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VOL. 18

ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC
COMMITTEE FOR CO-ORDINATION OF JOINT PROSPECTING FOR MINERAL RESOURCES IN ASIAN OFFSHORE AREAS (CCOP)

December, 1 9 8 6

ECONOMIC AND SOCIAL COMMISSION
FOR ASIA AND THE PACIFIC

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FOREWORD

The activities of CCOP since its establishment in 1967, have been regarded very highly not only by the member and cooperating countries, but they are recognized worldwide by those concerned with marine development. The major factor which contributed to this success, I feel, lies in the committee's work in fostering, among government authorities of the countries of East Asia, the awareness of the importance of geosciences and of international cooperation for national development.

For this, the Technical Bulletin played an important role. CCOP has been issuing this bulletin annually, containing papers on technical and scientific studies on marine geology, offshore prospecting and related subjects as well as on the results of surveys undertaken through CCOP sponsorship. Aside from contribution to scientific knowledge, these studies and reports have, we believe, helped in arousing interest in the mineral potential of the marine shelves of the region, and contributed to attracting investment of risk capital to the region. The Geological Survey of Japan has been publishing the Technical Bulletin as one of its very important contribution to the committee.

CCOP is now undergoing a change in its institutional structure. Regardless of the organization of the committee, it is our sincere hope that CCOP will continue to contribute scientifically and technically to the development of the region and also to meet the tremendous challenge in marine developmnt that lies ahead.

December 1986

Toshihiro KAKIMI
Director,
Geological Survey of Japan

NOTE BY THE EDITOR

This eighteenth volume of the CCOP Technical Bulletin is different from other volumes published in the past. It contains only one paper; a comprehensive treatise on the Permian geology of Southeast Asia by Henri Fontaine. This follows the study of the Jurassic geology of Southeast Asia by the same author which was published in the sixteenth volume and very highly regarded by in the geoscientists interested in the field. This work of reviewing the Permian geology, palaeontology, geochemistry, geographic evolution and mineral resources of this very large area is providing us not only with the present state of the geosciences of the region, but also with many insights for guiding future scientific study in this field. This, is a truly very significant contribution and I believe this paper should be referred to by all geoscientists working in this area. It is a great pleasure and priviledge to present this volume.

I wish to record my deep gratitude to Mrs. Yoshie Hanaoka of the Publications Office, GSJ, for the very thorough and painstaking efforts in technically editing this volume.

December 1986

Yoshihiko SHIMAZAKI
Chief Editor

CCOP TECHNICAL BULLETIN, VOLUME 18

THE PERMIAN OF SOUTHEAST ASIA

By
Henri FONTAINE

with contributions of
Nguyên Duc TIÊN
Daniel VACHARD
Colette VOZENIN – SERRA

CONTENTS

INTRODUCTION

This paper will not deal with the whole Southeast Asia. It is concerned by what has been called the "Pre-Tertiary core of Southeast Asia" (=Viet Nam, Laos, Kampuchea, Thailand, East Burma, Peninsular Malaysia, Sumatra, Sunda Shelf, West Borneo) and a block possibly rifted off from South China: the Palawan Block. This pre-Tertiary core is not a simple block, but appears to be composed of a few smaller blocks that collided and were sutured.

The divisions of this paper are classic and correspond to the main branches of the geological sciences. Seven appendices will bring new data on restricted areas, on microfacies of Permian limestones and on some fossils; they will also give many photographs to show the paleontological wealth of the Permian and its freshness. The common foraminifera species of the Upper Murgabian–Midian of Southeast Asia are represented by orientated thin sections; accordingly, figures of the appendices 2 and 3 can greatly help paleontologists in their fossil identifications.

This study has been possible thanks to the help received from the Bureau of Mines and Geosciences (Manila), the Geological Research and Development Centre (Bandung), the Geological Survey of Malaysia (Ipoh) and the Department of Mineral Resources (Bangkok). A visit to the Ministry of Geology (Beijing) and to the Geological and Palaeontological Institute of the Academia Sinica (Nanjing) has allowed some comparisons with the geology of South China. Geochemical analyses have been performed on a few samples at the laboratories of Elf–Aquitaine at Pau (South France). I am very grateful for all this help.

CHAPTER I

PALAEONTOLOGY

A very active palaeontological research has been carried out during the last twenty years in Southeast Asia, especially in Thailand. In 1964, Kobayashi gathered only a poor list of Permian fossils in a summary of the previous palaeontological papers concerning Thailand: one algae species, about 20 foraminifera species and 2 coral species. Later on, palaeontological studies have been undertaken by a rather large number of scientists; progress has been fast and steady. In 1980, two hundred sixty five species of foraminifera ranging from the Upper Bashkirian to the Upper Permian were mentioned in Thailand (Ingavat *et al.*, 1980), a great part of them collected from the Permian.

The amount of information on palaeontology in Malaysia was still very small in 1926 (Scrivenor, 1926); less than 20 species, all not definitely identified, had been assigned to the Permian or the "Permo-Carboniferous". Forty years later, the account of Jones *et al.* (1966) showed that a great progress had already taken place in Malaysia; more than one hundred species, a part of them definitely identified, were known at that time.

In Kampuchea, Laos and Viet Nam, many Permian fossils were described by Mansuy, Deprat and Colani between 1908 and 1920, by Patte and Gubler between 1920 and 1935, by many other authors since 1950 (See "Bibliography of the Stratigraphy and the Palaeontology of Viet Nam: 1882–1982" by Huyên *et al.*, 1982).

In the Philippines, Permian fossils were discovered for the first time in 1966 (Andal, 1966).

In Sumatra, a very important paper was published on the Permian fauna of Guguk Bulat by Lange in 1925. Permian fossils of Borneo have not been studied extensively.

Very recently, new fields have been opened in Southeast Asia: study of conodonts and ammonoids in Malaysia, study of algae and corals in Sumatra, study of fossil woods in Kampuchea and others.

Depositional environment was somewhat neglected in the old times. It is increasingly taken into account and palaeogeography will be easier to establish in the future. However, some groups of fossils can already help palaeogeographical research; their geographical distribution will be indicated by maps.

The most important fossils for stratigraphy and palaeontology are: continental plants, algae, foraminifera, corals, brachiopods; they have been studied more intensively than other groups. For instance, ammonoids are poorly known, probably because of their paucity in Southeast Asia. Research on conodonts is just starting. Bryozoa have been studied more in Thailand than in the other countries of Southeast Asia. Sponges which are very common in some Permian exposures have been hitherto neglected. Gastropods and pelecypods have been occasionally identified. Palynology has not been developed.

The Permian-Triassic boundary exhibits severe changes in fossils and a major bio-mass extinction. However, this extinction appears not to be abrupt for all taxa. Fusulinids and tetracorals display a gradual decrease. Conodonts survive the Permo-Triassic extinction practically unaffected. During the Permian, important regressions and reductions of epicontinental seas are evident in Southeast Asia. They killed many organisms; nevertheless, they are probably not the only one immediate cause that brought such a change at the close of the Permian.

Palaeontology indicates that metamorphism has not widely affected the Permian strata of Southeast Asia, even in Peninsular Malaysia where granites are very widespread. Old authors erroneously speculated that Peninsular Malaysia was almost deprived of fossils because of the thermal effects of the granitic intrusions and they made no intensive search for fossils; they based their studies mainly on lithologic correlation. However as an example, prolific and well-preserved faunas have been found near Kampar and near Chemor in the Kinta Valley from beds located between two granite massifs and considered "very unfavourable for the discovery of fossils" (Rastall, 1927). The Malay Peninsula is divided into three belts, following approximate north-south direction: Western, Central and Eastern Belts; the Central Belt contains only small plutonic bodies whereas intrusive masses are very large in the Western and Eastern Belts. Summarizing the geology of Malaysia, the last published annual reports of the Geological Survey concluded: "Metamorphism, both regional and thermal, is widespread. The most mappable metamorphic unit so far found is the Taku Schists in North Kelantan. . . . Radiometric datings indicate the latest metamorphism of the Taku Schists as Early to Middle Triassic". There is no true evidence for such a widespread regional metamorphism (See Taku Schists in the stratigraphic lexicon of the following pages).

CONTINENTAL FLORAS

Plant fossils have been found in many localities of Southeast Asia; Viet Nam, Kampuchea, Laos, Thailand, Malaysia and Sumatra. They suggest continental influences, especially where they are abundant and well-preserved. It is almost impossible for fragile land plants to be transported in abundance for great distance over the sea. Moreover, fresh water shells are locally present, as well as coal seams or bauxitic beds, also bases of tree trunks with their roots have been discovered, still in their original place, in the Jambi Province (Sumatra). Accordingly, some areas of Southeast Asia were emergent during the Permian. It generated depositional environments ranging from fresh water swamps or lakes to littoral facies with marine influence.

Vegetation modified rather suddenly during the Permian in Cathaysia. Thus, age is very important in the study of the relationships between different floras. On the other hand, Cathaysia stretched over a large part of the world, not as a single land mass, but as several emergent lands; variations in floras must be expected.

At first, we shall summarize what we know about the localities so far discovered, then, we shall deal with the main characteristics of the Permian floras found in Southeast Asia.

Localities of Viet Nam

In Central Viet Nam, shale containing coal seams provided some impressions of *Gigantopteris* leaves in the valley of the Song Ca 2 km upstream of Khe Bo and 30 km downstream of Cua Rao (Fromaget, 1947). No new information has been obtained on that flora. A careful research in the Khe Bo area has been recently carried out by the Geological Survey of Viet Nam; it failed to discover new samples of the Permian flora, but found Triassic fossils. The *Gigantopteris* remains are maybe a relict flora included in beds of the top of the Permian or already belonging to the Triassic. *Gigantopteris* ranges up to the base of the Triassic in China (Zhang *et al.*, 1982, p. 190).

Recently, *Gigantopteris* was collected in several localities of North Viet Nam belonging to the upper half of the Permian (Song Da area. Tiên, 1983; Tri *et al.*, 1977).

