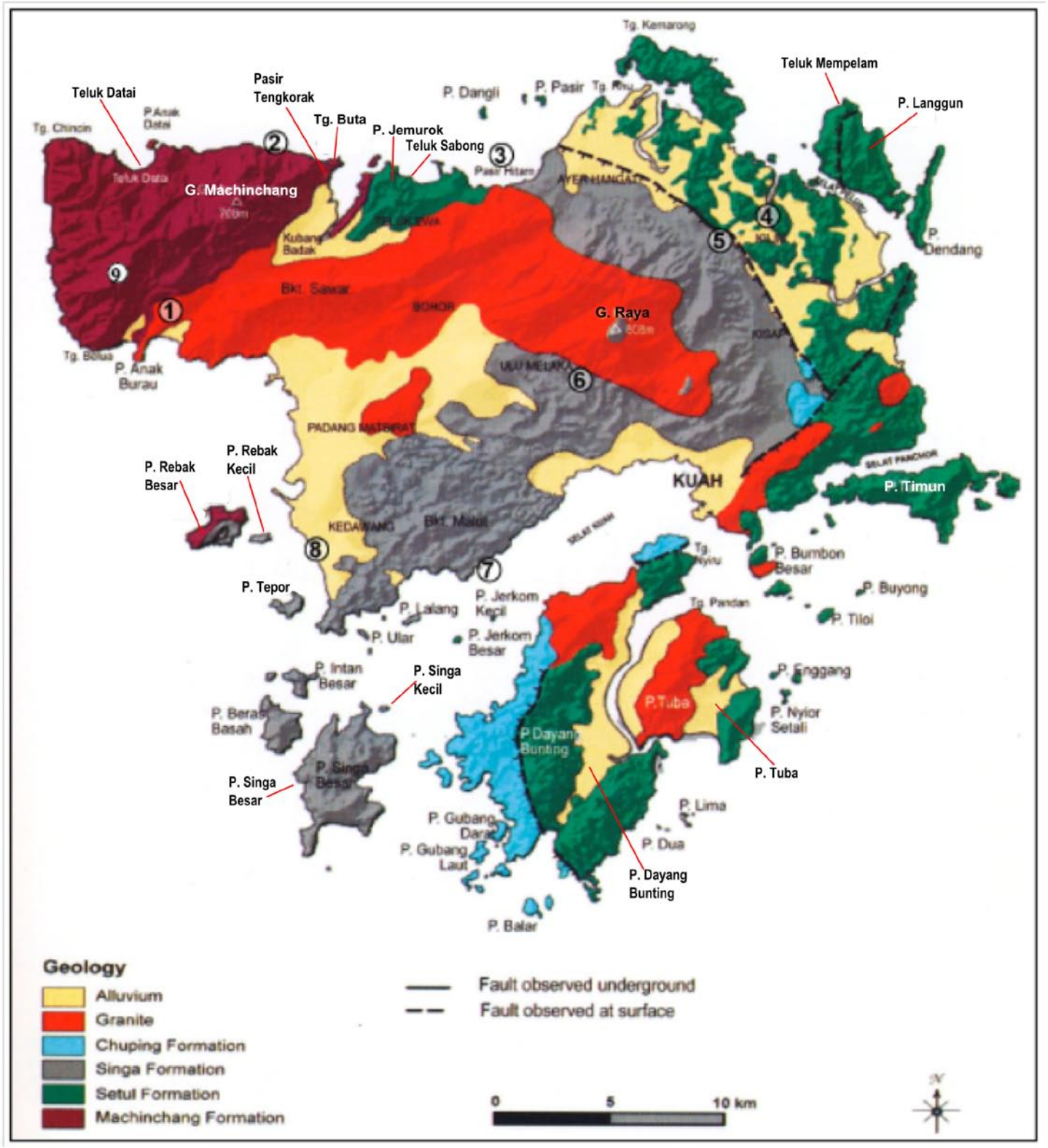


Figure 3. *Geological map of Langkawi Islands showing distribution of the various rock formations in the islands (after Leman et al., 2007). Common stops on field trip are numbered in circles.*

1. Machinchang Formation

The Machinchang Formation type locality is derived from the conspicuous long serrated quartzite ridge of five peaks aptly called Gunung Machinchang or Mat Chinchang meaning "chopped-up mountain" (Figures 5a & 5b).

