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THE PALAEOZOIC SEDIMENTARY ROCKS OF PENINSULAR MALAYSIA - STRATIGRAPHY AND CORRELATION

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ABSTRACT A well-represented sequence of Palaeozoic rocks ranging in age from Cambrian to Permian is found in Peninsular Malaysia. Two sedimentation regimes are recognized based on their different periods of initial sedimentation; a western regime to which Lower Palaeozoic strata are confined and where a conformable Cambrian-Permian succession is evident in the Langkawi, Perlis and Kedah area and an eastern regime where Carbo-Permian strata crop out in the central and eastern parts of the peninsula.

On the basis of their stratigraphic record and characteristics the western regime is subdivided into the northwestern zone and western zone and the eastern regime into the central zone and eastern zone. Representative lithostratigraphic units of the northwestern zone are the Machinchang formation, Setul formation, Mahang Formation, Kubang Pasu formation and the Chuping limestone. Those of the western zone are represented by the Baling group, Bentong group, Kinta limestone, Kati formation, Kenny Hill formation, Dinding schist, Hawthornden schist and Kuala Lumpur limestone; those of the central zone by the Raub group, Kepis formation and Taku schist and those of the eastern zone by the Kuantan group.

The earliest sedimentation began during Late Cambrian in the western regime and sedimentation was more or less continuous till the Permian in the northern part of the regime. An unconformity has been reported separating Upper Palaeozoic Kenny Hill formation from the Silurian Kuala Lumpur limestone and Hawthornden schist in the southern part of the regime. In the eastern regime, shallow marine sedimentation commenced in Early Carboniferous and probably continued uninterrupted till Late Permian. However, the central zone of the regime differed from the eastern zone in the accumulation of abundant volcaniclastics in the later stages of sedimentation while the eastern zone remained tectonically more stable and was characterized by more clastic sedimentation. Uplift of the eastern zone took place towards the end of the Permian whereas sedimentation continued in the tectonically unstable central zone into the Mesozoic.

INTRODUCTION

The last published geological map of Peninsular Malaysia based on rock stratigraphic units was by the Geological Society of Malaysia (Gobbett, 1972). The following year the Geological Survey of Malaysia published its current Seventh Edition of the Geological Map of Peninsular Malaysia. In it the geological succession is depicted essentially as time stratagraphic units.

Since the publication of these maps much more geological data have been collected as a result of sustained geological mapping by the Geological Survey as well as research carried out by the staff and students of Geology Departments in the universities. These additional data and especially the discovery of several new fossil localities serve to reaffirm or modify earlier concepts and interpretation of the stratigraphy of the Malay peninsula.

Most of the lithostratigraphic names used in the ensuing text have been given by Survey geologists who mapped their respective areas. It is also necessary in the interest of proper nomenclature and regional lithostratigraphic correlation to redefine some of the older names used while others are replaced by more suitable lithostratigraphic names in accordance with current practice in stratigraphic nomenclature.

Based on the stratigraphic record and characteristics, the area of Peninsular Malaysia is divided into four stratigraphic zones, viz. (i) northwestern zone, (ii) western zone, (iii) central zone, and (iv) eastern zone (Figure 1). Lithostratigraphic units are described according to their distribution in each zone, Figure 2 and Table 1.

BRIEF REVIEW OF INTERPRETATIONS OF THE PALAEOZOIC GEOLOGY

Palaeozoic rocks are marine and account for some 25 per cent by area of Peninsular Malaysia. The layout and structure of these rocks indicate that the sedimentary basins in general trend between northwesterly to northerly. Lower Palaeozoic outcrops are confined to the western part of the peninsula while more widespread Upper Palaeozoic rocks occur also in the central and eastern parts. The oldest sediments have been dated to be Late Cambrian and the youngest as Late Permian.

For a long time there was no clear concept of the structure and development of the sedimentary basins. Initially, sedimentary formations in different areas were correlated purely on their dominant lithology. Because of the lack of contiguity of outcrops and poor knowledge of their palaeontology such correlation was often dubious as was the case with rocks of the Arenaceous, Calcareous and Volcanic series (Richardson 1939, 1950, Fitch 1952, Alexander 1968). It was not until the emergence of the classic work of Jones (1968) and Burton (1967, 1970) that the basis and concept of the Malayan geosyncline was established. It was postulated that the