Locality of Kampuchea

Near Sisophon in Western Kampuchea, fragments of fossil woods were found in marine sediments belonging to the lower part of the *Yabeina*-zone (Midian) and containing a bauxitic material. They have been assigned to the Genus *Cathaysioxylon* by C. Vozenin-Serra (1966, 1977).

Localities of Thailand

In North Thailand near Fang, *Walchia piniformis* Schlotheim was discovered at the top of the Carboniferous or at the base of the Permian (Baum *et al.*, 1970). Other samples of *Walchia* were recently collected near Ngao (Personal communication of S. Bunopas), apparently in the same stratigraphical position.

In the Trang Province (Peninsular Thailand), at Pak Meng (Khao Meng) 30 km west of Trang, the upper part of the Phuket Group 15 m below a Middle Permian limestone yielded branchlets of *Walchia*, seeds of *Samaropsis* type and a leaf of *Taeniopteris* (Holden *et al.*, in press, Bunopas and Vella in press).

In Central Thailand near Saraburi, a claystone layer intercalated in a Murgabian limestone is rich in fossil plants, tentatively assigned to the genera *Alethopteris*, *Poacordaites* and *Cordaites*, and considered similar to the plants from the Petchabun area (Ingavat and Campbell, 1972).

Nine kilometers west of Loei in North Thailand, sixteen species of fossil plants

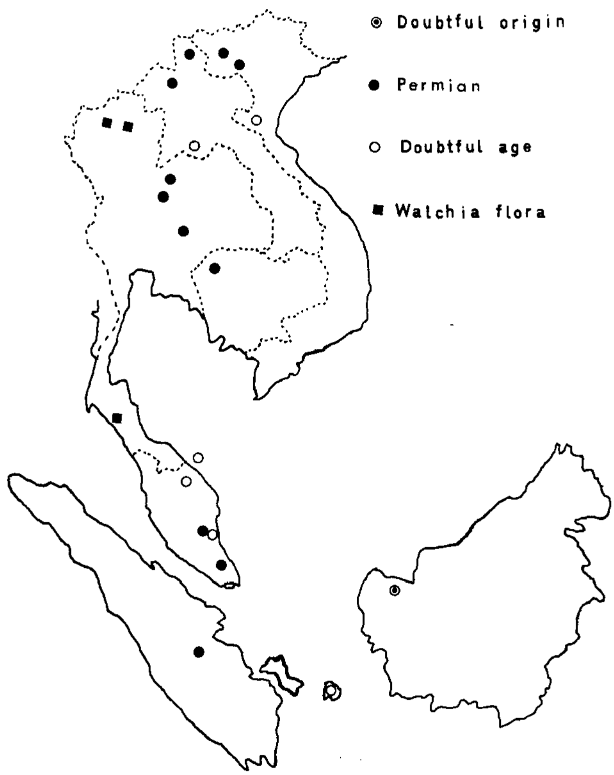


Figure 1. Permian plants localities.

were isolated by Asama *et al.* (1968) from a formation, 80 m thick, consisting of a black shale overlain by an alternation of shale and sandstone and displaying a facies change from black shale upwards to flysch-type rocks. Thus, the upper part of the formation was deposited under the influence of turbidity currents, but probably not in a deep water. The Loei flora includes three species of Gigantopterids, associated with typical elements of the Cathaysian flora: *Pecopteris lativenosa*, *Protoblechnum wongii*, the Genus *Shirakiopteris*. Its age is Late Permian. It is evident that the Loei flora must be assigned to the *Gigantopteris* flora.

Fifty kilometers south-southwest of Petchabun, 19 species of fossil plants were identified by Konno (1964) and Asama (1966). Konno (1964) found two typical genera of the Gondwana flora *Glossopteris* and *Palaeovittaria*, but his conclusion was "The Petchabun flora belongs evidently to the Cathaysian flora, though no species of Gigantopteroideae has been obtained: the Petchabun flora contains the typical Glossopteroidae which authenticates the direct migration of the Gondwana floral elements into the Cathaysia floral province through some passageways from the neighbouring Gondwana land". Such an invasion took place after the Artinskian and before the Kazanian. Asama (1966) collected plants from the same locality and failed to find new sample of *Glossopteris* and *Palaeovittaria*; on the other hand, he discovered *Protoblechnum wongii*, a species typical of the *Gigantopteris* flora. However, he could not gather characteristic plants of North Cathaysia such as *Bicoemplectopteris*, *Gigantopteris* and *Lobatannularia*.

Localities of Laos

In the Phong Saly area along the Nam Ou, a thick shale yields, throughout, impressions of *Bicoemplectopteris* with three horizons, namely a lower zone with *Protoblechnum wongii*, a middle zone with *Cordaites* cf *principalis* and an upper zone with *Schizoneura gondwanensis*. This shale underlies a grey shale with *Clathropteris* and overlies a shale with fresh water molluscs (Fromaget, 1933). Moreover, the shale with *Bicoemplectopteris* contains coal seams, not exceeding 50 cm in thickness. To the south, away from Phong Saly, the continental succession contains an increasing number of marine incursions.

In the Pou Noi area near Bun Tai (North Laos), Saurin (1950) discovered another *Gigantopteris* flora and considered it similar to the flora found by Fromaget in 1933 in the Phong Saly area.

In the valleys of the Nam Song and Nam Thon, northwest of Vientiane, shale with coal seams belongs to the Carboniferous and possibly also a part of it to the Permian; it has yielded two plant species (Fromaget, 1941), but no *Gigantopteris*.

Localities of Malaysia (Peninsular Malaysia)

In Kelantan, a small flora was recorded in shale about 500 m from the mouth of the Sungai Chiku, a tributary of the Sunga Galas. From that locality, Edwards (1926) described some fragments of *Pecopteris* and *Cordaites*; he suggested a similarity with the flora of Sumatra. Almost 60 years have elapsed and this flora remains poorly known.

At Pulau Redang (130°00′E, 5°45′N), black shale intercalated in conglomerate contains plant fossils as impressions, mainly leaves and stems. Some plant remains have been identified as *Pecopteris* and *Cordaites*. They might be Permian in age (Soon, 1977).

East of Maran along the road from Kuala Lumpur to Kuantan, a few plant fragments have been collected at Bukit Jaya from only one bed. They are associated with some pelecypod and brachiopod shells. They have been tentatively identified as well as the associated fauna (Azhar Bin Hussin, 1977). They are considered Lower Permian in age.

At the Jengka Pass west of Maran (Pahang), 21 species were collected from beds probably overlying marine strata containing brachiopods, bivalves, fusulinids (*Yabeina asiatica*, *Sumatrina annae*, *Verbeekina verbeeki*, indicative of the Uppermost Murgabian). This flora is composed of 2 euramerian species, 13 Cathaysian species, 3 Linggiu species and 3 unidentified species. It contains typical elements of the *Gigantopteris* flora (*Lobatannularia heianensis*, *Bicoemplectopteris hallei* . . .) and has nothing to do with the *Glossopteris* flora of Gondwana (Konno and Asama, 1970). Pecopterids are rare or absent. This fact is in sharp contrast with the Jambi flora. Pecopterids are also abundant in the Linggiu Flora (See the following lines).

From the Gunong Blumut area (Johore), Konno *et al.* (1970) described the "Linggiu flora" which is composed of 14 new species, 2 euramerian species, 1 Gondwana species (*Sphenophyllum speciosum*), 19 Cathaysian species and 4 unidentified species. This is the richest flora known in Southeast Asia after the Jambi flora. This flora contains the characteristic plants of the *Gigantopteris* flora: *Lobatannularia*, *Neuropteridium*, *Bicoemplectopteridium*, *Bicoemplectopteris*, *Gigantonoclea*, *Gigantopteris*, *Tricoemplectopteris*, and *Rhipidopsis*. By its main characteristics, this flora is correlative with the Upper Shikhotse Series in China, but displays minor differences in composition with the northern Cathaysia floras, maybe because of a slight difference in climatic or edaphic conditions between the two regions. It is slightly younger than the Jengka flora. Sphenophyta, Pterophyta and Pteridospermaphyta are prominent in the Linggiu Flora, with many kinds of genera; *Rajahia* (Pecopterid) is most abundant in the number of the species and individuals. Woody petrified stems belong to *Psaronius*. Coniferophyta and Cordaitophyta are absent whereas Gingkophyta are extremely rare. Lycophyta contains a single species of *Lepidodendron* which may represent a final survivor of this genus in Cathaysia.

Localities of Sumatra

In the Jambi Province west of Bangko, 85 species of fossil plants were collected in the valleys of the tributaries of the Merangin River. They were studied by Jongmans and Gothan (1935). The geology of these localities are Lower Permian in age and are in fair proximity to the limestone rich in fossils (algae, fusulinids, corals) and of Middle-late Asselian age (Ozawa, 1929; Thompson, 1936; Fontaine and Vachard, 1983; Beauvais, Fontaine, Suharsono and Vachard, 1983; Fontaine, 1984). Two species were assigned to *Gigantopteris* by Jongmans and Gothan, but later on, they were transferred to two other genera (Asama *et al.*, 1975). Thus, the Jambi flora cannot be designated as a *Gigantopteris*-bearing flora. It is composed of 33 new species, 26 euramerian species, 9 cathaysia species and 15 unidentified species. Of the 26 euramerian species, 15 species have been found in the Cathaysia flora. *Pecopteris* is predominant. The Jambi flora "differs essentially from the Gondwana flora and belongs evidently to the cathaysia flora, because a great majority of its component genera are decidedly the members of the Euramerian Carboniferous flora or its direct descendants" (Konno, 1964). The Jambi flora does not contain *Gigantopteris*, but have two genera of the same family. It is characterized by abundant *Taeniopteris*. *Lepidodendron posthumi* Jongmans and Gothan, a species of the Jambi flora, is abundant in the Taiyuan Formation of North China and is a leading element of the plant assemblage of this formation (Li, 1964), which is Lower Permian in age.

From the Belitung (=Billiton) Island, fragmentary plant remains were tentatively identified by Jongmans (Personal commun. to van Overeem, 1960). They were assigned to the Cathaysian flora.