This formation is composed of a thick succession of predominantly arenaceous rocks with minor interbeds of conglomerates, phyllitic slates and tuffs exposed in the northwestern corner of Langkawi. It has been divided into three members (Figure 6) according to Lee (2006) with a coarser sandy middle member sandwiched between two finer grained members. The overall depositional environment is that of a high-destructive, wave-dominated delta which had built over an offshore shelf deposit to produce a series of barrier-beach sands cut by small channels (Lee, 2006).

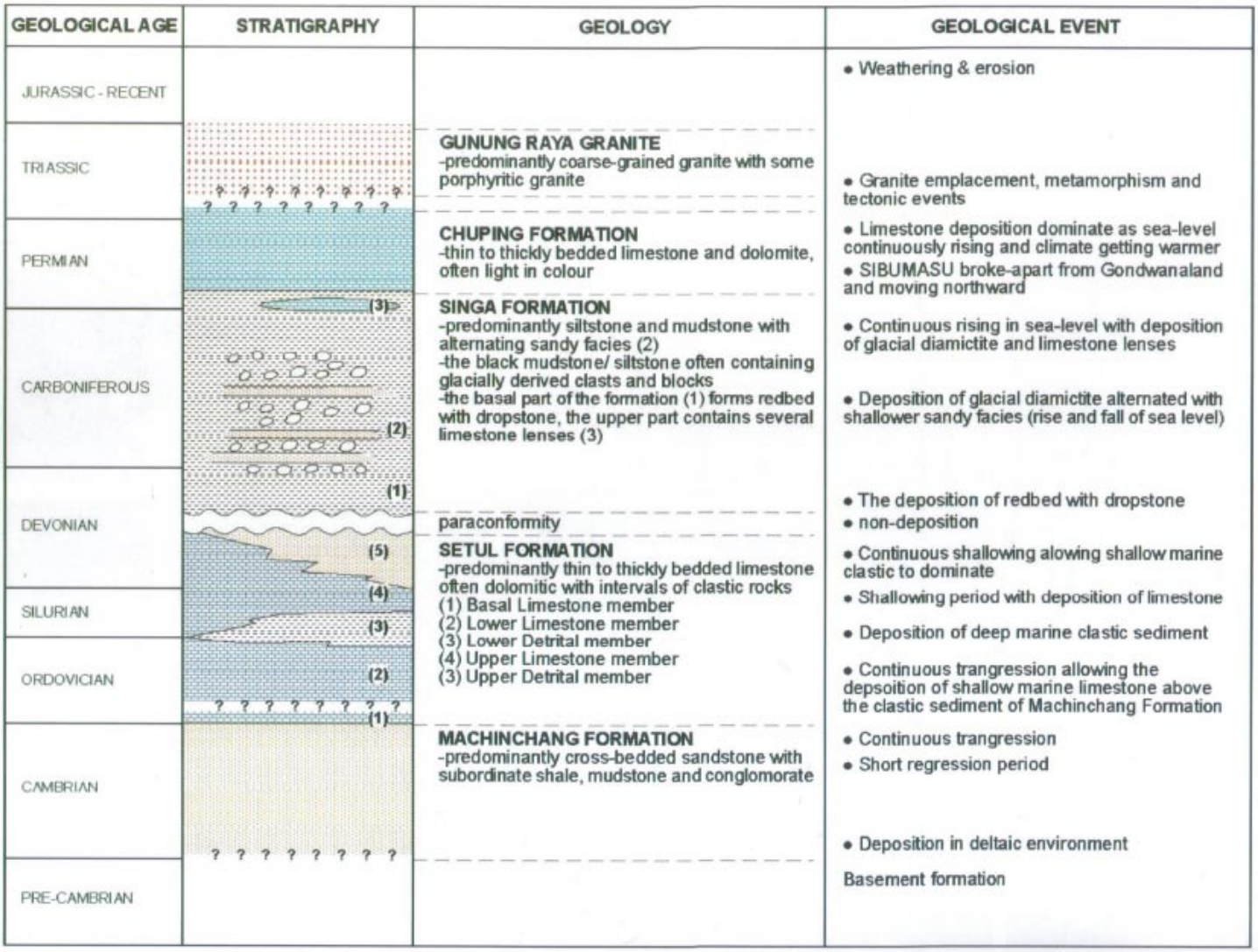


Figure 4. *Stratigraphy and major events in geological history of Langkawi islands (after Leman et al., 2007).*

