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Carboniferous and Permian Correlation in Southeast Asia

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Abstract: Middle and lower Upper Carboniferous (Hercynian) earth movements affected most of Southeast Asia and divide its later Palaeozoic history into three. The Prehercynian Lower Carboniferous is usually conformable with the Devonian with which it is strongly folded. Neritic and deeper water sediments, dated by Dinantian fossils, are known from the Annam Cordillera, Tonkin, Thailand and West Malaysia. Bashkirian, Moscovian and Gzhelian marine rocks have a more restricted distribution because of Hercynian tectonism and uplift. Faunas of this age are known from north central Thailand, Karen State in Burma, West Malaysia and West Sarawak, but the fusuline faunas of Indochina include no certain Middle Carboniferous species. The extensive Posthercynian limestones are transgressive. They include late Carboniferous (Triticites Zone) strata in north Indochina and perhaps locally in West Malaysia, but elsewhere are entirely Permian. The majority of their faunas are of Artinskian and Guadalupian age.

INTRODUCTION

Sedimentary rocks of Carboniferous and Permian age are widely distributed in Southeast Asia, the Permian being considerably more extensive than the Carboniferous. Their present outcrop (Fig. 1) forms a complex pattern due to Upper Palaeozoic and later earth movements and subsequent erosion. Over wide areas the strata are of marine origin but locally continental facies are important. The latter, although in places containing plant fossils of Westphalian and Permian age, are less easy to date and to correlate than the marine sequences and are not considered further here.

In attempting to synthesize the stratigraphy it is necessary to consider the region as a whole and to disregard national boundaries. However our knowledge tends to be compartmentalised into a series of national geologies.

Shan States and peninsular Burma. These were geologically surveyed on a reconnaisance scale by the Indian Geological Survey mainly during the period 1900–1941. During and after the last World War little work was done, but more recently important, though relatively modest investigations (Brunnschweiler 1970, Garson *et al.* in press), have been made. These have led to some revision of the geology but large areas still remain virtually geologically unknown and are covered by no large scale maps.

Vietnam, Laos and Cambodia. The French Service Geologique de l'Indochine carried out extensive mapping from about 1910 until 1939, and the general structure and stratigraphy of the region is relatively well known. In recent years very little new work has been carried out although some reinvestigations of local areas (e.g. Ishii *et al.* 1969) and some systematic palaeontology has been published.

Thailand. In Thailand there has been no systematic survey to produce large scale maps. There were in the 1920's and 1930's a number of detailed investigations in small selected areas connected with water supply and tin mining. The general geology of the country was summarised by Brown *et al.* (1951). Since then there has been further work in connection with oil prospecting (Borax and Stewart 1966), and a