Locality of Borneo

An old paper suggests the possible presence of a Permian flora, "The Sarawak coal beds I did not visit, but a collection of fossils was kindly sent to me by the Hon. Francis Maxwell, the Resident. I recognized at once well-known Australian and Indian forms, such as *Phyllotheca australis* and *Vertebraria*. These are entirely characteristic of the Newcastle deposits in New South Wales" (Tenison-Woods, 1885). This paper has usually been forgotten, probably because the origin of the fossils had not been precisely indicated.

Characteristics of the Permian Floras

During the Lower Carboniferous, floras displayed similarities throughout the world. During the Upper Carboniferous, floras began to be differentiated into floral provinces. And four distinct floral provinces come into existence during the Permian, namely Euramerian flora in the west, the Cathaysia flora in the east, the Angara flora in the north and the Gondwana flora in the south.

Paleobotanists have usually placed Southeast Asia in the Cathaysia province, even though some floral elements are different from one to another area. Disagreement arises mainly among geologists because of plate tectonic considerations. However, during the past few years, another flora appears to be found in Western Thailand: the "*Walchia* flora"; its significance must be interpreted carefully.

The Cathaysia flora have different meanings according to authors. Its early phase is the Euramerian flora whereas only the later phase is the characteristic *Gigantopteris* flora. In China, the *Gigantopteris* flora is the most developed in the Upper Shikhotse Series or the Wuchiapingian; it decreased during the Changhsingian. This flora extended towards the south as far as Johore in Malaysia.

The conifer *Walchia* primarily belongs to the Euramerian flora, although some species may have extended into the Angara flora. It has been found only in the western part of Thailand west of the "Pham Som geosuture". The *Walchia* flora displays a very low diversity, compared with the great variety of the Cathaysian floras known at Loei and Phetchabun in Eastern Thailand. Hence, Western and Eastern Thailand seem to be parts of separate continental blocks, especially if we follow old

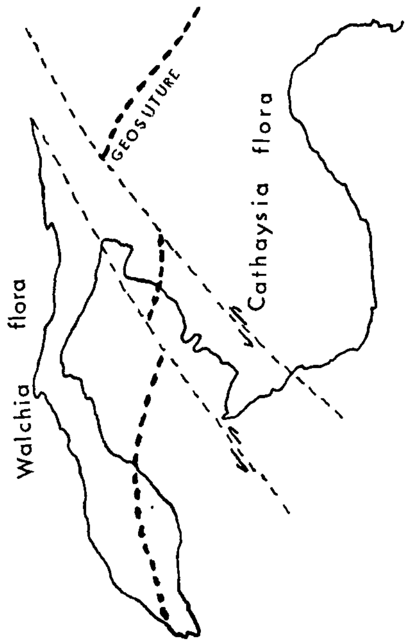


Figure 2. Apparent distribution of the Permian floras.

authors in saying that conifers are absent in the Cathaysia land (*Fig. 2*).

The idea that *Walchia* (conifer) is absent from the Cathaysian flora dates from Halle (1922). Since that time, *Walchia bipinnata* has been described by Li *et al.* (1974, p. 153, pl. 121, *Fig. 3–5*) from the Upper Shikhotze Formation (Late Permian) in North Shansi. Moreover, *Walchia* cf. *filiciformis* has been found in the "Lower Permian" of the Gansu Province and *Walchia pinniformis* in the Permian of the Yungcan District of the Gansu Province (Personal communication of Prof. Li). The genus *Walchia* appears as common in the northern hemisphere and is absent from Gondwana. An European species (*Callipteris conferta*), also considered absent from Cathaysia, has been discovered in Hebei Province, Central Shansi and North Anhuei (Personal communication of Prof. Li). In conclusion, the presence of *Walchia* in Western Thailand is not a strong reason to suggest that Western Thailand belongs to a continental block different from that of Eastern Thailand. However, the flora of Western Thailand is so far characterized by its paucity.

An important fact in Southeast Asia is the presence of many localities which contain Permian plants. It indicates that several areas were emergent. Those areas were girdled by shallow seas with corals and prolific faunas. If there were equivalents of modern mangrove swamps during the Permian, Southeast Asia should be a good place to study them.

ALGAE

Algae are very common in many limestone exposures, more common than what is indicated in the published literature. They have been found in all the countries of

Table 1. Stratigraphic distribution of the main Permian floras of Southeast Asia.

	SUMATRA	MALAYSIA	THAILAND	LAOS	KAMPUCHEA	VIET NAM
DORASHAMIAN						Khe Bo Flora
DZHULFIAN		Linggiu Flora Jengka Pass Flora	Loei Flora Phetchabun Flora	Phong Saly Flora Bun Tai Flora		Song Da Flora
MIDIAN					Sisophon Flora	
MURGABIAN			Saraburi Flora			
KUBERGANDIAN						
YAHTASHIAN						
BOLORIAN						
SAKMARIAN	Jambi Flora					
ASSELIAN			Walchia Flora			
UPPER CARBONIFEROUS						

Southeast Asia. They are abundant in reefal environments. Locally, they form the major part of some limestones; at Sungai Luati (Renah Lemabung) and at Sungai Tabir (Lubuk Cada) in the Jambi Province (Sumatra), algae fragments are the main component of grainstones. Green algae are frequent and indicate shallow marine environments. Stromatolites have been locally observed, commonly as fragments shifted from their original place.

Algae of Southeast Asia have a tethyan facies. In Thailand, R. Endo (1968) identified 64 species of algae in samples collected from limestone situated midway between Lopburi and Saraburi (Khao Phlong Phrab). Some genera had been already mentioned in many places of the tethyan realm; other genera (*Andrusoporella*, *Poikiloporella*, *Likanella*, *Salopekiella* and *Velebitella*) were reported for the first time in Southeast Asia and had been previously known only in Southern and Southeastern Europe. Endo (1968) isolated 8 species from Permian limestone pebbles of a Jurassic conglomerate exposed near Mansalay, Mindoro, Philippines. Tu (1970) described 14 species mainly from South Viet Nam. Tiên (1979) studied algae from Kampuchea. Algae have also been mentioned in Malaysia in the state of Perlis (Bukit Chondong and Bukit Temiang) by Jones *et al.* (1966) and in the Pahang State at Bukit Kepayang by Gowda (1965). In Sumatra, algae are common at Guguk Bulat (Padang Highlands) and in the Permian limestones of the Jambi Province.

FORAMINIFERA

Foraminifera are abundant in many limestone exposures of Southeast Asia. Among them, fusulinids are very reliable for stratigraphic zonation. They are easy to collect at surface and from boreholes. Known already in the Middle and Upper Carboniferous, they remarkably continued to diversify during the Permian. They were less frequent during the Upper Permian and became extinct a little before the end of the Permian, in China a few meters below the Lower Triassic with *Otoceras-Claraia*. Their Permian species are more than 2000 in number. It is true that the fusulinids are very rare or absent in some parts of the world, especially in high latitudes; they have not been found in Australia. Hence, they cannot be used all over the world.

In Southeast Asia, fusulinids have been studieed by many authors since the beginning of this century. They are found mainly in limestones which are very widespread in the Southeast Asia Permian. Fusulinids are commonly associated with algae and compound corals because they thrived in shallow, warm, aerated sea water, generally less than 30 m deep. Prasada Rao (1984) suggests a cold to temperate climate during the deposition of some Permian limestones of Malaysia containing fusulinids, but these results are still controversial. Because fusulinids are small organisms, their skeletons are easily transported by turbidity currents (Allodapic limestone of the Lom Sak area in Thailand). They are benthic dwellers, at least many of them.

Permian fusulinids of Southeast Asia belong to the Tethyan realm. During the Early Permian, connections with East European seas had some influence as far as Southeast Asia. During the Middle Permian, influences from West and North are less evident and eastern Tethyan elements are largely predominant.

Inside Southeast Asia, it is difficult to separate zones; it seems there are no marked differences among the fusulinid faunas. Thus, Southeast Asia appears as belonging to a single paleobiogeographic province. In Thailand, three Permian basins have been recognized, but not on paleontological basis. In Viet Nam, there is no clear difference between faunas from the northern and the southern parts of the country. In South China, Lin (1981) described three "biogeographic provinces" which correspond to "ecological habitats".

In open sea areas, fusulinids easily thrived whereas they were replaced by smaller foraminifera in confined environments. However, their absence must be interpreted with case. In the Temerloh region (Peninsular Malaysia), the Bukit Kepayang and Jengka Pass limestones are rich in fusulinids, especially large fusulinids, whereas a nearby limestone at Gunong Sinyum has yielded only small foraminifera, those last foraminifera are Triassic in age (Current study of D. Vachard) and the Gunong Sinyum limestone is not a lateral facies of the Permian as indicated in the geological map.

During the Upper Permian, seas decreased in importance; environments favourable to fusulinids shrank. The last fusulinids, i.e. *Palaeofusulina-Colaniella* assemblages (=Dzhulfian and Dorashamian stages), have been found only in some areas (see *Fig. 3*): 1—Lang Son vicinity (Liêm, 1967), North Viet Nam; 2—Lang Nac where the first *Palaeofusulina* and *Colaniella* were discovered (Deprat, 1913; Colani, 1924; Liêm, 1974), North Viet Nam; 3—Localities of Song Hong, Song Da and Song Ma areas (Tri *et al.*, 1977); 4—Ta Thiet Limestone (Liêm, 1983), South Viet Nam; 5—Eastern Kampuchea in the vicinity of Kampot (Tiên, 1979); 6—10 km west-northwest of Chiang Dao, North Thailand (Hahn and Siebenhuner, 1982); 7—10 km

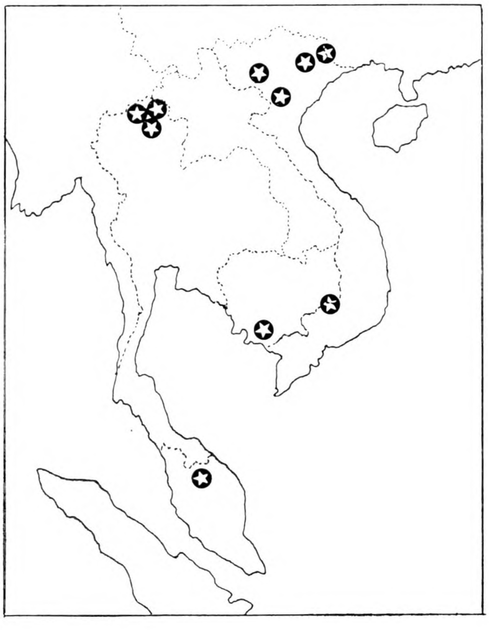


Figure 3. Palaeofusulina localities.

southeast of Ngao (Sakagami and Hatta, 1982), North Thailand; 8—South of Nan 20 km west of Amphoe Sa, North Thailand (Hahn and Siebenhuner, 1982; *Palaeofusulina* probably present); 9–13 km southwest of Phrae, North Thailand (Ingavat, 1983); 10—Several localities along Sungai Paloh and Sungai Relai (tributaries of Sungai Lebir), Kelantan, Northeast Peninsular Malaysia (Am *et al.*, 1977). They belong to the Aring Formation.