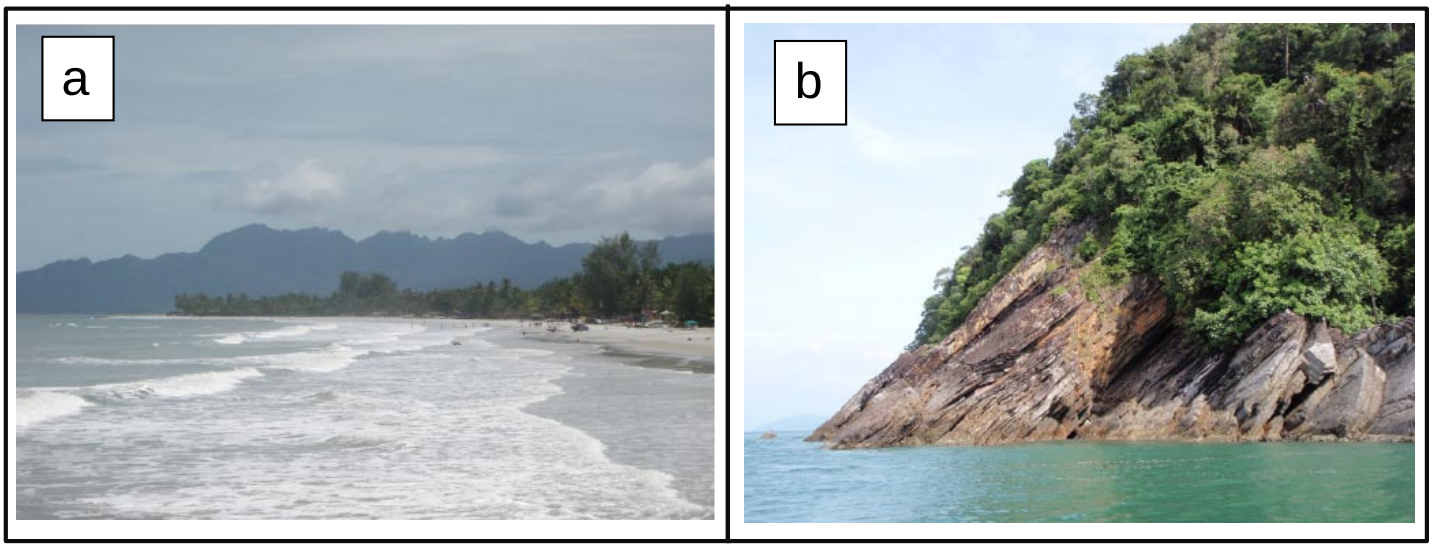


Figure 5. *a) "Chopped up" Machinchang Range view from the south; b) Machinchang Formation deltaic sandstone beds in western limb of anticline dipping steeply into Malacca Strait.*

In the Machinchang area these rocks spectacularly outcrop as an asymmetrical anticline with a relatively undisturbed western limb that dips and plunge into the waters of the Straits of Malacca (Figure 5b). Up section occurs a gentler more dome-like eastern limb that probably had been uplifted by underlying Mesozoic granite (Lee, 1983). The base of the formation is not exposed and the oldest part of the formation is the pelitic rocks exposed in the core of the Machinchang Anticline at Teluk Datai. The top of the formation has several thin calcareous horizons before passing conformably up into the succeeding Setul Formation limestone near Teluk Sabong.