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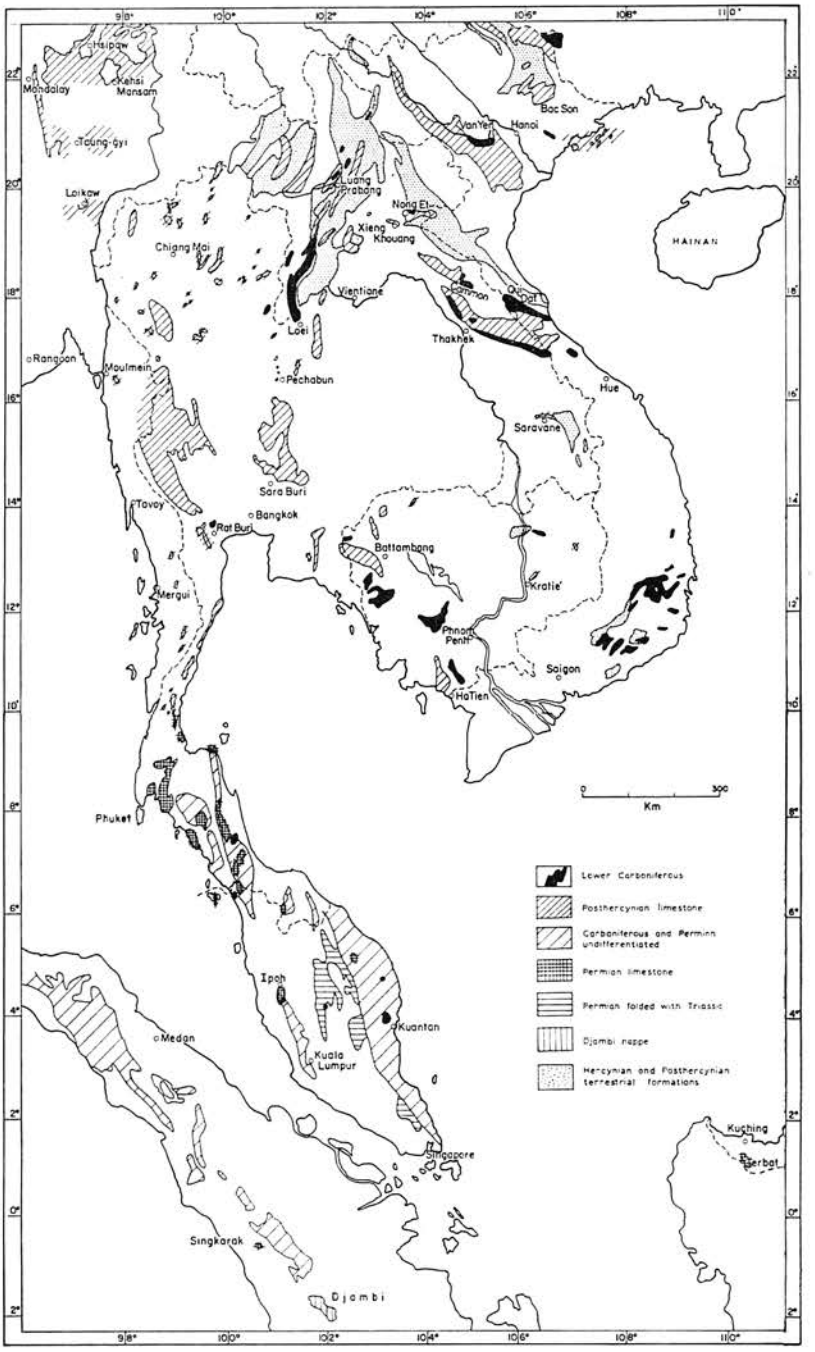

Fig. 1. Distribution of Carboniferous and Permian rocks in Southeast Asia.

series of Japanese expeditions, in association with the Department of Mines have added considerably to our knowledge of the stratigraphy and palaeontology of Thailand (Kobayashi and Toriyama 1964–1972). Also the German Geological Mission in Thailand have mapped extensive areas of north Thailand (Baum *et al.* 1970).

West Malaysia. The Geological Survey was begun in 1903 by Scrivenor and systematic mapping has been carried out (interrupted by war and terrorism) since about 1912. Parts of the country are relatively well known and in the last decade our understanding of the geology has vastly improved but large areas are still poorly understood.

Sumatra. The activity of the Dutch Survey in Indonesia before the last World War is well known and much of their work has been summarised by Bemmelen (1949). However in the extensive Palaeozoic sediments of this island there has been work published only on the Djambi 'Permocarboniferous' and the Permian of the Padang Highlands.

West Sarawak. During the last 20 years the Borneo Survey has carried out systematic mapping and published all its findings. However Palaeozoic rocks are very restricted in outcrop and the only fossiliferous Upper Palaeozoic formation is the Terbat Limestone.

SUMMARY OF LATER PALAEOZOIC EVENTS

In Southeast Asia marine sediments of Lower Carboniferous age are dated by faunas similar to those of the European Dinantian. They typically pass down into thick pre-Carboniferous sediments but are bounded above by an unconformity. The younger marine Carboniferous, where present, contains a fusuline-brachiopod-coral fauna allowing it to be correlated with that of the Russian platform. In many areas rocks of this age are missing or are represented by a thin incomplete sequence of variable facies and partly continental.

The marine Permian, and locally the Upper Carboniferous too, is characterised by massive fusuline limestones, especially well developed in the northern part of the region. These are transgressive over older rocks and are largely unaffected by the earth movements which folded and uplifted the older Carboniferous. The faunas of these limestones belong to the Tethyan province and readily allow correlation with Japan and the Salt Range. However, what is now defined as Lower Permian was termed, in the older literature, Carboniferous or Permocarboniferous so causing confusion unless faunal lists, preferably with revised taxonomy, are given.