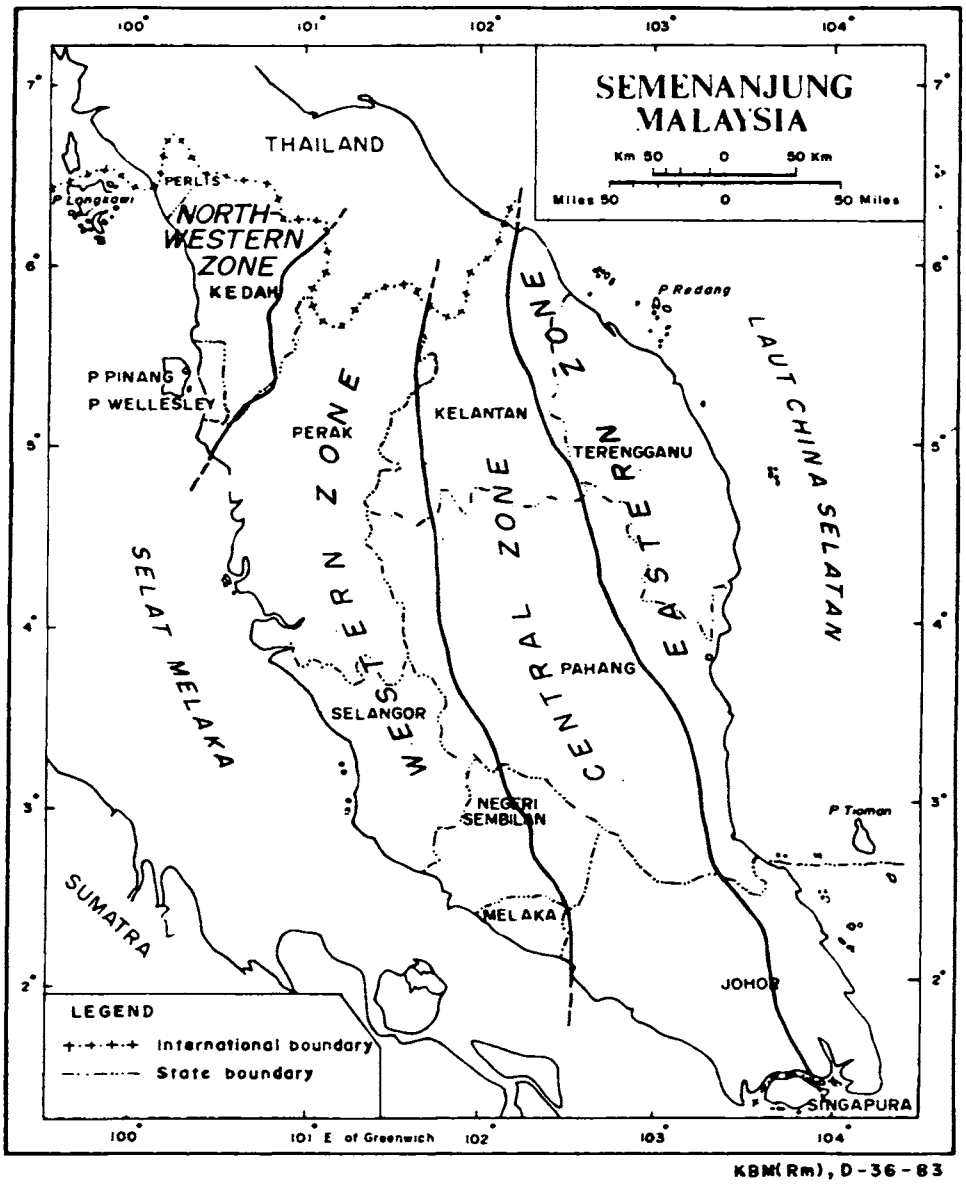

Fig. 1. Stratigraphic Zones of Peninsular Malaysia

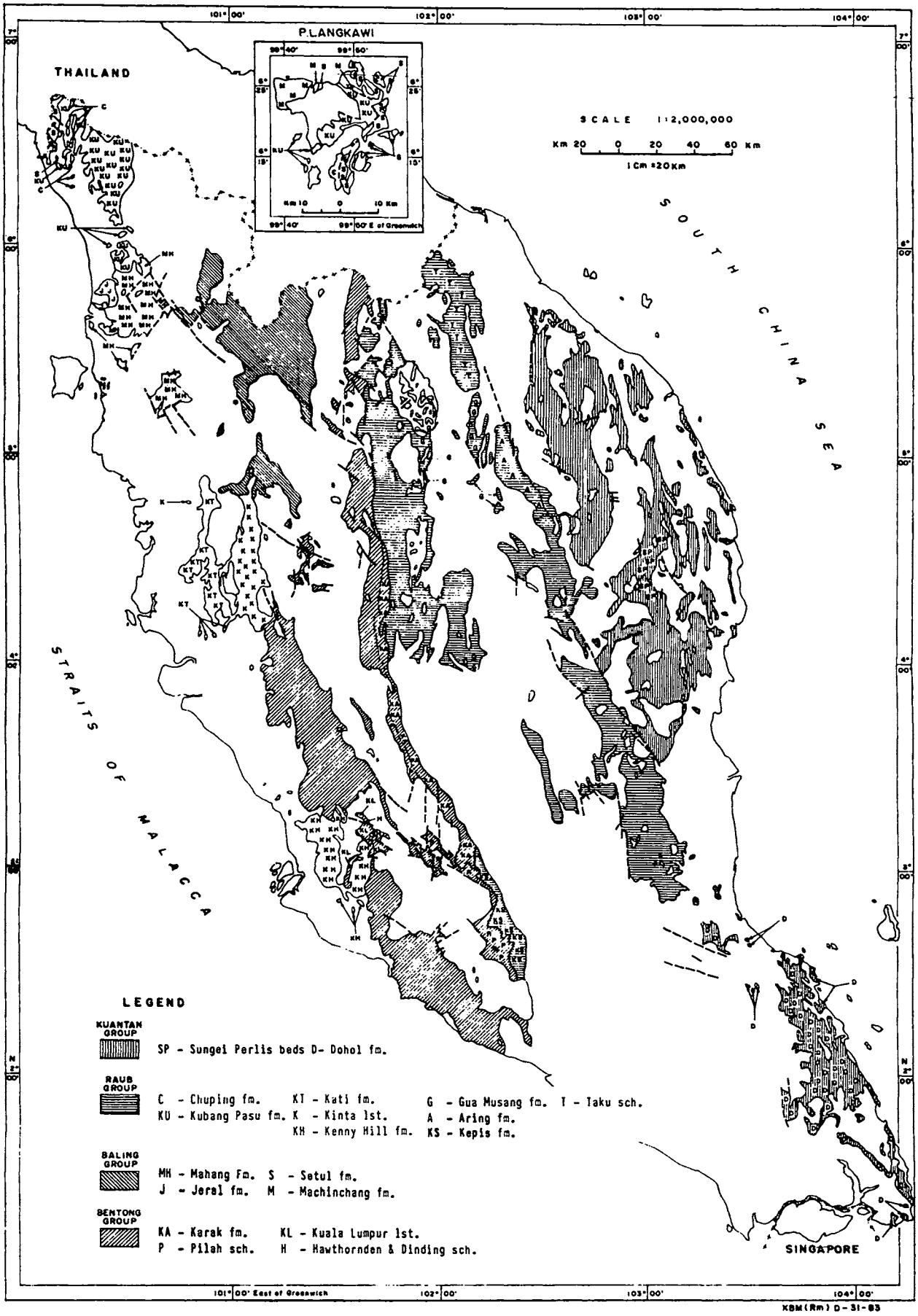

Fig. 2. Distribution of Palaeozoic Stratigraphic Units of Peninsular Malaysia

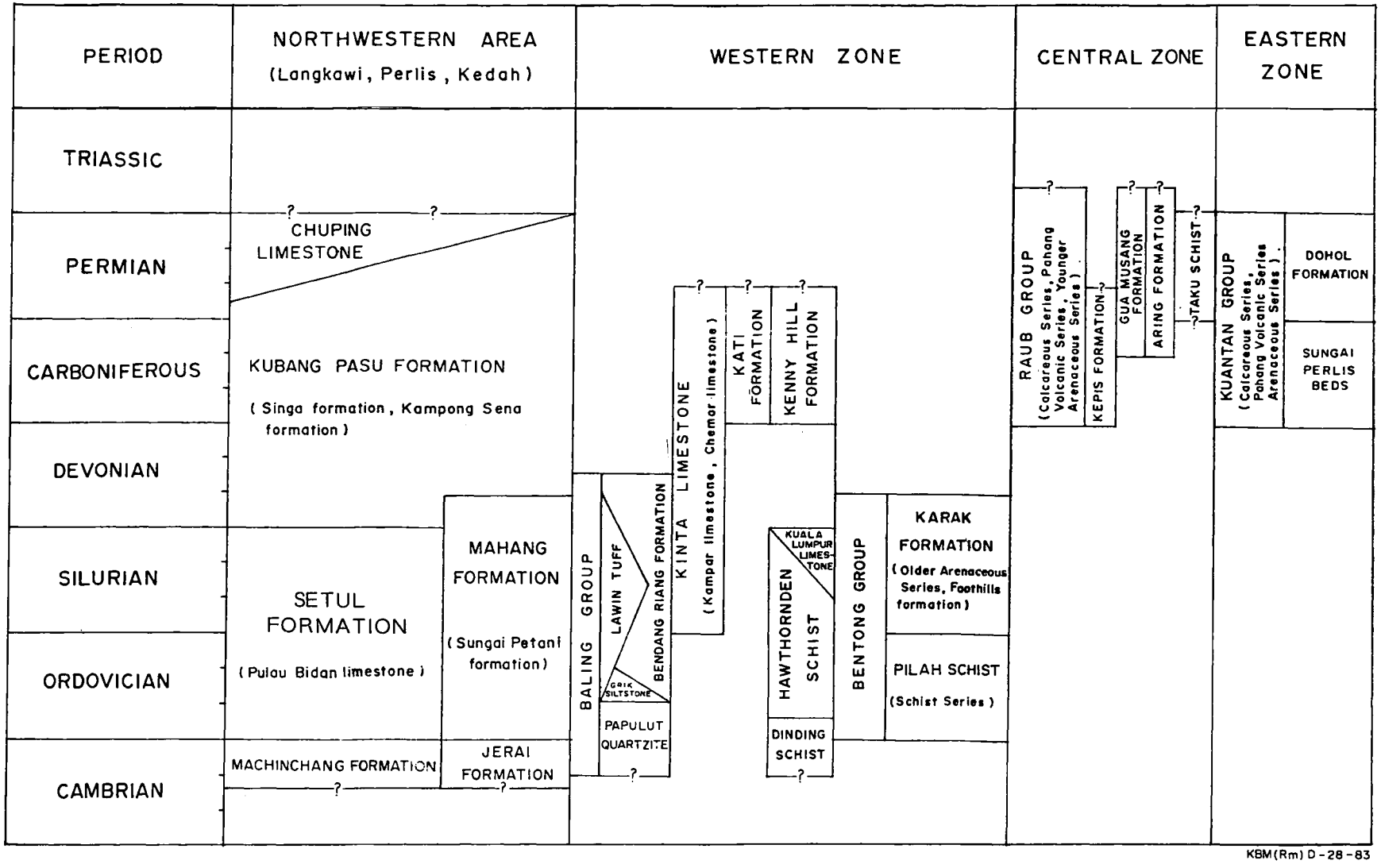

Table 1. Schematic Classification and Correlation of Palaeozoic Formations of Peninsular Malaysia

development of the geosyncline commenced during Late Cambrian in the northwestern part of Peninsular Malaysia and extended southwards along the western part of the peninsula to include the Malacca area by Ordovician and Silurian times. Sedimentation was believed to have been continuous during the Lower Palaeozoic in most of the areas. Formation of a geanticlinal ridge along the site of the present Main Range divided the trough into a miogeosyncline to the west and a eugeosyncline to the east. A major difference in the sedimentation of the two basins during the Upper Palaeozoic is the accumulation of abundant volcaniclastic rocks in the eugeosynclinal area. Migration of the geosyncline was believed to be eastwards culminating in the major Triassic orogeny which was accompanied by widespread emplacement of granitoids.