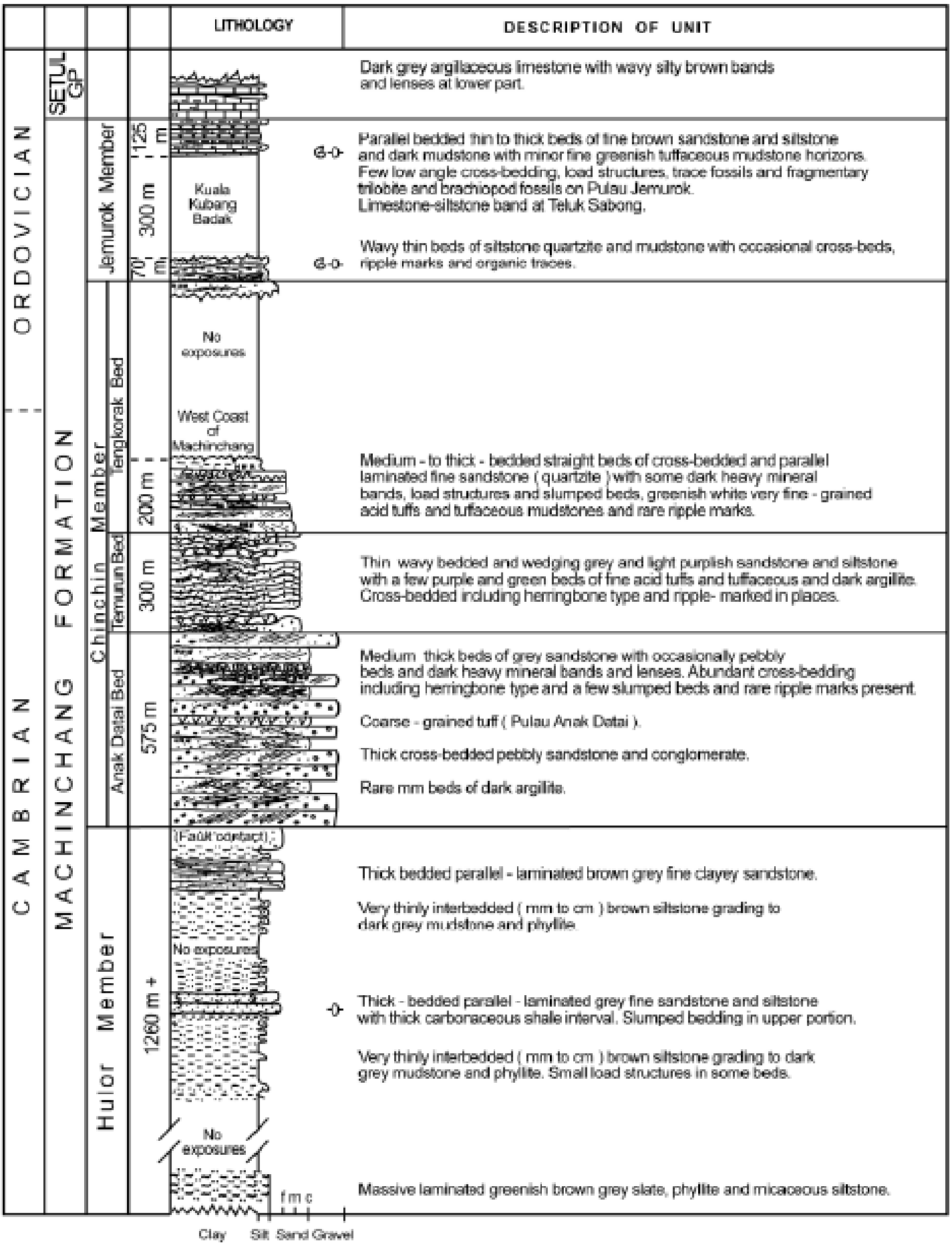


Figure 6. *Stratigraphy of the Machinchang Formation (after Lee, 2006).*

Interesting trace fossils including *Dictyodora* (Lee, 1980) and sedimentary structures such as various types of cross-beddings, convolute bedding and load casts can be seen in the upper parts of the formation at Pasir Tengkorak and Pulau Jemurok. Palaeocurrent studies on the abundant cross-beddings found in the formation gave a predominantly westward downcurrent direction.