Although now it has a restricted outcrop, the marine Lower Carboniferous was originally more widespread. Much of it was removed by erosion following a general mid-Carboniferous uplift. The subsequent Permian transgression did by no means cover all the uplifted land which remained as 'Indosinia' from Middle Carboniferous times onward and received continental sedimentation on a grand scale in Indochina and eastern Thailand. The later Palaeozoic history of Southeast Asia may thus be regarded as divisible into three: 1) the Lower Carboniferous (Dinantian); 2) a period of earth movements which may loosely be termed 'Hercynian' (Middle and lower Upper Carboniferous); 3) the post-Hercynian period (late Carboniferous and Permian). Each of these will be treated in turn below.

PREHERCYNIAN (DINANTIAN)

Marine sediments of known or presumed Middle Palaeozoic age are widespread in Southeast Asia and in many areas sedimentation continued into the Lower Carboniferous. However the succeeding Hercynian earth movements initiated the removal by erosion of most of the Lower Carboniferous rocks. Where it was preserved, subsequent folding and metamorphism make it difficult to distinguish from the older part of the sequence. Thus the upper part of the Mergui Series of peninsular Burma may include Dinantian strata as do the upper parts of the Phuket and Kanchanaburi Series of Thailand. More fossiliferous Lower Carboniferous is known in the main Hercynian fold structures in North Vietnam, east Yunnan and north Laos (Saurin 1956), and it also occurs in peninsular Thailand and Malaya.

Indochina

In the Annam Cordillera (Cam Mon, Qui Dat, Thak Hek) (Fig. 1) the Devonian is followed without a break by Tournaisian shales and dark limestones with *Chonetipustula*, *Plicatifera*, *Spirifer*, *Tylothyris*, *Martinia*, and *Zaphrentites*. Above is a marked unconformity marking the first of the Hercynian movements during which the Tournaisian was folded with the Devonian. The succeeding calcareous sandstone, shale and limestone contain a shelly fauna of Viséan brachiopods and corals (*Fluctuaria*, *Dictyoclostus*, *Gigantoproductus*, *Davisiella*, *Athyris*, *Pugnax*, *Lithostrotion*, *Syringopora*) and phillipsiid trilobites (Fig. 2).

However on the northeast flanks of the cordillera the Lower Carboniferous is represented by thick phyllites, shales and sandstones: occasional limestones with rare fossils indicate a Tournaisian (*Brachymetopus*, *Schellweinella*) and Viséan (*Nomismoceras*) age. The presence of radiolarian chert lenses suggest that this is a deep water facies.

In Cambodia, southwest of the Tongle Sap, calcareous sandstones with plants and oolitic limestones and marls with *Geinitziana*, *Endothyra* and polyzoa, probably of Lower Carboniferous age, are found at the top of a thick sequence of black shales and cherts with sponges and radiolaria. Similar radiolarian cherts and shales intruded and metamorphosed by Hercynian granites outcrop widely to the east of Saigon and are overlain unconformably by Upper Carboniferous continental deposits (Saurin 1956). In North Vietnam, Viséan clastic sediments with *Nomismoceras* are known in the vicinity of Van Yen, and the limestone hills north of Haiphong have a Viséan brachiopod-coral fauna. In north Tonkin and east Yunnan the Lower Carboniferous is also continuous with the Devonian and is strongly folded with it (Deprat 1912a).

Thailand

The south-southwest striking Upper Palaeozoic rocks of north Laos continue into Thailand where, near Loei, the Lower Carboniferous lies at the base of a fairly continuous Carboniferous and Permian sequence (Muir-Wood 1948, Hamada 1961, Kobayashi 1964).

