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Contributions from the Geology of Northeast Langkawi to Refining the Mid-Palaeozoic Stratigraphy and Palaeogeography of Peninsular Malaysia

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ABSTRACT Several localities of geological interest in northeast Langkawi are described. A new stratigraphic nomenclature is introduced based on observations on Pulau Langgun. The Kilim brachiopod beds provide clues to a glacial event during the Late Palaeozoic, and indicate close proximity of Langkawi to the super continent Gondwana during that time.

ABSTRAK Beberapa lokaliti yang menarik dari segi geologi di bahagian timur laut Langkawi diperihalkan. Satu pengelasan stratigrafi yang baru diperkenalkan berdasarkan pemerhatian di Pulau Langgun. Perlapisan-perlapisan brachiopod di kawasan Kilim memberi bukti wujudnya satu peristiwa penglasieran semasa Palaeozoik Lewat, dan data menunjukkan perhubungan geografi kuno yang rapat antara benua besar Gondwana dengan Langkawi.

(Langkawi, geology, stratigraphy, paleogeography, palaeoclimate)

INTRODUCTION

The Langkawi group of islands, off the coast of Perlis state, Peninsular Malaysia, possesses one of the most complete exposures of Palaeozoic rocks in Malaysia ranging in age from Cambrian (~540 million years ago) to Permian (~260 million years ago), which provides a glimpse of the early history of the region, spanning more than 250 million years. This paper focuses on the northeastern part of the Langkawi Islands, especially the area around Kilim, and the islands of Pulau Langgun and Pulau Tanjong Dendang. Some recent geological findings are also highlighted, and their implications to our understanding of the tectonic history of Peninsular Malaysia are discussed.

Outline of Langkawi Geology

The Langkawi group of islands consists of 104 islands located some 30km off the coast of Perlis and 112km north of Penang. Jones [1] produced the first detailed geological map of Langkawi, followed by a comprehensive study on the geology of Perlis, north Kedah and Langkawi [2]. These remain the definitive references on the geology of Langkawi.

The rocks that are found in the Langkawi island group can be divided into two main groups, namely, sedimentary rocks and igneous rocks (Figure 1). Sedimentary rocks are the predominant lithology and range in age from the Cambrian to Permian. These sedimentary formations consisting of both clastics and carbonates had been deposited within differing palaeoenvironments and under different palaeoclimates. Jones [1] originally placed the Palaeozoic sedimentary rocks of Langkawi under four formations. They are, from oldest to youngest:-

Machinchang Formation
Setul Formation
Singa Formation
Chuping Formation

The oldest dated rocks on Langkawi are mudstone, siltstone and quartzitic sandstone beds of the Machinchang Formation, which forms the Machinchang anticline in the northwestern part of the main Langkawi Island. Fossils from similar rocks on Tarutao Island, just 5km north of Langkawi, give a Late Cambrian to Early Ordovician age to the uppermost part of the Machinchang Formation, while fission track studies on zircon grains give an age of 555±37 million years [3]. Rocks definitely older than

Cambrian are not exposed on Langkawi, but Tjia [4] reported a Datai Formation paraconformably underlying the Machinchang Formation in northwest Langkawi, which he suggests to possibly be Precambrian in age.

The Setul Formation [1] is predominantly made up of dark coloured platform carbonates with minor black detrital bands. These beds are widely exposed on the eastern shore of Langkawi (Figure 1). The Setul Formation is divisible into a Lower Setul Limestone of Ordovician age occurring below black flaggy shales of the Lower Detrital Member containing latest Ordovician to earliest Silurian fossils (Figure 6); followed by an Upper Setul Limestone of Silurian to Early Devonian age. The top of the formation is represented by the Upper Detrital Member, a largely arenaceous unit with minor argillaceous beds containing Lower Devonian fossils.

The Langgun Red Beds [5] are made up of quartzitic sandstones interbedded with red and grey coloured mudstone, and are exposed on Pulau Langgun, Pulau Rebak Besar and Pulau Rebak Kecil. Fossils indicate an Early Carboniferous age [6]. Jones [2] considers these beds as the base of the Singa Formation. The Singa Formation is a siliciclastic unit typified by crudely laminated, dark grey, poorly sorted mudstones with scattered dropstone horizons. The dropstones range in size from granules to boulders, and are mainly composed of sandstone, limestone, vein quartz, granitic, volcanic and metamorphic rocks. They are interpreted to possibly be of glacial origin. Brachiopods from the uppermost part of the Singa Formation at Kilim, Batu Asah and Pulau Singa Besar give an Early Permian age [7]. Most of the Singa Formation must, therefore, be Carboniferous in age, as the basal Langgun Red Beds is Early Carboniferous in age.