In the correlation study of sedimentary basins of the ESCAP region, Aw (1977) considered the Malay peninsula to be made up of 3 basins, viz. western, central and eastern, on the basis of their distinctive tectonic and sedimentary histories. The eastern limit of the Western Basin is demarcated by the Bentong-Raub Line (Hutchison, 1975) which has been interpreted as the site of Lower Palaeozoic subduction by Hamilton (1972). This basin includes most if not all of the Lower Palaeozoic sediments as well as some Upper Palaeozoic formations. The Central Basin occupies most of Kelantan, west Pahang, east Negeri Sembilan and west Johore and includes most of the Permian and Mesozoic sediments of the peninsula. It is separated from the Eastern Basin by an arbitrary boundary drawn along the trend of granitoids from Kelantan to south Johore. Most of the sediments in the Eastern Belt are of Carbo-Permian age. Some Lower Triassic ignimbrite and Upper Mesozoic continental sediments crop out in the southern part of the basin.

STRATIGRAPHY OF THE NORTHWESTERN ZONE

The northwestern zone is defined here as the area encompassing the Langkawi islands, Perlis and mainland Kedah. It covers most of the area of the miogeosyncline (Jones, 1973). It is also the area where the most detailed work on the Lower Palaeozoic stratigraphy has been accomplished and published. The Palaeozoic stratigraphy is represented by a conformable sequence of sediments which range in age from Late Cambrian to Late Permian. It appears that there is no apparent break in the sedimentation record of the Palaeozoic.

Machinchang Formation

The oldest stratigraphic unit here is the Cambrian Machinchang formation which forms a spectacular range of hills in the northwest part of Pulau Langkawi, Jones (1968) classified it as a shelf deposit of deltaic facies within the miogeosyncline. The 1980 m sequence consists of a lower areno-argillaceous part of subgreywacke, siltstone and shale overlain by an upper rudo-arenaceous part of current-bedded sandstone and feldspathic grit. The formation grades upwards through a series of passage beds into limestone of the Setul formation (Ong, in prep.).

In the Kedah Peak area, a 1425 m thick sequence of unfossiliferous and variously metamorphosed quartz arenite, quartz-mica schist and phyllite was found to occur beneath what is believed to be Setul limestone and the Mahang Formation. On the basis of lithological similarity and stratigraphic position this sequence is correlated with the Machinchang formation.

Setul Formation

The Setul formation of Ordovician to Silurian age is a predominantly calcareous unit which crops out in the eastern part of Pulau Langkawi. It also forms the adjacent islands and the limestone range bordering Thailand in west Perlis. Jones (1973) classified the 1550 m fossiliferous formation as shelf limestone which has prominent development of clastic beds at two levels. The lower detrital band located some 1000 m from the base contains graptolites and trilobites indicating an Early Silurian age. The upper detrital band which is situated at the top of the formation contains *Tentaculites* indicating an Early Devonian age. The Setul formation passes conformably into the younger Kubang Pasu formation.

Mahang Formation

This unit which was formalized by Burton in 1967 occurs as two large outcrops in central and south Kedah. The Mahang Formation is highly carbonaceous and has been described as corresponding closely to the euxinic facies of Pettijohn (1957). It consists of 4 facies, viz. (i) a dominant argillaceous facies, (ii) a subsidiary arenaceous facies, (iii) a minor siliceous facies, and (iv) a very restricted calcareous facies. The formation is dated by fossils to range from Ordovician to Early Devonian age. The base of the formation has not been recognized but the top passes conformably into the Kubang Pasu formation (also known as Kampong Sena formation). The age and stratigraphic position of the Setul formation and Mahang Formation are similar and have been interpreted to represent contemporaneous shallow water shelf conditions and deep water restricted basin conditions of the miogeosyncline respectively (Jones, 1973).

Kubang Pasu Formation

Originally the name 'Kubang Pasu formation' was used to refer to a sequence of red and grey Upper Palaeozoic rocks cropping out in central and south Perlis and north Kedah. They are the stratigraphic equivalent of lithologically similar, red and grey to black rocks occurring in north Perlis and Langkawi islands to which the name of 'Singa formation' was also given by Jones (1973). Some uncertainty exists concerning the pros and cons of using both names or one name in preference to the other. The name 'Kubang Pasu formation' is preferred and used here to include rocks of both formations in view of its wider usage and much larger outcrop area. The areno-argillaceous 'Kampong Sena formation' mapped by Burton (1964) in Kedah is a southward continuation of the Kubang Pasu formation.