No evidence of Lower Carboniferous rocks in Burma has been published although according to Thein and Haq (1969) Carboniferous fossils have been recently collected from the Shan States. In the Kanchanaburi Series of peninsula Thailand, Reed (1920) described a Viséan fauna from Patalung which included *Chonetipustula*, *Plicatifera and Pronorites*. The Viséan brachiopods *Marginirugus* and *Kitakamithyris* are also known from the southern end of peninsular Thailand (Hamada 1961). The

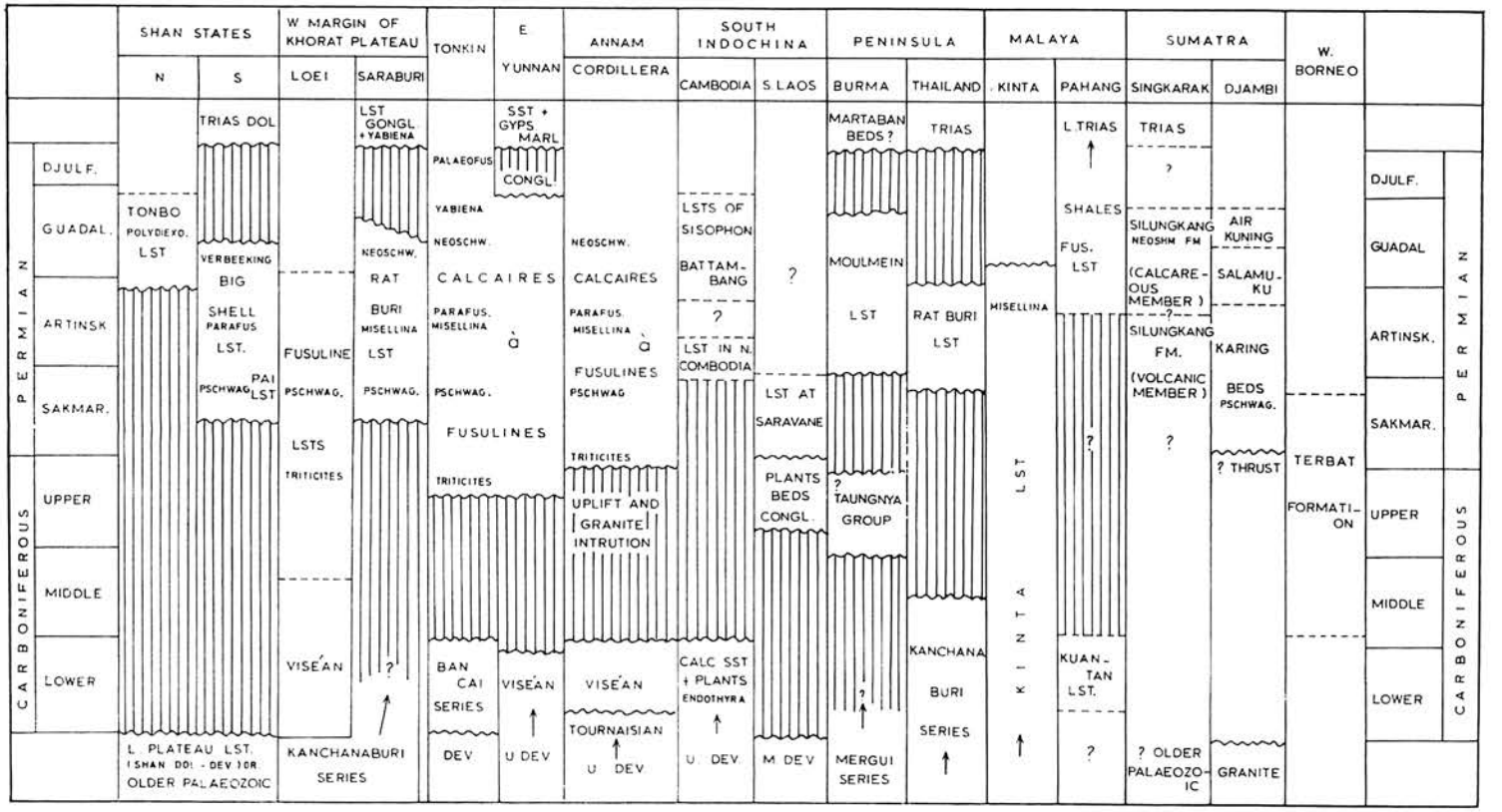

Fig. 2. Correlation chart of Carboniferous and Permian formations in Southeast Asia.

latter occurs in Japan around the Tournaisian/Viséan boundary. Sakagami (1966a,d) described Lower Viséan fenestellid polyzoa from near Rat Buri.