The Machinchang Formation is poorly fossiliferous and only poorly preserved fragments of trilobites and brachiopods had been found at Tg. Buta and Pulau Jemurok. Better preserved fossilized saukid trilobites and orthid brachiopods are found on Tarutao Island just 5 km north of Langkawi in Thailand which give a Late Cambrian to Early Ordovician age to the uppermost part of the Machinchang Formation. This is confirmed by fission track studies on zircon crystals which give an age of 555±37 Ma.

Acid volcanics or tuffs also occur as thin, fine grained, pale green layers in the Machinchang Formation indicative of acid volcanism during Cambrian times.

2. Setul Formation

The Setul Formation ranges in age from Early Ordovician to Early Devonian. It is divisible into a Lower Setul Formation of Ordovician age, occurring below the Lower Detrital Band on Pulau Langgun and a Silurian to Devonian Upper Setul Formation above this band (Figure 4). The top of the formation is represented by the Upper Detrital Band, a largely arenaceous unit with minor argillaceous beds at Teluk Mempelam on Pulau Langgun. The formation has been estimated to be about 1500 m thick and was raised to group status in Cocks et al. (2005) and Lee (2009).

The Setul Formation is made up of predominantly dark coloured shelfal limestone with minor black detrital bands. It is largely metamorphosed on the main island but good fossiliferous outcrops of the limestone are present in the vicinity of Pulau Langgun. The impure limestone contains a rich fauna of fossils such as gastropods, bivalves, nautiloids, brachiopods, trilobites, crinoids and stromatolites while the hardened black mudstones have preserved graptolites, tentaculitids and trilobites.

The unusual scyphocrinoid, probably *Camarocrinus* (Figure 7), with its calcareous floating lobolith has been discovered (Lee, 2005) from the top part of the Upper Setul limestone at Teluk Mempelam on Pulau Langgun. It is restricted in age to the uppermost Pridolian-lowermost Lochkovian (Late Silurian to Early Devonian) and enables correlation with similar limestones in Myanmar (Ayeko Aung, *pers comm.* 2010). Microfossils such as conodonts and ostracods are also found in these limestones.

3. Rebanggun Beds

The quartzitic sandstones and red to grey mudstones known as the Rebanggun Beds outcrop on Pulau Rebak Besar and Pulau Rebak Kecil and have been grouped together with similar beds found above the Setul Formation at Pulau Langgun.



Figure 7. *Upper Setul limestone bed with scyphocrinoid loboliths at Teluk Mempelam, Pulau Langgun, northeast Langkawi.*

Correlation with better exposed sequences in Perlis has placed the Langgun Redbeds higher up instead of at the base of the transitional unit (Lee, 2009) to the Singa / Kubang Pasu Formations. Fossils in this unit are sparse and consist of small ambocoeliid brachiopods, *Posidonomya* (*Posidonia)* bivalves and the trilobite *Macrobole kedahensis*. The age of the unit is probably Early Carboniferous

4. Singa Formation

The Singa Formation is best exposed in the southwestern part of Langkawi. The basal contact with the Rebanggun Beds is unexposed and the top is gradational into the overlying Chuping Formation limestone that is exposed on Pulau Singa Kecil.

The age of the formation is probably Carboniferous to Early Permian. The Singa Formation, named after Pulau Singa Besar, is a clastic unit typified by crudely laminated, dark grey, poorly sorted mudstones with scattered dropstone horizons. The dropstones range in size from granules to boulders (Figure 8) and are mainly composed of sandstone with subordinate limestone, vein quartz, granitic, volcanic and metamorphic rocks.