The Kubang Pasu formation is well-bedded, varying in colour from red to grey to black, and consists of rapidly alternating shales and siltstones and poorly sorted sandstones. Black carbonaceous argillites are common in Langkawi and north Perlis. Characteristic sedimentary features include

graded-bedding, cross lamination, fucoidal markings and slump structures. The thickness of the formation is estimated at 1500 m or more. It is conformable over the Setul formation and Mahang Formation. The top of the formation becomes increasingly calcareous and passes upwards without any stratigraphic break into the younger Chuping formation in both Langkawi islands and part of the mainland. In north Kedah the Chuping limestone appears to grade laterally to rocks similar to the Kubang Pasu formation.

The age of the Kubang Pasu formation ranges from Devonian to Permian. Following the observation of Yancey (1975) that the Lower Devonian strata grade into the Upper Devonian strata in Pulau Langgun, the base of the Kubang Pasu formation (Singa formation) should include the reddish Lower Devonian strata which were considered by Jones (1982) to be part of the upper detrital band of the Setul formation. Where the formation is not overlain by Lower Permian Chuping limestone the upper age limit could range till the upper age limit of the Chuping limestone where the latter has lensed out.

Chuping Limestone

Chuping limestone constitutes the youngest unit of the Palaeozoic sequence in the northwest area cropping out in the Langkawi islands, Perlis and Kedah. It rests conformably on the Kubang Pasu formation and has a minimum thickness of 600 m. The limestone is massive, crystalline and generally white to pale-coloured. Fossils which are abundant in the formation indicate an Early to Late Permian age. Jones (1968) included within this formation younger limestone which has since been formalized as the Kodiang Limestone (de Coo & Smit, 1975).

STRATIGRAPHY OF THE WESTERN ZONE

The western zone refers to the area stretching from the Perak-Thai border southwards to the state of Malacca. It includes the area occupied by the Lower Palaeozoic eugeosyncline and geanticline and part of the miogeosyncline of Jones (1973). Two main stratigraphic groups are the Baling group in north Perak and the Lower Palaeozoic Bentong group which occurs as an unbroken belt along the eastern foothills of the Main Range. Other important units are the Lower Palaeozoic formations of Dinding schist, Hawthornden schist and Kuala Lumpur Limestone in Selangor. The limestone and argillites of the Kinta valley are classified under the Kinta limestone and the Baling group respectively while the westerly clastics along the Perak River are grouped under the Kati formation. In Selangor the Upper Palaeozoic clastics are known as the Kenny Hill formation.

Baling Group

The group represents sediments deposited in the geanticlinal area and is the lateral equivalent of the Mahang Formation and Setul formation of the miogeosyncline. Jones (1973) described the 3000 m thick group as consisting of four formations, viz. (1) Papulut quartzite, (ii) Grik

siltstone, (iii) Bendang Riang formation, and (iv) Lawin tuff. He correlated tentatively the Papulut quartzite with the Machinchang formation. The formational status of the Grik siltstone is questionable since it is lenticular and extremely localized and may be better classified as a member within the Bendang Riang formation. The Lawin tuff is for the most part contemporaneous with the Bendang Riang formation which is contrary to the interpretation of Jones that the volcanic activity coincided in time with transition from shallow water Papulut quartzite to deep water Bendang Riang formation. The age of the Baling group is indicated by fossils to be Ordovician to Early Devonian.

Kinta Limestone

The Baling group can be traced southwards into the Sungei Siput area where it is replaced further south by a calcareous formation called the Kinta limestone. The limestone is generally pure but in places dolomitic, pale coloured and marmorized, and is interbedded with subordinate schists and phyllites which are commonly carbonaceous. The formation is dated by fossils to be Silurian to Permian. Suntharalingam (1968) described a continuous sequence of fossiliferous limestone west of Kampar ranging in age from Early Devonian or older to Early Permian.

Correlation The Kinta limestone forms part of the 'Calcareous Series' of Ingham and Bradford (1960); the other part of the 'Calcareous Series' consists of an argillaceous facies comprising phyllite, quartz-mica schist and quartzite. Some of the schists are graphitic. This unit can be correlated with the 'Quartzite and Schist' unit of Savage (1937) and further north with similar rocks in the Baling group.

Kati Formation

The Kati formation is typically areno-argillaceous in composition (Foo, in prep.) and consists of interbedded phyllite, metaquartzite, sandstone, shale and siltstone. The finer sediments are characteristically laminated and grey in colour. Sedimentary structures observed include rhythmic bedding, rare graded bedding and flute casts (Wong, in prep.). The formation is correlated with the Kubang Pasu formation.

Dinding Schist

Gobbett (1964) described the 3340 m thick formation as comprising two parts of quartz-mica schist separated by a quartzite member. Calcsilicate schists occur in the upper part of the formation. A schistose conglomerate occurs within the quartzite member. The lower part of the Dinding schist appears to be correlatable with the Machinchang formation.

Hawthornden Schist

The Dinding schist grades upwards into the 910 m thick Hawthornden schist which is typically fine-grained and black as a result of the presence of carbonaceous and pyritic material. This unit is correlated with the Mahang Formation and Baling group. Yin (in prep.) grouped the Dinding and Hawthornden schists as a single unit and called it the Hawthornden schist. He however, separated out a younger unit 'Kajang schist' overlying the Hawthornden schist on the basis of the former being less graphitic and

containing lenses of limestone. The writer interprets the 'Kajang schist' and Hawthornden schist as one unit and considers the former to be stratigraphically equivalent to the Kuala Lumpur limestone but merely represents a mixed/intermediate facies between the limestone and the schist.