West Malaysia

In northwest Malaya occurs a trilobite-brachiopod fauna of uppermost Devonian or lowest Carboniferous age (Kobayashi and Hamada 1966, Hamada 1969) and a younger fauna recorded by Jones *et al.* (1966, p. 323) which is closely comparable to the Patalung fauna. In Pahang the middle to upper Viséan brachiopod-coral-conodont faunas from Sungei Lembing have been described by Muir-Wood (1948), Igo and Koike (1968) and Yanagida (1971); it is probable that the Lower Carboniferous is widespread in the eastern part of the country. Viséan limestone is also known in Kinta (Suntharalingam 1968).

HERCYNIAN (MIDDLE AND LOWER UPPER CARBONIFEROUS)

The Middle Carboniferous was a period of major uplift in Indochina accompanied by the intrusion of calc-alkali granites and much erosion (Fig. 2). Throughout the rest of the Palaeozoic two major facies were developed. The continental Lower Indosinian was widespread and characteristically of grey measures with Westphalian plants (*Sigillaria brardi*, *Calamites*, *Pecopteris*, *Sphenopteris*) and locally coals. Volcanic activity was important and gave rise to extensive andesite lavas and pyroclastics, especially in Tonkin, North Vietnam, north Laos and Cambodia. Emergence during the Middle Carboniferous is indicated by thin ferruginous sandstones and iron rich conglomerates in north Laos (Nong Et) and elsewhere in the Annam Cordillera.

Evidence for shallow water limestones of Middle Carboniferous (Moscovian) age in Indochina has been based on the identification of the fusuline foraminifer *Pseudostaffella* (Saurin 1956). However this occurs with *Neofusulinella* and *Schwagerina* which are Lower Permian genera. Other small fusuline and endothyracean foraminifera are not age diagnostic. In fact no undoubted Middle or Upper Carboniferous fusulines have yet been recorded from Indochina, the oldest faunas containing *Triticites* and *Schwagerina* being Lower Permian ('Ouralien' of Saurin 1956).

Locally however, deeper water marine sediments are present—black sulphurous limestones with *Homoceras*, *Nomismoceras*, and *Daraelites*. Vertical tectonic movements were probably important in producing basins with restricted circulation in which these sediments were laid down.

To the west and southwest of Indosinia the Hercynian movements were less pronounced and thicker and more continuous sequences are locally preserved. In the Loei area of Thailand, fusuline-coral limestones of Moscovian age have been recorded (Kobayashi 1964) and Hamada (1964) has described the brachiopods *Brachythyrina* and a species of *Purdonella* similar to one from the Middle Carboniferous of China. In Karen State, Burma, the Taungnyo Group (Brunnschweiler 1970) is an unmetamorphosed clastic sequence. It includes grey and pink siliceous limestone in the lower part containing a brachiopod fauna, probably of Upper Carboniferous age, including *Dictyoclostus*, *Mesolobus? Spirifer*, and aff. *Squamularia*. The occurrence of the Moscovian fusulinid, *Fusulina konnoi* (Ozawa) from a boulder of silicified limestone from Perlis (Scrivenor 1926) has never been substantiated. However, from the Terbat Limestone forming the western part of Gunong Selabor in west Sarawak, Sanderson (1966) identified late Bashkirian and Moscovian fusulines including *Profusulinella*, *Pseudostaffella*, *Fusulinella* and *Fusulina*. In the Kinta Valley, West Malaysia, there

appears to be a conformable sequence of limestones from the Lower Carboniferous to the Lower Permian (Suntharalingam 1968) but no diagnostic Middle or Upper Carboniferous fossils have been recorded.

Deep water sedimentation throughout most of the Carboniferous is probably represented by the uppermost part of the Lower Formation of the Phuket Group (Mitchell *et al.*, 1970). Here the presence of *Cyrtosymbole* allows correlation with the Devonian/Carboniferous boundary mudstones of northwest Malaya. Above this horizon are laminated mudstones, sharp-based sandstone beds, slumps and pebbly mudstones interpreted by Mitchell *et al.* (1970) as pelagic sediments, turbidites and mass flow deposits, typical of the continental slope and rise. The Singa Formation of the Langkawi Islands is readily correlated with this sequence. It passes up into Permian limestone. Part of the Mergui Series of peninsula Burma also seems to belong to this facies.