The following lines will give a general picture of the geographic and stratigraphic distribution of the fusulinids in Southeast Asia, as we know it to-day.

In Sumatra, the fusulinids belong mainly to two stages: Asselian and Murgabian and less commonly to the other stages of the Lower and the Middle Permian. The Upper Permian appears to be devoid of these fossils. Fusulinids are also present in the Bangka Island (Cavernous silicified limestones of the Sungai Liat area near Aerduren) and the Belitung Island (de Neve, 1961). At the Belitung Islands, they were found in limestone from drill holes made just off the northern shore of the island and were tentatively identified as schwagerinids (van Overeem, 1960).

In Borneo, the Permian is known in West Sarawak where its fusulinids have not been extensively studied.

In Peninsular Malaysia, several localities of the Central Belt have yielded abundant fusulinids Middle-Upper Murgabian to Lower Midian in age: Bukit Kepayang, Jengka Pass and Sungai Atok in Pahang; Sungai Badong in Southeast Kelantan. The upper part of the Lower Permian and the Lower part of the Middle Permian are well documented: Sumalayang Limestone, Lee Mine Beds. The *Palaeofusulina*–zone (upper part of the Upper Permian) is known in one small area of the Central Belt. The Lower Permian, probably extensive in Northwest Malaysia, has provided few fusulinids.

In the Philippines, fusulinids have been found at the small Carabao Island and in the northern part of the Palawan Province. They belong to the Middle Permian and especially to the Murgabian.

In West Thailand and especially Northwest Thailand (Chiang-Mai-Mae Hong Son Region), several localities have provided fusulinids (Toriyama, 1944; Konishi, 1953; Ingavat and Douglas, 1980; Hahn and Siebenhuner, 1982). They belong to the Lower and Middle Permian, and to the lower half of the Upper Permian. In Peninsular Thailand, fusulinids have not been extensively studied; it is interesting to mention the occurrence of peculiar Upper Permian foraminifera (*Shanita intercalaria* and *Hemigordius renzi*) in the Surat Thani Province and south of Phang-nga (Ingavat, 1983). Fusulinids of the western part of Central Thailand will be better known in the near future because of geological mapping undertaken in that poorly-investigated area.

In Central Thailand (Lampang, Nan, Phrae areas), the Permian is well-developed and has yielded Early to Late Permian fusulinids. The presence of the *Palaeofusulina–Colaniella* assemblage deserves a special mention.

In Eastern Thailand, fusulinids are common in many localities; they belong to the Lower Permian, the Middle Permian and the lower part of the Upper Permian (Midian).

In Western Kampuchea, fusulinids are Murgabian–Midian in age whereas their range is much wider in Eastern Kampuchea and covers almost all the Permian.

In Laos, the Lower and the Middle Permian are present, with fusulinids. The Upper Permian has not been found.

In South Viet Nam, Permian is not widespread; Murgabian to Upper Permian fusulinids have been identified (Tiên, 1970; Liêm, 1983).

In North Viet Nam, the Permian limestones have provided rich fusulinid assemblages, Early to Late Permian in age.

Fusulinids are also present in Limestone pebbles of conglomerates of Mesozoic or Cenozoic in age. The most interesting localities are; Kutai in East Borneo (Tertiary conglomerate), about 18 km west of Palembang (Sumatra) in the Sekaju area (Neogene conglomerate), in Mindoro in the Philippines (Mesozoic and Cenozoic conglomerates) and in the Tay Ninh—Bien Hoa area in South Viet Nam ("Old alluvium").

CORALS

Corals are common in the Permian of Southeast Asia. Recent studies show that they are useful for palaeogeography and stratigraphy. In China, corals of Thibet and Western Yunnan are different in some respects from those of South China. Thibet has genera such as *Iranophyllum*, *Wentzelella*, *Praewentzelella* which are absent from South China where *Ipciphyllum* is particularly abundant (Wu, Liao and Zhao, 1982). Such a provincialism has not been clearly established in Southeast Asia.

From the Maping Limestone (= Gzhelian and Sakmarian s.l.) in China, a rich coral fauna has been described from the upper part of the limestone. Among other corals, it contains varied types of massive corals and new genera have been isolated; *Kepingophyllum*, *Nephelophyllum*, *Antheria*, *Anfractophyllum*, *Parawentzellophyllum*, *Peiraphyllum* (Wu and Chou, 1974; Yu, 1977; Yu, 1980; Wu, Liao and Zhao, 1982; Wu and Zhou, 1982). A new family has been coined: the Kepingophyllidae (Wu and Zhou, 1982). This fauna is still almost unknown in Southeast Asia.

In China, corals of the Maping Limestone belong to two assemblages: 1—*Parawentzelophyllum–Kepingophyllum–Peiraphyllum* assemblage corresponding to the *Pseudoschwagerina*-zone; 2—*Pseudocarniaphyllum–Chuanshanophyllum–Gintingophyllum* assemblage corresponding to the top of the Carboniferous (*Triticites* zone). Hence, corals in this area appear to favour the lower boundary of the Permian within the Maping Limestone.

Corals are often mentioned in papers concerning the Permian of Southeast Asia; hence, the common impression is that coral reefs are well-developed and geographically widespread from bottom to top of the Permian sections. This is not actually correct. Permian corals include corals that were unable to form reefs, i.e. to erect rigid topographic structures by frame-building, sediment retention and binding.

Tiny hornshape corals without dissepiments as well as branched colonies of tubular Tabulata are found in varied environments, from shallow water (reefal environment) to deeper water (mud mounds). They are not indicative of a reef. They are locally associated with bryozoa and crinoids; they are included in pure limestone or

Figure 4. Massive corals (Rugosa) localities.

in shaly limestone.

Fasciculate and especially massive colonies of Waagenophyllidae, on the contrary, thrived only in favourable conditions with shallow, aerated, warm and clean water. They were associated with algae and a prolific and diverse fauna. Because of that, the localities where they are rather abundant are indicated on a map (*Fig. 4*). Waagenophyllidae are more common in the *Neoschwagerina* and *Yabeina*-zones than in the other zones of the Permian.

An outlook on the geographic distribution of the corals in Southeast Asia will be depicted in the following lines with an emphasis on Malaysia where little information, has been published.

In Malaysia, Permian corals are poorly known, probably because of a lack of search for them. Reliable information concerns only a few localities; Bukit Biwah (Chung, 1962), Lee Mine (Jones *et al.*, 1966, Suntharalingam, 1966), Pulau Jong (Foo, 1964) and a few other localities of the Langkawi Islands and of the Perlis state (Jones *et al.*, 1966), Ulu Sungai Atok (Igo, 1964), Bukit Kepayang (Jones *et al.*, 1966), the Jengka Pass (Jones *et al.*, 1966) and its surroundings (Jones *et al.*, 1966). At Bukit Biwah (Central Trengganu), *Huangia* cf. *chihsiaensis* Yoh a fasciculate waagenophyllidae is associated with *Parafusulina gigantea* and *Schubertella giraudi*. *Ipciphyllum* has been found in the Bukit Biwah area (Jones *et al.*, 1966). At Lee Mine west of Kampar (Perak), a few solitary Waagenophyllidae (*?Iranophyllum* and *Pavastehphyllum* (*Sakamotosawanella*) *permicum* and a fasciculate coral

(*Waagenophyllum* cf. *virgalense* Waagen et Wentzel) have been found in association with *Misellina claudiae*. At Pulau Jong (Langkawi Islands), *Sinopora dendroidea* Yoh and *Caninia* cf. *liangshanensis* Huang are present in a limestone belonging to the lower part of the Middle Permian (="Upper Artinskian" and "Kungurian"). At Ulu Sungai Atok (North Pahang, 102°15′E, 4°21′N), *Sinopora* cf. *dendroidea* and *Parawentzelella* (?) *malayensis* Igo have been discovered in a limestone with *Verbeekina verbeeki*, *Sumatrina annae* and *Yabeina* cf. *tobleri* (=base of the Midian and top of the Murgabian).

At Bukit Mata Ayer in North Perlis, *Caninia* sp. and *Chaetetes* sp. have been mentioned. *Wentzelella* should be present at Pulau Singa Besar in the Langkawi Islands and associated with some Lophophyllidiidae, *Michelinia* and *Sinopora dendroidea* Yoh (Jones *et al.*, 1966); it is impossible to know if *Wentzelella* has been correctly identified.

At Bukit Kepayang (=Kampong Awah Quarry) between 100 and 101 milestones of the East-West Highway 16 km east of Temerloh, corals are not abundant; they are fasciculate; *Waagenophyllum* aff. *indicum* Waagen et Wentzel, and massive; *Ipciphyllum elegans* Huang (Jones *et al.*, 1966). They are associated with fusulinids (Cummings, 1965; Gowda, 1965; Igo, 1967), algae (Gowda, 1965) and bryozoa (Sakagami, 1973). At the Jengka Pass east of Kampong Awah, a road-cut along the East-West Highway displays limestone beds with corals (*Ipciphyllum* and *Protomichelinia*), brachiopods (*Leptodus*, *Schellwienella ruber*, *Spinomarginifera*, *Linoproductus* . . .) and fusulinids. In the vicinity of that road-cut at the Sungai Jengka near its confluence with the Sungai Padang, a limestone has provided *Neoschwagerina* sp. and *Yatsengia* aff. *sisophonensis* Fontaine (Jones *et al.*, 1966).