They have been interpreted as glacial marine dropstones derived from peri-Gondwana margin ice sheets during the Carboniferous (Stauffer & Mantajit, 1981; Stauffer & Lee, 1986). Fossils are only common in its uppermost section but burrows and soft sediment deformation structures can be found in some parts. Long paired vertical burrows exceeding a meter in length are found on Pulau Tepor. The brachiopods found in the uppermost part of the formation associated with dropstone horizons at Kilim, Batu Asah and Pulau Singa Besar are “cool-water” forms of Permian (Visėan) based on *Macrobole* and its stratigraphic position above Late Touraisian chert beds. These fossiliferous mudstones and associated sandstones that are pebbly in places were deposited in a quiet prodelta environment with occasional turbiditic input. These redbeds are quite widespread and correlatable with the Khao Chunong Formation in south Thailand.
(Sakhmarian) age (Waterhouse,1982; Leman, 2003). Other associated fossils are bryozoa, bivalves, gastropods, corals and crinoid stems. Sandstone beds are few and often calcareous.

The formation can be correlated with similar glacial marine diamictites found in the Mergui, Martaban and Lebyin Groups of Myanmar, the Kaeng Krachan Formation of the Phuket Group in Thailand and the Bohorok Formation of Sumatra.

5. Chuping Limestone

The Chuping Limestone is a unit of thickly bedded to massive, light coloured limestone (Figure 9) that sits conformably above the Singa Formation in the southeastern part of the island. It can be easily distinguished from the more clayey and darker coloured Setul limestone.

The Chuping limestone is fossiliferous in its basal part with fusulines, brachiopods, bivalves, gastropods, corals, bryozoans and algae ranging from a late Early Permian or early Middle Permian age in Langkawi to the Triassic on the mainland (Metcalfe, 1990). Chert nodules are common at its base in Pulau Singa Besar. The once famous Langkawi marble is a white saccharoidal ornamental stone quarried from metamorphosed equivalents of this limestone in southeastern Langkawi and Pulau Dayang Bunting.



Figure 8. *Glacial marine dropstones in pebbly mudstone horizon in Singa Formation at Pulau Ular.*



Figure 9. *White coloured marble of Chuping Formation behind former Kedah Marble factory near Kisap.*



Figure 10. *Tourmaline-quartz vein in Langkawi granite block.*

Mesozoic Igneous Rocks

Two granitic bodies are found in the islands. The Raya and Tuba granites cover some 113 km^2 of the islands. The huge Gunung Raya massif which rises to 878 m forms the highest part of the island. It is Late Cretaceous in age while the smaller pluton in Pulau Tuba is Late Triassic in age. The granites are petrographically similar and hard to distinguish in the field. Both are porphyritic biotite granites with tourmaline clots and veins (Figure 10).

Large K-feldspar phenocrysts and spherical quartz phenocrysts are common. Alignment of the large K-feldspar crystals is common at the margins of the plutons. The Raya Granite appears to be the most southerly body of a belt of Late Cretaceous granite extending from west Thailand.

Metamorphic Rocks

Langkawi occurs within the Patani Metamorphic Terrane which trends northwest from mainland Kedah (Khoo, 1984) Rocks older than mid-Permian within this terrane have suffered severe deformation and low grade regional metamorphism related to the collision of the Sibumasu micro-plate with Indochina Rocks of the Machinchang, Setul and the Singa Formations have developed at least one set of low angle cleavages.

These rocks occur as slates, phyllites, quartzites and fine grained marbles where unaffected by later contact metamorphism while rocks adjacent to the granites have recrystallized to mica schists, coarse grained marbles and tough metaquartzites. Small bodies of skarn have developed at the contacts between the igneous intrusions and some of the limestones.

CONCLUSIONS

Langkawi plays an important role in the palaeogeographic reconstruction of the northwestern part of Peninsular Malaya.

The discovery of Lower Permian (Sakmarian) cool-water shelly fauna particularly brachiopods in the Singa Formation (Waterhouse,1982; Leman, 2003; Shi et al., 1997) in addition to glacial marine dropstones (Stauffer & Mantajit, 1981; Stauffer & Lee, 1986) has enabled correlation with similar deposits in the Canning Basin of Australia (Hutchison, 2009b). This establishes the connection of Langkawi to Gondwana in pre-Late Permian times, when it formed part of the Sibumasu microcontinent.

Sibumasu subsequently drifted north into lower palaeo-latitudes and eventually collided with the warmer climate provinces of the Indochina Block of Cathaysia, along the Bentong-Raub Suture of Peninsular Malaysia during the Late Triassic.

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