POSTHERCYNIAN (UPPERMOST CARBONIFEROUS AND PERMIAN)

In areas unaffected by Mesozoic earth movements the Posthercynian Upper Carboniferous and Permian is unmetamorphosed and structurally simple. Carbonate sediments are dominant in many areas and form thick sequences of massive limestones resistant to weathering. These form extensive plateaux generally in the northern parts of the area and scattered more or less isolated groups of limestone hills in the southern part. The limestones are frequently rich in fusuline foraminifera which allow their correlation with other parts of the Tethyan province and particularly with Japan. Rich brachiopod and coral faunas are developed locally; most of them allow a correlation with the Middle and Upper Permian of the Salt Range.

The base of the Posthercynian sequence is generally unconformable to and transgressive over older rocks but its age varies considerably. In Yunnan, North Vietnam and the Loei area of Thailand, the Upper Carboniferous is present. The exact correlation of this Upper Carboniferous with Japan or elsewhere is difficult because of the generally restricted fusuline faunas, which in many cases are poorly described and imperfectly known. In Yunnan and northern Indochina, what has been called Moscovian and Uralian is probably largely late Carboniferous and Lower Permian.

Shan States

The massive Plateau Limestone, widespread in the Shan States, was formerly regarded as a single formation spanning the Upper Palaeozoic. Locally it has yielded faunas of Middle Devonian and Middle to Upper Permian age. However the Permian part of the sequence, the Tonbo Limestone, is lithologically distinct and lies disconformably on the dolomitic Devonian part (Brunnschweiler 1970). The Tonbo Limestone is a dark calcitic algal micrite with waagenophylliid corals and brachiopods (Diener 1911, Reed 1932, Smith 1941) and the fusuline *Polydiexodina*. The brachiopods include *Spirigerella*, *Leptodus*, and *Notothyris* and the brachiopod fauna as a whole compares closely with that of the Wargal and Chidru formations (Middle and lower Upper Productus Limestone) of the Salt Range. A similar brachiopod fauna is also known from the clastic Yinyaw Beds of the Southern Shan States (Hobson 1941).

In the Southern Shan States Garson *et al.* (in press) have mapped massive micritic limestone with poorly preserved corals and large brachiopod shells (Big Shell Limestone Formation), which is dolomitized in its lower part. Fusuline genera within

the limestone include *Yangchienia*, *?Verbeekina* and *Parafusulina* indicating a Leonardian and/or lower Guadalupian age. The dolomite, however, contained *Pseudoschwagerina* and *Monodiexodina* cf. *kattaensis* of Sakmarian age.

Peninsular Burma

Small, scattered hills of Moulmein Limestone here rest unconformably on the Mergui Series. The Moulmein Limestone locally contains the Guadalupian productid brachiopod *Tyloplecta sumatrensis* and waagenophylliid corals (Rau 1930). However, in Karen state, immediately north of Moulmein, Brunnschweiler (1970) has mapped the Moulmein Limestone as a patchy development of reef limestone complexes in places underlain by biostromal limestone, resting unconformably on the Taungnyo Group (Fig. 2).

Thailand

Posthercynian limestones in Thailand are called the Rat Buri Limestone. They are typically micritic algal—fusuline limestones, locally with rich macrofaunas. They rest unconformably on the folded clastics of the Kanchanaburi Series (Pitakpaivan 1965). The oldest faunas so far recognised in the Rat Buri Limestone are Sakmarian. *Pseudoschwagerina* and other Sakmarian fusulinids have been recorded from northwest Thailand (Toriyama 1944, Konishi 1952). *Pseudoschwagerina* is also known near Phetchabun in central Thailand (Pitakpaivan 1965) and from the Loei area (Borax and Stewart 1966), from where also Yanagida (1967) has described a Sakmarian brachiopod fauna.