Gan (1979) discovered Ordovician gastropods and cephalopods in limestone interbedded with Hawthornden schist near Tanjung Malim.

Kuala Lumpur Limestone

The Kuala Lumpur limestone which is a 1820 m thick calcareous unit overlies the Hawthornden schist without any sharp break. The limestone is usually white to grey in colour, dolomitic in places, and contains minor interbedding of schist and phyllite. It has a rich fauna which indicates Middle to Late Silurian age. The formation can be correlated with the upper part of the Setul formation and the lower part of the Kinta limestone.

Bentong Group

The Bentong group (Alexander, 1958) has two conformable sequences of Lower Palaeozoic rocks cropping out in the Bentong area, viz. the 'Schist Series' and the 'Older Arenaceous Series'. Mapping of the area further south has identified the 'Schist Series' with the Pilah schist (Khoo, 1975, Loganathan, in prep.) and the 'Older Arenaceous Series' with the Karak formation (Jaafar, 1976, Loganathan, in prep.).

The Bentong group can be traced northwards into the Raub and Merapoh areas where Richardson (1939) called the upper unit the 'Arenaceous Formation'. The areas further north have not been mapped but where the newly completed East-West Highway meets the inferred northward continuation of the group graphitic quartz-mica schists are exposed in the road sections.

South of the Bentong and Karak area the two-fold sequence of the Bentong group is visible again in the Negeri Sembilan - Pahang border area. Early Silurian graptolites were recently discovered in the Karak formation near Durian Tipus (Loganathan, in prep.). Based on this discovery the Pilah schist here would be older than Early Silurian, probably Ordovician. Further south in the Kuala Pilah area the Karak formation has not been recognized so that the Pilah schist is overlain probably unconformably by the Carbo-Permian formation (Khoo, 1975). In the Malacca-Johore boundary area the Kepis formation and Pilah schist are evident as separate outcrops fringing the southern end of the Main Range granite.

Pilah schist The formation consists essentially of low grade quartz mica schist, graphitic schist, metaquartzite and phyllite. Serpentinite and chert occur within the formation. The unit is correlated with the Hawthornden schist and is probably Ordovician in age.

Karak formation Jaafar (1976) described the 4800 m thick Karak formation to be argillaceous and commonly carbonaceous. It consists predominantly of argillite with interbeds of conglomerate, chert, quartzite

and subgreywacke. Five rock facies are recognized, (1) rudaceous-arenaceous, (2) argillaceous, (3) chert, (4) limestone, and (5) pyroclastic. Serpentinized ultrabasic and basic rocks including some amphibolites are associated with the sediments. Graptolites indicate an age range of Early Silurian to Early Devonian. The formation is also known as 'Foothills Formation', 'Older Arenaceous Series' and 'Arenaceous Formation'.

STRATIGRAPHY OF THE CENTRAL ZONE

The central zone referred to is bordered on the west by the Main Range granite and Lower Palaeozoic sediments of the Bentong group; the Lebir Fault forms the northern part of the eastern boundary while the southern part is an arbitrary line joining the Lebir Fault and the western boundary of the Dohol formation in Johore. The oldest sediments recorded in the central zone are sporadic outcrops of Carboniferous limestone. Permian sediments which form the bulk of Upper Palaeozoic sediments occur as linear belts flanking the Mesozoic sediments of the zone on both sides reaching as far south as north Johore. Apart from the Taku schist which appears to be anomalous in its lithology and possibly age, the Upper Palaeozoic sediments of the central zone consist of four facies, viz. (i) argillaceous, (ii) volcanic, (iii) calcareous, and (iv) arenaceous. The argillaceous and volcanic facies are generally the more important facies although in a specific area any one of the four facies or mixture of them could be prominent enough to form mappable units. Stratigraphic units identified so far are the Raub group, the Gua Musang formation, the Aring formation and the Kepis formation.

Raub Group

Rocks of the 'Calcareous Series' in the Malay peninsula were renamed the 'Raub group' by Alexander in 1958. These rocks which are of Carbo-Permian age were mapped by Richardson (1939, 1950), Procter (1980) and Alexander (1968) as a continuous belt stretching from Kelantan southwards to Bentong in south Pahang. In the Benta area of Pahang, Procter (1980) described three formations under the Raub group but these formations appear to have been loosely erected and cannot be continued beyond the boundaries of the map area. Triassic rocks which also occur in the Benta area were classified by Procter under the 'Lipis Group'. Subsequently, Jaafar (1976) mapped the Karak area south of Bentong and described two formations, 'Semantan Formation', and 'Kaling Formation', as constituting the Raub group overlying the Karak formation. These units were interpreted on some fossil evidence to be entirely Mesozoic in this area although the rocks are continuous along strike northwards with both Triassic and Upper Palaeozoic strata in the Raub and Benta areas.

The name 'Raub group' is used here to include all the Carbo-Permian strata which crop out along the central zone from Kelantan to Johore. It includes all the rocks referred to previously as the 'Calcareous Series' and the 'Pahang Volcanic Series'. In Kelantan, formations included within this group are the Gua Musang formation and Aring formation. Marine strata of

Triassic age which are lithologically similar and gradational with the Carbo-Permian strata and consequently difficult to separate out are also included in the Raub group. These would include rocks of the 'Younger Arenaceous Series' (Alexander, 1968) and the Semantan formation and Kaling formation of Jaafar. However, Triassic components are not depicted in Figure 2.