The Chuping Formation is a unit of thickly bedded to massive, light coloured limestones conformably overlying the Singa Formation in the southeastern part of Langkawi (Figure 1). Abundant fossils in the limestone give an age range from Early Permian to early Middle Permian.

Igneous rocks in Langkawi occur in the form of two granitic bodies. The Gunung Raya massif rises to 878m above sea level and forms the highest part of the island (Gunung Raya). It is dated as Late Cretaceous in age. A smaller granitic pluton is present on Pulau Tuba, and is Late Triassic in age. Both bodies are petrographically similar, being porphyritic biotit granites with tourmaline clots and veins. Large K-feldspar phenocrysts and spherical quartz phenocrysts are common. Some acid volcanics or tuffs occur as thin, fine grained, pale green layers in the Machinchang Formation indicative of volcanism during Cambrian times. Superficial deposits of Quaternary to Recent age are also widespread throughout Langkawi, and are composed of unconsolidated mud, sand and gravel overlying the older formations along the coast and river valleys.

General Geology of northeast Langkawi

The northeastern part of the island group (comprising the northeastern portion of the main island, Pulau Langgun, Pulau Tanjong Dendang, and several smaller islets) is somewhat representative for the whole island group, but does not contain exposures of the Machinchang and Chuping Formations (Figure 2). Intrusion of the Gunung Raya massif during the Cretaceous resulted in the warping of the Palaeozoic sedimentary rocks around the granitic body, forming an arcuate belt of Singa Formation and Setul Formation rocks in the northeastern part of Langkawi, dipping east and northeastwards, away from Gunung Raya. Traces of contact metamorphism are observed in the Singa Formation as hornfelses and quartzites. The Setul Formation is observed to be thrusted over the younger Singa Formation at a low angle in northeastern Langkawi, forming the Kisap Thrust Fault. The trend of the Kisap Thrust Fault is also curved, due to the intrusion of the Gunung Raya massif.

Important Localities In Northeast Langkawi

The Pulau Langgun section: a complete middle Palaeozoic record.

Pulau Langgun is a small, elongate island located just northeast of the main Langkawi island (Lat. 6° 26' N and long. 99° 53' E) (Figure 2). Despite its small size, Pulau Langgun has been the focus of great geological interest, as it possesses one of the most continuous sections of Middle Palaeozoic rocks in Peninsular Malaysia. The main focus of the study is on Teluk Mempelam, on the northwest coast of Pulau Langgun (Figure 3).

Figure 3. Panoramic view of the northern part of Teluk Mempelam, facing northeast (near locality 5 of Figure 4). In the foreground are folded quartzite beds of the Timah Tasoh Formation. A cliff made up of the Kaki Bukit Limestone is observed in the background..

Teluk Mempelam exposes a continuous succession of sedimentary rocks from Ordovician (~490 million years ago) Lower Setul Limestone to Carboniferous aged (~350 million years ago)Langgun Red Beds, ie. a time spanning roughly 143 million years. The trends of the sedimentary units are varied due to complex deformation, but the beds generally dip steeply northwards with the beds getting younger in that direction (Figure 4). The rock exposures are in the form of low cliffs, promontories and boulders along the northwest coast best accessed when the tide is out. Recent studies on the section has resulted in a revision of Jones' [1] previous stratigraphic nomenclature, and the proposal of a new Mid-Palaeozoic stratigraphy for northwest Peninsular Malaysia (Figures 4 and 5). The study has also uncovered certain clues to the events that formed the early history of our region. The new stratigraphy discards the use of the terms Setul Formation, and divides the former Setul Formation subunits into separate formations [8][9]. The decision was made based on recent data which indicate that the subunits of the Setul Formation were lithologically and biostratigraphically distinct enough to form their own, separate formations. The continued use of the Setul Formation would only cause confusion, and the new stratigraphy would be better adapted to recent advances in sequence and event stratigraphy. The new classification is given below:-

1. *Kaki Bukit Formation*

The name replaces the older term Lower Setul Limestone (Figures 4 and 5), and is derived from Kaki Bukit, a small town at the foot of the Setul Boundary Range in north Perlis, where Lower Setul Limestone is also exposed. The unit forms the main lithology of Pulau Langgun. There is no complete section for the Kaki Bukit Limestone, but the top part of the formation is exposed at Teluk Mempelam, where it is overlain by the Tanjong Dendang Formation. The Kaki Bukit Limestone is massive, and apparently devoid of macrofossils, although occasional seams or lenses of shell-bearing limestone sometimes occur.