Reading D. Hill (1961), it appears that Indonesia is poor in Permian corals and that many localities have only solitary, non-dissepimented corals like Permian exposures of Australia. This characteristic is not true for Sumatra, where corals are abundant in two areas; at Guguk Bulat in the Padang Highlands (Middle Permian; Fontaine, 1983) and in the western part of the Jambi Province (Lower Permian; Fontaine, 1984).

In Thailand, corals are very common along the western edge of the Khorat Plateau, especially from Saraburi to Phetchabun. Elsewhere, they are few or absent.

In Laos, Permian corals are still poorly known and have been studied only in three localities (Fontaine, 1961).

In Kampuchea, some Permian exposures are very rich in corals and are distributed mainly in West and Southeast Kampuchea (Fontaine, 1961; Fontaine, 1967).

In South Viet Nam, Permian corals have been collected in the Ha Tien area (Fontaine, 1967).

In North Viet Nam, corals are present in many Permian localities (Fontaine, 1955, 1961; Fontaine, 1968).

BRACHIOPODS

Brachiopods are somewhat abundant in the Permian all over the world; they are more tolerant of facies than the fusulinids. However, they have been studied only in a few localities of Southeast Asia. The first main studies were carried out by Mansuy (1913, 1914, 1916) on fossils from Kampuchea, Laos and Viet Nam. Brachiopods from Peninsular Thailand have received the largest attention in recent years with six papers devoted to them (Waterhouse and Piyasin, 1970; Yanagida, 1970; Grant, 1976; Waterhouse, 1981; Waterhouse, Pitakpaivan and Mantajit, 1981; Waterhouse, 1982). Brachiopods are common and diverse in many localities of Southeast Asia; they deserve more attention.

In Thailand, Grant and Stehli made an intensive search for brachiopods in the very fossiliferous Saraburi region, without success (Grant, 1976, p. 8). Hence, brachiopods are not common everywhere. However, geologists from the Department of Mineral Resources (Bangkok) have recently discovered a locality near Muaklek (Saraburi region) rich in brachiopods (Personal communication of B. Sektheera).

Brachiopods, prolific in some places, are usually associated with other faunas indicating shallow water and tropical or subtropical climate. Nevertheless, Waterhouse recognized some signs of cool-water species migrating to Southeast Asia (Waterhouse, 1973; Waterhouse, 1982) occasionally and locally penetrating warm climatic barrier or attracted by cooler regions in Western Thailand.

Brachiopods, Early Permian in age (not Carboniferous as suggested by Hamada, 1960), have been collected at Ko Muk and Ko Phi Phi, in Peninsular Thailand

Figure 5. Main brachiopods localities.

from pebbly mudstones. They are considered a cool-water association, but the temperature was not as cold as for faunas associated with glacial sediments over much of Gondwana during the Late Asselian (Waterhouse, 1982). This brachiopod fauna has been found about 65 m below the Ratburi Limestone.

The main brachiopod faunas found in Southeast Asia belong to the Asselian, the Middle Permian and the base of the Upper Permian.

In Peninsular Malaysia, a gray shale at Sungai Spia (Pahang; 102°40′E, 4°32′N) contains abundant brachiopods (*Spiriferellina cristata, Dictyoclostus* . . .) associated with tribolites, solitary corals and bryozoa (Igo, 1964). This fauna was considered late Middle Permian or Upper Permian in age; it is the richest of Malaysia.

Another brachiopod fauna of Malaysia has been collected from shales exposed in the Sungai Jemuru near Kuala Lipis; it consists of *Dictyoclostus*, *Uncinella timorensis* Beyrich, *Spiriferellina*, *Leptodus* cf. *tenuis* Waagen . . . (Jones *et al.*, 1966). Another locality north of Kuala Lipis at the Sungai Yu has also yielded brachiopods with *Leptodus* (Jones *et al.*, 1966). Farther north in South Kelantan at the mouth of a tributary on the Sungai Galas 13 km southwest of Gua Nineck, *Leptodus* is again present. These exposures with *Leptodus* are located on a line trending north-northwest and 50 miles long.

In Kampuchea, Laos and Viet Nam, brachiopods were described by Mansuy and Patte at the beginning of this century. More recently, a few studies were carried out in Western Kampuchea (Termier, 1959; Tran thi Chi-Thuan, 1961; Nakamura, 1972) and in Central Viet Nam (Tran thi Chi-Thuan, 1962).

In Sumatra, there has been no recent research on the Permian brachiopods.

The localities of Thailand which have recently provided abundant brachiopods are indicated on a map (*Fig. 5*).

Uppermost Permian (Changhsingian or Changxingian) brachiopods are abundant and diverse in South China, with 60 genera and 130 species (Liao, 1980). At 15 localities of South China, brachiopods are even present in beds corresponding to the Permian boundary and containing a mixed fauna of Permian-like brachiopods and Lower Triassic ammonoids such as *Otoceras* (firmly identified according to Sheng *et al.*, 1984), *Glyptophiceras* and others; Permian-like brachiopods occur from 0.2 to 2 m above the line of appearance of the first Triassic ammonoids (Liao, 1980). In other words, some Permian brachiopods appear to have survived for a short span of time in the earliest Triassic, if we accept the traditional boundary between the Permian and the Triassic. An association due to reworking is ruled out by Chinese Paleontologists (Sheng *et al.*, 1984).

BRYOZOA

From ten localities of Thailand and West Malaysia, 128 species of Permian bryozoa have been isolated by S. Sakagami. They are assigned to the Early Permian and the Middle Permian with the exception of those from Khao Hin Kling, probably of Late Permian in age.

Bryozoa are very abundant in other Permian exposures where they have not been studied, for instance in Thailand at Ban Phu Plu in the Kanchanaburi Province, at Km 48 between Mae Sot and Umphang, at Km 52–54 between Tak and Mae Sot in the Tak Province, north of Nan along the Nam Yao River in the Nan Province. Accordingly, it appears that bryozoa are common in the Permian of Western and Peninsular Thailand.

CONODONTS

The number of conodont genera is relatively small world-wide during the Permian compared to other periods of their existence from the Cambrian to the Triassic. They showed evolutionary bursts from the Ordovician to the Lower Carboniferous and during the Triassic.

The Permian conodonts have been studied only in a few localities of Southeast Asia. From Tham Nam Maholan in northeast Thailand (Igo and Koike, 1966; Igo, 1974), some Lower Permian conodonts have been described. In northern Thailand, a German team collected many rock samples from which D. Stoppel isolated a great number of conodonts, mainly from northwest Thailand; nothing was found in the Nan area; only one species, Upper Carboniferous or Permian in age, was collected in the Chiang Rai area (30 km southeast of Chiang Rai). In the Chiang Dao area, several localities yielded Permian conodonts; namely Artinskian conodonts 15 km east of Chiang Dao, Murgabian conodonts 40 km southeast of Chiang Dao, Dorashamian conodonts 20 km west–northwest of Chiang Dao, Murgabian conodonts near Ban Muang Haeng 40 km northwest of Chiang Dao. In west and northwest of Mae Sariang, five localities yielded Permian conodonts; namely Murgabian–Midian conodonts at three localities west-northwest of Ban Mae La Noi (about 40 km northwest of Mae Sariang), Murgabian–Midian conodonts at the Mae Nam Salawin 40 km northwest of Mae Sariang (about 12 to 20 km south or southwest of the three localities west of Ban Mae La Noi) and Murgabian conodonts 10 km west of Mae Sariang. Halfway between Mae Sariang and Amphoe Tha Song Yang, *Neogondolella bisselli* has been found in the upper reaches of Mae Nam Ngao; 23 km north of Amphoe Tha Song Yang, a more varied fauna has been identified (*Neogondolella prolongata*, *N. rosenkrantzi*, *Xaniognathus tortilis*). Thirty five kilometers southwest of Amphoe Li at the Mae Nam Ping, *Neogondolella bisselli*, *N. rosenkrantzi*, *N. serrata serrata* and *Streptognathodus* sp. have been isolated; they indicate Murgabian age. Three localities of northern Thailand have yielded relatively varied faunas that are listed in the following lines. Artinskian conodonts have been mentioned at a locality 12 km northwest of Amphoe Phrao: *Idiognathoides noduliferus japonicus*, *Neogondolella bisselli*, *N. idahoensis*, *Neostreptognathodus* cf. *prayi*, *N. sulcoplicatus*, *Streptognathodus excelsus*, *S. lateralis*, *S. Oppletus*, *S. wabaunsensis*, *Xaniognathus tortilis*. Conodonts from a locality 20 km west–northwest of Chiang Dao have been assigned to the Dorashamian: *Anchignathodus* cf. *minutus*, *A. parvus*, *A.* cf. *scitulus*, *A.* cf. *spiculus*, *Hindeodus alatoides*, *Hindeodella* cf. *tenuis*, *Lonchodina* sp., *Neoprioniodus* cf. *montanaensis*. At the Mae Nam Salawin northwest of Mae Sariang, conodonts have been considered Murgabian–Midian in age: *Anchignathodus typicalis*, *Cyprido-*

della muelleri, *Ellipsonia delicatula*, *E. tribulosa*, *Neogondolella babcocki*, *N. bitteri*, *N. rosenkrantzi*, *Neostreptognathodus* cf. *clinei*, *Xaniognathodus tortilis*. In Central Thailand (Thong Pha Phum area), *Anchignathodus typicalis* has been isolated from a locality 12 km west of Amphoe Si Sawat. In Peninsular Malaysia, two areas have yielded Permian conodonts; they are limestone in the vicinity of Kodiang in Northwest Malaya (Metcalfe, 1981), limestone of Gunong Kanthan north of Chemor in Perak (Ramly bin Khairuddin, 1979; Metcalfe, 1981). The distribution of conodonts is influenced by variation in depositional environments; accordingly, Metcalfe failed to discover any conodont during an intensive search in the Kampar area of the Perak State where other Permian fossils are abundant.