Gua Musang formation The Gua Musang formation was mapped by Yin (in prep.) in south Kelantan. It consists of a calcareous-argillaceous sequence of crystalline limestone with interbedded argillites and subordinate sandstones and volcanics. The shales are usually grey but can vary to black when carbonaceous. The sandstones include greywacke, protoquartzites and orthoquartzites but metaquartzites are the most common. The volcanics vary in composition from rhyolitic to andesitic and include tuffs, lavas and agglomerates. A Late Carboniferous to Triassic age is indicated by fossils present.

The formation is the lateral equivalent of the Aring formation which is pyroclastic. It can also be considered to be synonymous with the Telong formation of Aw (in prep.) who estimated a thickness of about 650 m for the unit in south Kelantan.

Aring formation The type area of the Aring formation is the Sungei Aring area of south Kelantan (Aw, in prep.). Two types sections are described by Aw, one in Sungei Nuar and the other in Sungei Relai. The formation is estimated to be about 3000 m thick and consists predominantly of pyroclastics, minor lavas, dolomitic marble and argillite. Aw identified a basal section to be composed of 270 m thick of dolomitic marble overlain by tuff and calcareous argillite. The top of the Aring formation is formed by an argillo-tuffaceous limestone unit 'Paloh member' measuring about 1000 m thick. The rest of the formation consists mainly of fine to coarse pyritiferous tuffs with subordinate amounts of interbedded lavas of rhyolite to andesite composition, argillite and limestone.

The age of the Aring formation is dated by foraminifera and bivalves to range from Late Carboniferous to Early Triassic. It is the stratigraphic equivalent of the Gua Musang formation which is a calcareous-argillaceous sequence.

The Aring formation can be correlated with the 'Pahang Volcanic Series' further south in the northwest and western parts of Pahang. In the Chegar Perah and Merapoh areas where the best development of these volcanics is seen, Richardson (1949) described the occurrence of abundant tuffs of rhyolitic to andesitic in composition, agglomerate, lavas of rhyolite, trachyte, trachyandesite and andesite. He stated further that the older part of the succession is predominantly rhyolitic in composition; more basic material varying from trachyte to trachyandesite and agglomerate occur in the upper part. The pyroclastics are interbedded with marine sediments of argillaceous, calcareous and arenaceous facies and are believed to be largely Carbo-Permian in age.

Kepis Formation

Beds of the Kepis formation are belived to rest unconformably on the Pilah schist (Khoo, in prep.) in the Kuala Pilah area. The sequence is generally grey to reddish brown in colour and essentially areno-argillaceous in composition. Typical rock types are carbonaceous shales, siltstones, mudstones, sandstones. A minor rudaceous facies of conglomeratic rocks is present while carbonaceous limestone occurs locally as lenses.

A fauna of brachiopods, corals and nautiloids indicates an Early Carboniferous to Middle Permian age while the fusulinids in one location indicate an Early Permian age.

Taku Schist

The Taku schist occurs as an elongate body of about 80 km long and 8 to 22 km wide stretching from the Thai border near Tanah Merah to central east Kelantan near Manik Urai. The Taku schist is mainly pelitic consisting of quartz-mica schist, quartz-mica-garnet schist and garnet-mica schist; occurring within these are bands of amphibolite schist and narrower bands of quartz schist and serpentinite. The age of the Taku schist is still uncertain as its origin remains very much a matter of controversy.

STRATIGRAPHY OF THE EASTERN ZONE

The eastern zone is that part of the Malay peninsula east of the Lebir Fault including the eastern part of Johore. Marine sediments exposed in this area are mostly Carboniferous in age with notable Permian outcrops in Terengganu and east Johore. The sediments in this zone are mostly of shallow marine origin and do not vary diversely in composition as their stratigraphic equivalents in the central zone. The only stratigraphic group recognized in the eastern zone is the Kuantan group. So far two formations are identified, viz. the Sungei Perlis beds and the Dohol formation.

Kuantan Group

The name 'Kuantan Group' was first used by Alexander (1959) to replace the 'Calcareous Series', a group of argillaceous and calcareous Upper Palaeozoic rocks exposed in the Kuantan area (Fitch, 1952). However, 'Kuantan group' is used here to include all the Upper Palaeozoic sediments occurring in the eastern zone of the Malay peninsula from Kelantan to Johore. It therefore also includes the 'Arenaceous Series' of Fitch (1952) the 'Sungai Perlis Beds' of Chand (1978) and the 'Dohol formation' of Rajah (in prep.).

In general, the Kuantan group consists of a dominant shale facies with subordinate limestone, sandstone and volcanic facies. The subordinate facies forms interbeds or may become locally important like the limestone facies in the Bukit Biwah and Kuantan areas and Gunung Sumalayang. The dominant argillaceous strata consist of well-bedded shale, mudstone

and siltstone, and their metamorphic equivalents of slate, phyllite, argillite and schist. The argillaceous rocks contain a significant amount of carbonaceous material rendering them a grey to dark grey colouration. Lamination is a common characteristic. Where the sandstone facies becomes important rhythmic bedding may be common. The calcareous facies comprises massive crystalline limestone forming small hills. The volcanic facies seems to assume some importance only in north Terengganu, Kuantan area and south Johore. It consists of both pyroclastics and lavas ranging from rhyolitic to andesitic in composition. The arenaceous facies is represented commonly as interbeds of sandstone, quartzite and grit.