2. *Tanjong Dendang Formation*

The name replaces the former Lower Detrital Member of the Setul Formation, and is named after Pulau Tanjong Dendang, located just east of Pulau Langgun (Figure 2). The section at Pulau Langgun is continuous, with the top of the unit observed to be underlying the Mempelam Limestone (Figure 4). The lithologies of this formation, which is about 60m thick on Teluk Mempelam, vary from well-bedded quartzites through siltstone to dark shales, and sometimes included interbedded cherts (Figure 6). The Pulau

Tanjong Dendang exposure has been greatly deformed. The graptolite fauna described from Pulau Langgun and Pulau Tanjong Dendang indicate that the unit spans the Ordovician - Silurian boundary.

3. *Mempelam Formation*
The name replaces the former Upper Setul Limestone, and is derived from Teluk Mempelam, where a complete section is exposed. It is made up of 182m of bedded, dark grey limestone interbedded with dark shales. The unit is conformably overlain by black shales of the Timah Tasoh Formation. Fossils give a Silurian to earliest Devonian age (~440-415 million years ago).

4. *Timah Tasoh Formation*
The name corresponds to the former Upper Detrital Member of the Setul Formation, and is named after the Timah Tasoh Dam in north Perlis, just east of the type section at Kampung Guar Jentik, Perlis. The lithology is composed of dark mudstones with occasional cherts at the base, followed by sandstone. Graptolite and tentaculitid fossils from black shales at the base of the unit at Pulau Langgun give an Early Devonian age.

5. *Langgun Red Beds*
The name of the red mudstone beds on Pulau Langgun is retained, but separated from the Singa Formation. More complete exposures of the similar rocks are known in Perlis State, where they are known as the Binjal Formation.

The Silurian-Devonian boundary at Teluk Mempelam

The boundary between the Mempelam Limestone and Timah Tasoh Formation is well exposed on Teluk Mempelam., Pulau Langgun (roughly near location 19 in Figure 19 of [2]). The boundary is conformable and gradational, with the lithology gradually changing from medium to thin bedded dark micritic limestone to black shales. The uppermost boundary of the Mempelam Limestone is relatively rich in fossil content, with most of the fossils being unidentified straight shelled nautiloids and crinoid fragments. The discovery of scyphocrinoid loboliths at location 3 (Figure 4) indicates the exposure of Silurian-Devonian boundary beds [10]. The loboliths are found in nodular limestone beds roughly 50m below the top of the Mempelam Limestone (Figure 7). They are of the plated lobolith type (either *Camarocrinus* or *Marhoumacrinus*), which range from the uppermost Silurian (Late Pridoli) to lowermost Devonian (Early Lochkovian) [11]. Earliest Devonian (Lochkovian) conodonts have also been reported from the same outcrop [12]. This would put the Silurian – Devonian boundary roughly 50m below the top of the Mempelam Limestone.

The black shales forming the lower boundary of the Timah Tasoh Formation are highly fossiliferous, with abundant dacryoconarid tentaculitid remains, including *Nowakia (Turkestanella) acuaria* Alberti, and *Styliolina* sp. Jones [13] reported the occurrence of two monograptid species from the black shales, ie. *Monograptus langgunensis* Jones and *Monograptus* cf. *uniformis* Jones. Also present is the brachiopod *Plectodonta (Plectodonta) forteyi* Boucot and Cocks [14]. The tentaculitids and graptolites give an Early Devonian (Late Pragian to Early Emsian) age.

A major increase in sea level occurred on the Sibumasu Terrane during the Late Pragian – Early Emsian, marked by the gradual vertical transition from subtidal pelagic limestone of the Upper Setul Limestone to the Lalang Formation deeper water tentaculitid shales marks a major increase in sea level during the latest Silurian – earliest Devonian. The transgressive event at the Mempelam Limestone and Timah Tasoh Formation boundary can be correlated to the marine transgression occurring in the southern part of the South China Block, starting in the Lochkovian and persisting into the Pragian, which marks the initial rifting of the terrane from Gondwana [15], leading to the opening of the Palaeo-Tethys Ocean [16,17].