Conodont colour changes under thermal effects, thus they are used to measure temperatures undergone by sediments. In the same way, their surface changes from smooth and vitrous to pitted and grainy. In the Lower Paleozoic strata of Peninsular Malaysia, they are commonly black; in the upper Paleozoic and the Triassic, their colour is varied. North of Chemor, it seems that the presence of granite affects the colour and it changes with the distance from the granite (Ramly bin Khairuddin, 1979).

MOLLUSCS

Gastropods have been studied by a few authors (Roemer, 1880–1881; Mansuy, 1913, 1914; Delpey, 1941–1942; Batten, 1972; Ishii and Murata, 1974). In Peninsular Malaysia at the Lee Mine no. 8 in the Kinta Valley (101°06′E, 4°17′N), abundant fauna has been unearthed (Batten, 1972). The material is composed of 28 species of Bellerophontids and Pleurotomarians, it is the richest fauna known in Southeast Asia from a well-documented horizon. The Permian of Kampuchea (Delpey, 1941–1942, Ishii and Murata, 1974) has provided about 14 species of Pleurotomarians whereas the fauna of the Lee Mine includes 22 species of that group. Gastropods of Southeast Asia are common elements in most Permian faunas of the world.

Pelecypods are not very well-known. Among them, a bizarre family, the Alatoconchidae deserves special attention. This distinctive group is represented in Peninsular Malaysia (Runnegar and Gobbett, 1975; Yancey and Boyd, 1983); it seems to be also present in northeast Thailand (Person. comm. of C. Pendexter). Alatoconchidae are the largest bivalves of Late Palaeozoic and display an unusual form; they were first described only in 1968. Presently, they are known in Tunisia, Yugoslavia, Iran, Afghanistan, Malaysia, Japan and maybe Thailand. They are absent in the Americas. They belong to the Middle Permian. In Peninsular Malaysia, they have been collected at the H. S. Lee Mine and consist of two subgenera: *Shikamaia* (*Tanchintongia*), and *Saikraconcha* (*Dereconcha*); they are the oldest Alatoconchidae, Bolorian in age.

Ammonoids, discovered at the Lee Mine no. 8 (Malaysia), were described in 1980 by C. Lee. Probably Late Artinskian in age, they belong to *Adrianites*, *Neocrimites* and *Prostacheoceras* (*P. skinneri* Miller). Other ammonoids were discovered at Sungai Cheroh north of Raub in the Pahang State (Peninsular Malaysia): *Agathiceras suessi* Gemmellaro, *Adrianites elegans* Gemmellaro and *Popanoceras* cf.

scrobiculatum Gemmellaro; they were considered Early Murgabian in age (Lee, 1980). In Indonesia, ammonoids have been collected in the Belitung Island from a sequence of sandstone with intercalations of claystone, siltstone, conglomerate, radiolarian chert and tuffaceous sediment (Kruizinga, 1950; Archbold, 1983). One ammonite was replaced by cassiterite (Kruizinga, 1950).

A belemnite-like Aulacocerid has been described from the Saraburi area in Thailand (Dawson, 1978). The specimens were found at one horizon only, belonging to the Kubergandian.

TRILOBITES

Trilobites are uncommon fossils which have been poorly studied. A few samples have been described from the Lower Permian of Tham Nam Maholan (Loei area) in Thailand and from a Middle or Upper Permian shale near Kuala Lipis in Peninsular Malaysia (Kobayashi and Hamada, 1979). "*Phillipsia proetoides*" was coined by Mansuy (1913) for a trilobite from the Permian of Laos.

Other samples have been collected in Peninsular Malaysia from a roadcut (Highway Kuala Lumpur–Kuantan) near the Sungai Luit and at the Sungai Remih, a tributary of the Sungai Spia in northeast Pahang. In north Thailand north of Nan and in west Thailand between Mae Sot and Umphang, trilobites have also been collected. All those trilobites have not been identified.

ECHINODERMS

Crinoids have been mentioned in many localities, but usually not identified and described. From the east coast of the Belitung (also known as Billiton) Island, the relatively rare crinoid genus *Moscovicrinus* has been collected, it occurs in a rock which is heavily mineralized. The fossils, as well as the former sedimentary matrix are completely altered by mineralization. The fossils are replaced by a serpentine mineral and are included in a magnetite matrix. They are Early Permian in age, according to other fossils previously collected from the Belitung Island (Strimple and Yancey, 1976).

Mansuy (1912, 1914) described a few fragments of urchin shells from the Middle Permian of Laos (in the vicinity of Luang Prabang) and Western Kampuchea (Phnom Takream).

OSTRACODS

Ostracods are locally abundant. They have rarely been identified. In Thailand, two genera (*Amphissites* and *Polytilites*) have been mentioned 15 km north of Nan and one genus (*Healdia*) south of Amphoe Khun Yuam west of Chiang Mai (Hahn and Siebenhuner, 1982).

VERTEBRATES

Permian vertebrates are very poorly known in Southeast Asia. A skull of *Dicynodon* was collected from a green sandstone exposed in the vicinity of Luang Prabang in Laos (Repelin, 1923; Piveteau, 1938). Although it was assigned to the Upper Permian by Piveteau, its identification and age remain questionable. It cannot be used for biogeographic reconstructions.

CHAPTER II

STRATIGRAPHY

At the outset, this chapter will deal with the boundaries of the Permian, a problem not perfectly settled. Then, it will discuss the divisions of the Permian which vary with authors. Finally, it will give a lexicon of the numerous Permian formations that have been recognized in Southeast Asia.

BOUNDARIES OF THE PERMIAN

Although field studies, accurate identification of fossils and research on sedimentology are still needed, our knowledge of the stratigraphy of the Permian of Southeast Asia has advanced greatly during the last 20 years. The boundaries of the Permian are becoming more and more clear and the upper boundary is much better defined in many areas than the lower boundary. "Natural boundaries" are still used by some geologists even though such boundaries are not precise because they are commonly associated with gaps due to unconformities or paraconformities. They do not correspond to the wish of well-defined boundaries expressed by the International Geological Congress of New Delhi (1964).

In this paper, the lower boundary of the Permian is the boundary accepted by international congresses, especially the congress of Moscow (1975) on the Carboniferous. The upper boundary is the traditional one, at the base of the *Otoceras woodwardi* zone; this boundary has been accepted by a great majority of stratigraphers since it was proposed in 1895 by Mojsisovics, Wagen and Diener according to sections in Himalayas.

Lower Boundary

The Carboniferous is far less known in many areas than the Permian. During the last few years, prolific Carboniferous microfaunas have been collected from beds that were previously considered Permo-Carboniferous or even Permian in age. Detailed palaeontological studies are necessary to define the lower boundary of the Permian in many areas.

In North Thailand (Baum *et al.*, 1970), no clear boundary exists between the Carboniferous and the Permian, except in the region of Mae Hong Son and Chiang Dao where a transgressive limestone, Lower–Middle Permian in age and reefal in appearance, overlies the so-called "Upper Carboniferous Red Beds". Elsewhere, clastic sedimentation (north and west of Mae Sariang, north of Lampang) or limestone deposition (west of Fang, southwest of Nam) were initiated during the late carboniferous and continued into the Permian.

In southern Thailand and Peninsular Malaysia, the lower boundary of the Permian is within the poorly fossiliferous shale-mudstone-sandstone sequences called: Kaeng Krachan Formation, Phuket Formation or Group, Singa Formation, Kubang Pasu Formation (*Fig. 16*).

In the Kinta Valley (Peninsular Malaysia), limestone forms an apparently continuous sequence from the Silurian to the Middle Permian. Rastall (1927) put emphasis on the continuity of the Kinta Limestone in disagreement with a previous theory which had suggested the existence of two limestones, different in age and separated by a break. New palaeontological discoveries in the northern part of the Kinta Valley in the vicinity of Chemor suggest a possible continuous sequence, Silurian to Lower Carboniferous (Serpukhovian) in age, and the presence of Lower Permian. A conodont species that had been assigned to the Westphalian A is considered Namurian (A–B) in age by Metcalfe (1979). In the Kampar–Batu Gajah area, the Devonian and the Lower Carboniferous are partly documented. The Middle and the Upper Carboniferous remain poorly known; a single fusuline species (*Eoschubertella* aff. *obscura* Lee and Chen) has been assigned to these periods and indicates a Moscovian age for a limestone near Batu Gajah. Accordingly, a stratigraphic hiatus cannot so far be ruled out; however, some unfossiliferous clastic beds (Kim Loong no 3 Beds) might fill the apparent stratigraphic gap (*Fig. 17*).

In Sarawak (Terbat Formation), the boundary between the Permian and the Carboniferous is also within a limestone sequence which has not been studied in detail.

In Loei area (northeast Thailand), a limestone sequence, Carboniferous and Permian in age, displays a palaeontological hiatus according to present knowledge; no foraminifera indicates the presence of the upper part of the Upper Carboniferous (Toriyama *et al.*, 1975). However, clastic sediments corresponding to the Khao Luak Formation (Saraburi Group in the stratigraphic lexicon) may represent the top of the Carboniferous.

Hagen and Kamper (1976) did some general remarks on the Permian stratigraphy of Thailand and were not in favour of using rock stratigraphic units which

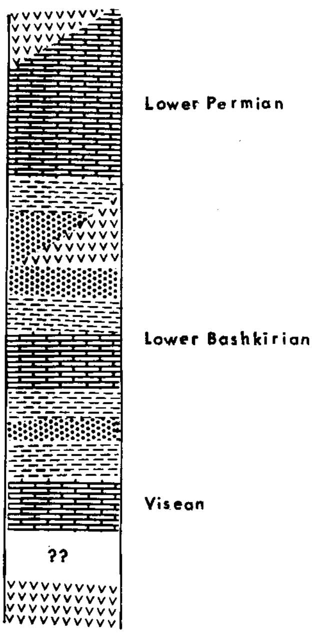


Figure 6. Schematic stratigraphy of Chon Daen, Thailand.