Abundant fossils of brachiopods, corals, foraminifera and plants in limestone and shale indicate an Early Carboniferous age in several localities but an upper age limit of Late Permian is indicated by fossil plants found in Johore.

Sungei Perlis Beds

The type area of the Sungei Perlis beds is in Ulu Paka, Terengganu (Chand, 1978). The formation is at least 1500 m thick and is typically argillaceous consisting of an interbedded sequence of grey to dark grey carbonaceous slate, argillite, phyllite and variably metamorphosed siltstone and sandstone including some conglomerate and some beds of limestone. Lamination is a characteristic feature varying from fine to coarse and convolute types. The formation is rich in fauna and flora which include lamellibranchs, brachiopods, bryozoans, crinoids and plant remains indicating a Carboniferous age.

Dohol Formation

The formation crops out in east Johore and is predominantly argillaceous with minor beds of arenites, limestone and volcanics (Rajah, in prep.). Within the formation is a calcareous unit, the 'Sumalayang limestone member' which contains fusulines indicating a Middle Permian age. Rocks of the Dohol formation are generally grey and include carbonaceous shale, siltstone, slate, phyllites and schists. Thickness of the formation is estimated at more than 900 m.

Rajah (in prep.) also described another unit in south Johore calling it the 'Linggiu formation' which is continuous and in part similar to the Dohol formation. The arenaceous component in this unit is better developed resulting in some rhythmic bedding of shale and sandstone and the local prominence in some places of conglomeratic beds. Plant fossils found in the 'Linggiu formation' indicate a Late Permian age. This unit is classified as part of the Dohol formation.

CURRENT SYNTHESIS

The Machinchang formation marks the first initiation of a sedimentation basin during the Cambrian in the northwestern zone. The extent of this basin (comprising northwestern and western zones) could have been as far south as Kuala Lumpur during the Cambrian but had certainly reached the Malacca-Johore boundary by Ordovician times. There is no evidence that this Lower Palaeozoic basin had extended eastward beyond the Western zone up till the Devonian times as the oldest rocks found so far in the central zone are limited to the Carboniferous. There appears to be continuous sedimentation during the Palaeozoic within most of this western basin especially in the northern part where no break is evident in the Langkawi sequence and the Kinta limestone. However, in the southern part the Palaeozoic stratigraphy is less well known in the absence of adequate palaeontological data. Sedimentation appears to be continuous till the Early Devonian. Strata younger than Lower Devonian have not been recognized except for the Kenny Hill formation which has been interpreted by several workers to be unconformable over the Lower Palaeozoic sequence in the Kuala Lumpur area.

In the central zone, strata of the Raub group have been interpreted by several workers to be unconformable over the Bentong group (which includes the Devonian strata of the Karak formation). Sedimenation was probably initiated during Early Carboniferous. The zone of deposition was typically shallow and was also the seat of active submarine volcanism which probably started during Late Carboniferous and reached its peak development in the Permian and Trias. Sedimentation with intermittent volcanism appears to continue from Carboniferous through the Permian to the Mesozoic. In south Pahang and Johore ignimbrite probably of Early Triassic age overlie unconformably Permian phyllites marking the change from submarine to subaerial volcanism.

In the eastern zone the oldest sediments are probably Early Carboniferous and sedimentation was again continuous throughout the Carboniferous till Early Permian in the northern part. In the southern part Middle to Late Permian sediments occur overlain by Early Triassic ignimbrite. The depositional environment of the eastern zone appears to be typically shallow marine to mixed conditions. There appears to be marked reduction of the volcanic facies in the northern part of the eastern zone compared with the central zone indicating probably increased distance from the source of volcanism. No marine sediments younger than Permian have been found so far in the eastern zone. This indicates the elevation of the eastern zone towards the end of the Permian probably coinciding with the explosive deposition of the Johore ignimbrite.

CONCLUSION

Based on the different periods of initial sedimentation, the Malay peninsula can be divided into two sedimentation regimes, a western regime with sedimentation beginning in Late Cambrian, and an eastern regime with sedimentation beginning in the Early Carboniferous. The western regime includes what has been described as the northwestern and western zones. More or less continuous sedimentation record right through to the Permian is evident especially in the northern half. The eastern regime includes both the central and eastern zones described and is characterized by the persistence of shallow water shelf sedimentation till the Permian. However, in the later stages the central zone became tectonically unstable and this resulted in the accumulation of abundant volcanic material derived from submarine volcanism within the zone itself. The eastern zone was tectonically more stable and was characterized by a quieter environment of shallow marine to mixed facies.

Towards the end of the Permian the eastern zone was uplifted probably along the Lebir Fault and remained a continental area ever since. This set the stage for Mesozoic sedimentation along the mobile central zone and subsequent tripartite evolution of the peninsula. It would appear that the most likely period of Palaeozoic orogeny, if present at all, is at the end of the Permian period. The postulated Devonian orogeny remains doubtful; if it occurred, it was most likely towards the end of the Devonian and probably affected only the eugeosynclinal sediments of the Bentong group. This folding of the eugeosynclinal sediments could form the barrier separating the non volcanic sedimentation of the Kinta limestone, Kati formation and Kenny Hill formation as distinct from volcaniclastic sedimentation of much of the Raub group.

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