Middle Permian corals are known from northwest Thailand (Minato 1944) but the Artinskian is better known in the Loei area (Borax and Stewart 1960) and particularly in the region north of Sara Buri where the Rat Buri Limestone has rich fusuline faunas including *Misellina* and *Neofusulinella* (Toriyama and Kanmera 1968, Toriyama *et al.*, 1969). The Guadalupian is also present in this area, represented by limestone with large *Parafusulina*, *Sumatrina*, *Verbeekina*, and *Neoschwagerina* (Toriyama and Sugi 1959, Pitakpaivan 1965). *Yabeina* has been recorded in cobbles in a limestone conglomerate overlying Artinskian limestone (Endo 1969). An Upper Guadalupian brachiopod fauna including *Tyloplecta*, *Haydenella* and *Orthotetina*, occurs near Phetchabun (Yanagida 1964).

Less is known about the palaeontology and age of the Rat Buri Limestone in peninsular Thailand although Upper Sakmarian and Artinskian polyzoa have been described from five localities in the peninsular by Sakagami (1963, 1966b,c, 1968a,c, 1970a,b). At Khao Phrik, near Rat Buri, the polyzoa are associated with a rich silicified brachiopod fauna of Lower Guadalupian age (Waterhouse and Piyasin 1970, Yanagida 1970).

Indochina

In Indochina the widespread 'Calcaires à fusulines' (Fig. 1) ranges in age from uppermost Carboniferous (Triticites Zone) to Upper Guadalupian and to Djulfian in Tonkin. These limestones are transgressive and the Lower Permian is not everywhere represented. Notably in West Cambodia, Guadalupian limestone rests on volcanic rocks Ishii *et al.*, 1969) or the Lower Carboniferous. The rich fusuline faunas have been described by Deprat (1912b, 1913), Colani (1924) and Gubler (1935) and the brachiopod-coral faunas by Mansuy (1913). Posthercynian andesites were widespread, particularly in Tonkin, north Laos and Cambodia and often the limestone is found associated with volcanic rocks.

West Malaysia

The Chuping Limestone of Perlis is of Artinskian and Guadalupian age. Fusulines are rare but *Parafusulina* and *Neoschwagerina* have been recorded (Newton 1926). Sakagami (1963) has described Artinskian polyzoa from Langkawi. This limestone is clearly the equivalent of the Rat Buri Limestone in peninsular Thailand.

In the Kinta Valley the highest exposed part of the Kinta Limestone contains *Pseudofusulina*, *Misellina*, Waagenophyllid corals, and a rich molluscan fauna (Suntharalingam 1968, Batten 1972) of Artinskian age. Below are Sakmarian brachiopods (Jones *et al.*, 1966) and older limestones probably of Upper Carboniferous age but without diagnostic fossils.

Clastic beds associated with volcanic rocks and containing thin impure limestones with Guadalupian fusulines and brachiopods are present in central Malaya. Further north shales with *Leptodus* and numerous bivalved molluscs appear to be concordant with Lower Triassic *Claraia* shales.

Sumatra

The Djambi 'Permocarboniferous' is a clastic sequence with tuffs, andestic lava and limestone lenses. *Pseudoschwagerina* occurs low in the succession which is entirely Permian in age (Thompson 1936). In central and northern Sumatra, Permian fusuline limestones are probably widespread. Thompson (1936) mentioned Middle Permian fusulinids from numerous localities but they have been described only from Singkarak in the Padang Highlands (Fig. 1) where they are of Guadalupian age (Lange 1925, Yabe and Hanzawa 1931) and are associated with the productid brachiopod *Tyloplecta* and waagenophylliid corals. Klompé *et al.* (1961) have described the Singkarak sequence as the Silungkang Formation, recognising a lower volcanic and an upper calcareous member (Fig. 2).

West Sarawak

The Terbat Formation of chert, shale, and marl includes limestone with the Sakmarian fusulinids *Pseudoschwagerina*, *Zellia* and *Paraschwagerina* (Cummings 1962). This is the only proven Permian in Borneo.

COMMENT

In preparing this brief review I have become aware that a better understanding and a more precise correlation of the late Palaeozoic of Southeast Asia would be aided by three lines of research. 1) More systematic work on the fossils and their collection from *measured sections* (see Borax and Stewart 1966); 2) Mapping to trace unconformities in the succession, particularly in the Middle and Upper Carboniferous; and 3) radiometric dating of volcanic rocks associated with fossiliferous sediments.

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