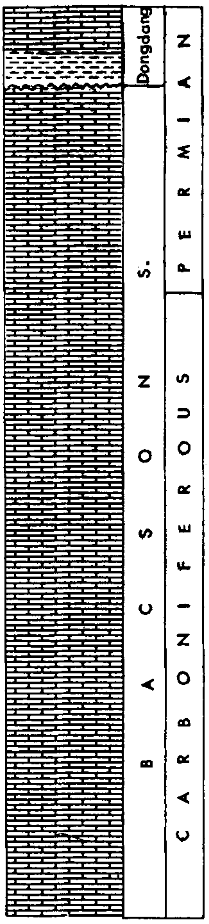


Figure 7. Stratigraphic column of Bac Son, North Viet Nam.

had not been adequately defined. In calcareous facies, they mentioned the occasional continuity of the Upper Carboniferous with the Permian. Because limestone began to accumulate already during the Late Carboniferous in north Thailand, they proposed that a name valid for all Thailand would require the reintroduction of the old name "Permo-Carboniferous Limestone". This solution will not encourage further studies.

In southeast Kelantan in Peninsular Malaysia, marine sedimentation was continuous from the Upper Carboniferous through the whole Permian to the Lower Triassic (Aw, 1972). In central Trengganu, Permian limestone of Bukit Biwah conformably overlies quartzites and shales, Carboniferous to Lower Permian in age (Chung, 1962).

In the vicinity of Chon Daen in Central Thailand (*Fig. 6*), a Visean to Early Bashkirian sequence is overlain by shale, sandstone and siltstone with unidentified fossils, then by a limestone of probably Early Permian in age. There is no apparent unconformity in that area (Chonglakmani *et al.*, 1983).

In most of Kampuchea, the Permian unconformably over lies older rocks.

The lower boundary of the Permian in North Viet Nam is commonly located within a mass of limestone without marker bed (See *Fig. 7* a stratigraphic column of the Bac Son area, North Viet Nam). If Liêm (1982) follows this point of view, other Vietnamese geologists place the lower boundary of the Permian at the top of their "*Schwagerina—Pseudoschwagerina* zone" (Tri *et al.*, 1977), because this boundary is easily observed in some areas of Viet Nam.

In the same way, many Chinese geologists select the base of the Chihsia Formation (marine) or the base of the Shansi Formation (continental) as the lower boundary. There is a sharp contrast between the Maping Series and the Chihsia Formation. The Maping Series are whitish grey massive limestone whereas the Chihsia Formation is dark grey or black limestone containing irregular chert-bands (Sheng and Lee, 1964). Moreover in the middle and lower reaches of the Yangtze River, the Chihsia Formation begins generally with a thin coaly shale with *Taeniopteris, Emplectopteris* and *Lepidodendron* (Sheng and Lee, 1964). On the other hand, the Maping Limestone displays more affinities with the Weining Limestone than with the Chihsia Limestone. In North China, the Taiyuan Formation is composed of sandstones and shales with limestone intercalations whereas the Shansi Formation consists mainly of continental sandstones and shales with coal seams and a few calcareous shales in the lower part (Sheng and Lee, 1964). The lower boundary of the Permian should be within the Maping Limestone and within the Taiyuan Formation.

Upper Boundary

The evidence for the top of the Permian has been clearly observed in a few narrow areas by marine fossils. In the same way, the Lower Triassic is known only in a few places. At the end of the Permian, a marine regression took place over wide zones. Plants appeared on emergent lands (See the chapter on Palaeontology). An unconformity or at least a stratigraphical hiatus is rather common between the Permian

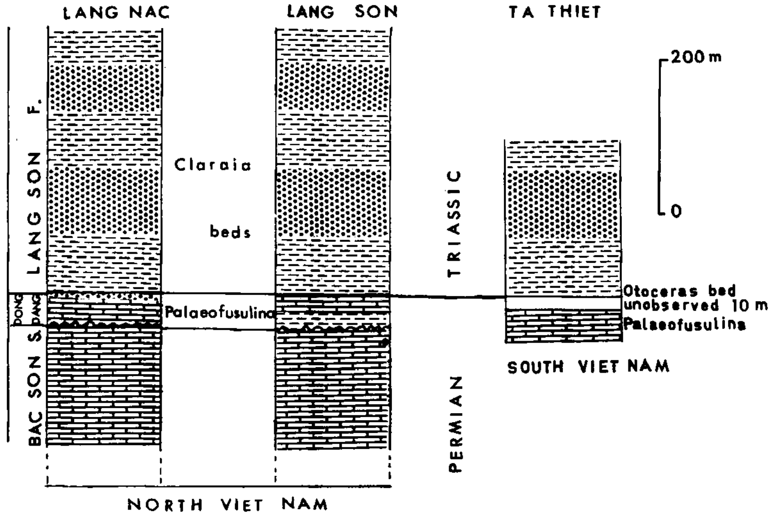


Figure 8. Upper boundary of the Permian in Viet Nam.

and the Triassic. An unconformity has been described at the Jengka Pass (about 24 km east of Temerloh) in Peninsular Malaysia, where steeply dipping Permian beds (*Fig. 12*) with *Yabeina asiatica*, *Sumatrina annae* and *Verbeekina verbeeki* (Igo, 1967) are overlain by a clastic sequence with a conglomerate at its base (Ichikawa *et al.*, 1966). This clastic sequence is equivalent to the Tembeling Formation which is Upper Triassic to Jurassic in age. In the Kinta Valley (Malaysia), the Kinta Limestone (Silurian to Permian) is nowhere in contact with Triassic exposures and this fact means an abrupt change at the end of the Permian and a marine regression continuing into the Triassic. In the Trengganu State, the Triassic is unknown in the area where the Permian crops out (Bukit Biwah, *Parafusulina* zone of the Leonardian according to Cummings, 1965). In western Kampuchea, it is the same. In Sarawak (Terbat Formation), the Permian is unconformably overlain by the Upper Triassic. It is the same in the Mae Sariang area in northwest Thailand (Ingavat and Douglas, 1981). In the Nam Yao Valley of the Nan area (north Thailand), Meesook and

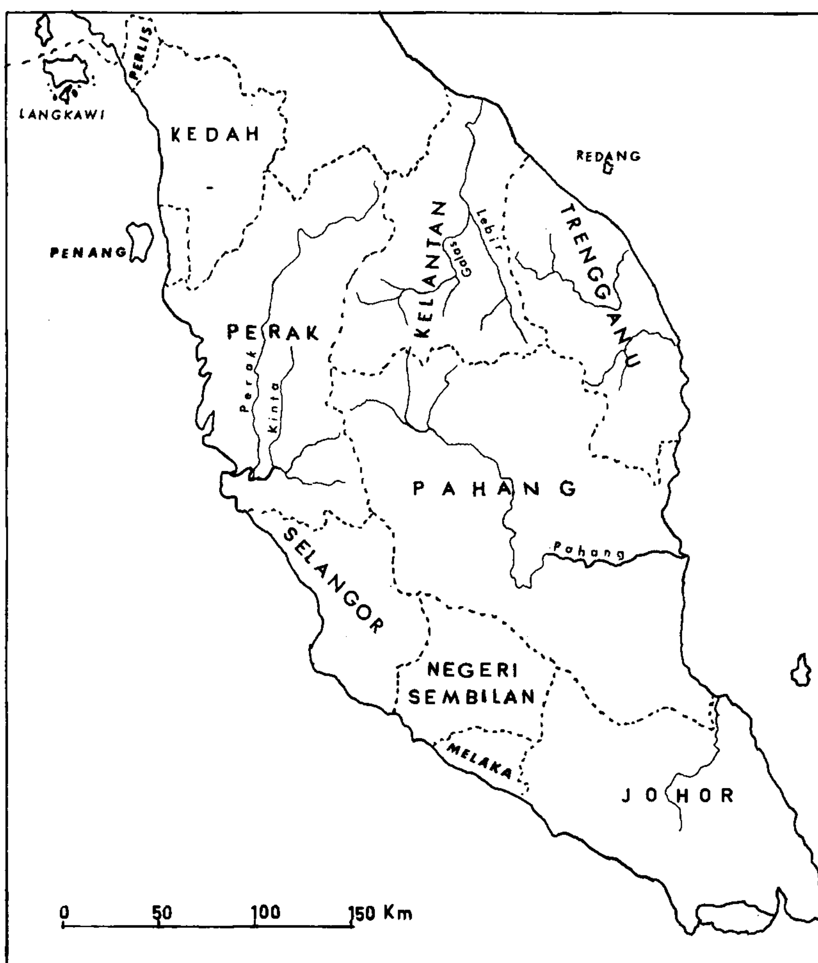


Figure 9. States of Malaya.

Vanapeera (1983) have always found a conglomerate between the Permian and the Triassic; the triassic strata are young, Carnian in age. In central Thailand southwest of Phetchabun, the Upper Permian of Khao Hin Kling dated by bryozoa (Sakagami, 1975) crops out in an area where the Triassic is unknown. In the Cao Bang area in North Viet Nam, an unconformity with a stratigraphic gap is present between the Permian and the Triassic (Bao and Tran Tinh, 1982). This unconformity, however, is not present everywhere in Southeast Asia.