The Devonian-Carboniferous boundary at Teluk Mempelam

There is an abrupt colour change from light coloured sandstones and shales of the upper Timah Tasoh Formation into bright red mudstone observed at the northwest coast of Pulau Langgun. The red mudstone is fossiliferous, containing abundant specimens of marine benthos. This change represents a paraconformity between the two formations - there is no evidence of an angular unconformity. The brachiopod *Tournquistia burtonae* Hamada and the pelecypod *Posidonia becheri* Bronn are found in the red beds. Both genera are known from the Early Carboniferous of Europe.

Interestingly, the paraconformity on Pulau Langgun is situated between Devonian aged rocks of the Timah Tasoh Formation and the Early Carboniferous age Langgun Red Beds (Figure 4). Therefore, it is possible that the paraconformity represents the global regression which occurred near the Devonian-Carboniferous boundary [6, 18-27].

Palaeogeography and palaeoclimate

Nine taxa of of fossil nautiloid cephalopods have been reported from several horizons in the Kaki Bukit Limestone of northeast Langkawi, including Pulau Langgun [28]. Comparison with other nautiloid fauna throughout the world indicates the Langkawi assemblage is similar to those from the Georgina Basin of northern Australia [29]. This supports the idea of close proximity between Australia and the Sibumasu Terrane (which includes western Peninsular Malaysia) during the Ordovician. The gastropod bearing horizons have yielded *Teiichispira*, which is also known from Ordovician carbonates of Thailand, Australia, Argentina and France [29]. Interestingly, these deposits have been shown to have been located near the palaeo-equator. The occurrence of *Teiichispira* in Langkawi indicates a warm, equatorial climate during the Ordovician.

The Kilim – Sungai Itau brachiopod beds: clues to past climate and palaeogeography

Pebbly mudstones of the Singa Formation are exposed east of the Gunung Raya Massif, in northwest Langkawi (Figure 2). Two significant fossil bearing localities have been reported from the area [7, 30], one near Kilim, and another at Sungai Itau Quarry. Both localities are part of a NW-SE trending ridge near Kampung Kilim. The fossils are usually found in pebbly mudstone horizons and associated bioclastic, byrozoan limestones. The Kilim locality is in an abandoned quarry belonging to the Kedah Cement Factory. A roughly 55m thick section is exposed, which represents the upper part of the Singa Formation. The fossil assemblage contains a diverse marine fauna which includes bryozoans, crinoids, pelecypods, and of particular interest, brachiopods. Nine brachiopod taxa are reported from Kilim, and they indicate an Early Permian age. The Sungai Itau locality is on the northwestern tip of the Kilim ridge. The sequence is also composed of pebbly horizons interbedded with calcareous horizons. The dropstones of the Singa Formation are probably glacial dropstones derived from some palaeo-Gondwana margin in the Carbo-Permian [30]. Mohd Shafeea Leman and Asmaniza Yop [29] suggested that the alternating sequence of pebbly mudstone and sandstone with calcareous horizons represents cyclic sea-level fluctuations caused by glaciation and deglaciation of the nearby continent due to climatic changes. Late Palaeozoic glacial deposits are only known from the supercontinent of Gondwana, and it is most probable that northwest Peninsular Malaysia (part of the Shan-Thai or Sibumasu Terrane) was at the margins of this supercontinent. Biogeographical studies indicate that the brachiopods can be assigned to the Cimmerian Province which is the transitional biogeographical unit between cold to cool water Gondwanan faunas and the warm water equatorial fauna of the Cathaysian Province during the Permian [31].

CONCLUSION

The northeastern part of the Langkawi Islands preserves a spectacular and relatively complete geological record. It provides a rare glimpse into the Palaeozoic history of our region. Pulau Langgun in particular provides a guide for a new stratigraphic nomenclature for northwest Peninsular Malaysia. It also records important events during the Palaeozoic, including the Devonian-Carboniferous boundary regression, and the initial rifting of the Sibumasu continental sliver during the Devonian. The limestones of the Kaki Bukit Limestone and Mempelam Limestone also contain a diverse shelly fauna, with clues to the palaeogeography and palaeoclimate of Langkawi. The pebbly mudstones of the Singa Formation in the Kilim area represents spectacular evidence of glaciation during the Carboniferous and Early Permian periods, and also supports the hypothesis of close proximity with the supercontinent Gondwana. Such localities of geological interest should be conserved for the study and appreciation of geoscientists and laymen alike.

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