Locally, the boundary between the Permian and the Triassic is within a limestone sequence. In that case, it is impossible to recognize it without a detailed palaeontological study. At Bukit Hantu near Kodiang (Kedah, Peninsular Malaysia), conodonts of the Late Permian and of the Early Triassic have been discovered in the "Kodiang Limestone" (Metcalfe, 1981); thus, the Kodiang Limestone extends down

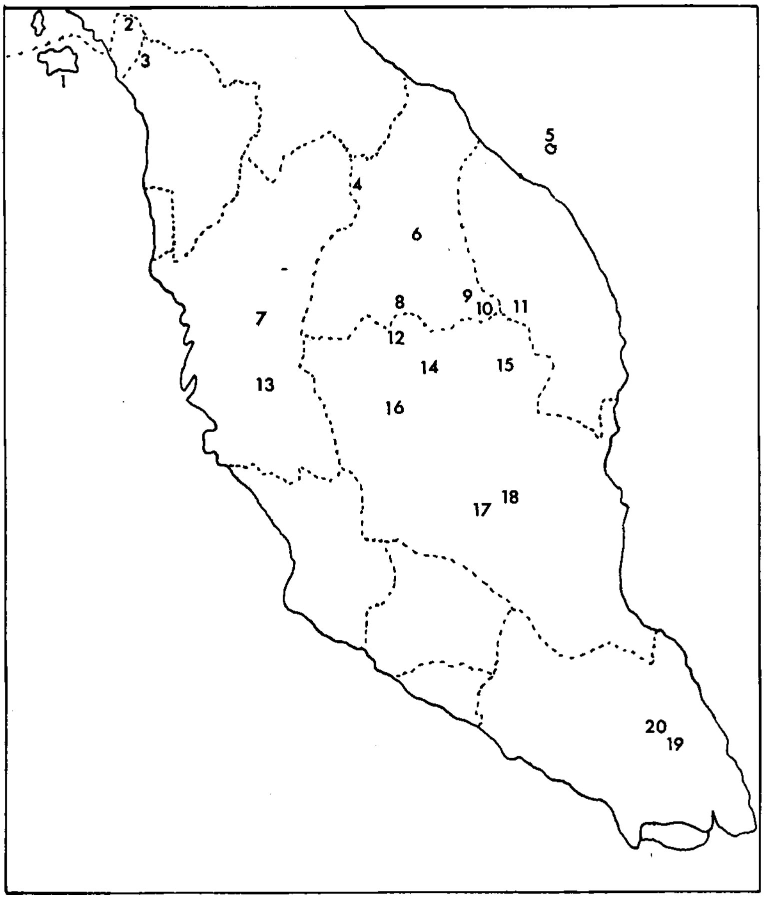


Figure 10. Main Permian areas of Peninsular Malaysia.
1. Pulau Singa; 2. Mata Aer; 3. Kodiang; 4. Sungai Pergau; 5. Pulau Redang; 6. Sungai Chiku; 7. Chemor; 8. Gua Ninek; 9. Sungai Aring; 10. Sungai Badong; 11. Sungai Biwah; 12. Sungai Yu; 13. Kampar (=Lee Mine); 14. Sungai Atok; 15. Sungai Remih; 16. Sungai Spia; 17. Bukit Kepayang (=Kampong Awah Quarry); 18. Jengka Pass; 19. Gunung Sumalayang (=Sungai Sedili); 20. Linggiu

into the Permian and is considered to be continuous with the underlying Chuping Limestone. There is no clear break between the Permian and the Triassic, however, in the section of Bukit Hantu, the Upper Permian is less than 10 m thick and a stratigraphical hiatus cannot be ruled out. At Gunong Keriang, 18 km south of Bukit Hantu, a stratigraphical gap is clear; 8 meters above a bed with Early Permian conodonts, Early Triassic conodonts are already present (Metcalfe, 1981). In some localities of Burma (Mitchell *et al.*, 1977; Garson *et al.*, 1976; Gramman *et al.*, 1972; Bender *et al.*, 1983), the boundary between the Permian and the Triassic is located within a dolomitic sequence and cannot be defined. The same may happen in western Thailand.

There is no place in Thailand, Malaysia and Sumatra where a continuous marine succession from the Upper Permian to the Lower Triassic has been described and ascertained by a detailed study of the fossils. In Sumatra, the Upper Permian and the Lower Triassic have so far never been evidenced. In Thailand, the lowermost beds of the Triassic with *Claraia* are known only in a small area north of Lampang. The Upper Permian with *Palaeofusulina* has recently been discovered north of that area near Ngao (Sakagami and Hatta, 1982). Hence, the Lampang region might provide a good section to study the passage from the Permian to the Triassic. In localities north of Lampang in the vicinity of Chiang Rai, the Upper Permian consists of terrigeneous sediments continuing into the Triassic. Because of the lack of fossils, the boundary between the Permian and the Triassic is impossible to be established; thus, sequences have been mapped as Permo-Triassic (Baum *et al.*, 1970). In Malaysia (Kelantan, Sungai Aring area), *Palaeofusulina* has been found in an argillo-tuffaceous limestone, intercalated in pyroclastic rocks with minor interbeds of argillaceous sediments (See Aring Formation in the stratigraphic lexicon). There seems to be 8 layers of argillo-tuffaceous limestone, 5 to 25 m thick, occuring at various level of the upper part of the pyroclastic sequence and locally at a level difficult to decipher because of discontinuous outcrops. The pyroclastic sequence is conformably overlain by a limestone layer, 40 m thick with interbeds of shale containing *Claraia* (Aw *et al.*, 1977). Hence, the boundary between the Permian and the Triassic is known with some precision. In another area south of Gua Musang, *Claraia* is also present but no Upper Permian is well-dated in that area. Eight kilometers south of Gua Musang, Igo *et al.* (1965) mentioned a limestone with fusulinids late Middle Permian in age 800 m apart from a limestone (Gua Panjang) rich in conodonts and Lower Scythian (formerly considered Anisian) in age. Between the two limestones is a flat land without outcrops. There is no evidence of any major stratigraphic break. *Claraia* has been found in hills 3 km southwest and 6 km south of Gua Panjang (Tamura, 1968). Near Kuala Lipis, the discovery of *Leptodus* (Upper Permian) and *Claraia* gives hope to find a section passing upwards from the Upper Permian to the Lower Triassic. Along Sungai Atok (Pahang), the top of the Murgabian is exposed not far from calcareous siltstone with *Costatoria*; the relationship between the Permian and the Triassic has not been described. In South China and in Viet Nam, *Claraia* reached its greatest prominence in the number of species and the number of individuals. Moreover, it is associated with a few ammonites. A few areas of Viet Nam have provided nice sections where the Triassic is in continuity with the Upper Permian

(*Fig. 8*). In North Viet Nam, the Triassic (Lang Son Formation) consists of shales and sandstones and it conformably overlies the Upper Permian with *Palaeofusulina*. At Lang Nac, the terminal beds of the Permian are 2 m thick and composed of sandstone and siltstone. They rest upon a limestone with the *Palaeofusulina–Colaniella* fauna. They contain Permian brachiopods. In the vicinity of Lang Son, the limestone with *Palaeofusulina* is overlain by the Triassic Lang Son Formation, probably without intermediate beds. In South Viet Nam at Ta Thiet (106°26′40″; 11°42′40″), a limestone with *Palaeofusulina* is exposed in the banks of the Saigon River and it is separated from a Triassic bed with *Otoceras* by an interval of 10 m where rocks are concealed.

In Southeast Asia, the boundary between the Permian and the Triassic is commonly drawn by authors at the base of the *Otoceras woowardi*–zone, apparently a few meters higher than the top of the *Palaeofusulina sinensis*–zone. Some authors (Newell, 1978; Waterhouse, 1976) disagree with this traditional definition and put the boundary at a higher level between the *Ophiceras* and *Gyronites* zones. Newell notes, that the traditional boundary is represented by an unconformity or paraconformity in many places in the world. He prefers to transfer the Permian–Triassic boundary to the base of the Dienerian because the Griesbachian (= the traditional lower part of the Scythian) displays some Paleozoic characteristics in its fauna.

DIVISIONS OF THE PERMIAN

The division of the Permian has not yet been established on strong and varied bases. There is still no consensus among the authors at present but efforts are being made to arrive at a classification applicable throughout the world. The Permian has been divided into two or three parts, and in different ways. Dividing the Permian into two parts, Gobbett (1968) and Bao and Tran Tinh (1982) considered that the base of the *Neoschwagerina* zone was the base of the Upper Permian whereas Sakagami (1976) restricted the Upper Permian to the *Palaeofusulina* zone with a very long Lower Permian from the *Pseudoschwagerina* zone to the *Yabeina* zone.

A three-fold division is increasingly accepted by various authors (Waterhouse, 1973; Toriyama *et al.*, 1975; Ingavat *et al.*, 1980; Leven, 1976, 1981; Liêm, 1982), but still in different ways according to the main interest of the authors. Waterhouse (1973) put emphasis on climatic events; "Each of the three major Permian divisions started with glaciation, in the southern hemisphere at least, and ended with relative warm temperatures, and diverse faunas, so that the divisions are natural ones" (Waterhouse, 1973, p. 188). Toriyama *et al.* (1975) gave a three-fold division, the Middle Permian corresponding to the *Cancellina–Neoschwagerina* and *Yabeina*–zones, i.e. consisting of the Kubergandian, Murgabian and Midian (= *Yabeina* zone). Ingavat *et al.* (1980) used almost the same three-fold division.

Because fusulinids are common fossils in Southeast Asia, it is logical to adopt a division mainly based on these fossils. Accordingly, the division proposed by Leven in 1976 and emended in 1981 by the same author is used in this paper (1),

(1) Leven, E. Ya., 1976, A stage scale for the Permian deposits of Tethys. *Internat.*

Geology Rev., vol. 18, no. 7, p. 807–819.
Leven, E. Ya., 1981, Permian Tethys stage scale and correlation of the sections of the Mediterranean–Alpine folded belt. *IGCP no. 5 Newsletter*, vol. 3, p. 100–112.

although this division is not perfect; it is already a good framework that needs only

Table 2. Divisions of the Permian after Leven, 1981.

Upper Permian	Dorashamian	Paratirolites kittli	Gondo-
		Shevyrevites shevyrevi	lella
		Dzhulfites spinosus	subca-
		Iranites transcaucasium	rina-
		Phisonites triangularis	ta
	Dzhulfian	Vedioceras ventroplanus	
		Araxoceras latum	Gondolella orientalis Gondolella leveni Araxilevis beds
	Midian	Yabeina, Lepidolina	Gondolella bitteri Stepanovites inflatus Merrilina divergens (Ammonoid : Timorites)
Middle Permian	Murgabian	Neoschwagerina margaritae. Appearance of Metadoliolina and Kahlerina	
		Neoschwagerina cratulifera. Appearance of Sumatrina	
		Neoschwagerina simplex. Appearance of Verbeekina	
	Kubergandian	Cancellina cutalensis and other species. Appearance of Cancellina	
		Armenina, Misellina (Misellina) ovalis	
	Bolorian	Misellina (Misellina) parvicostata	
		Misellina (Brevaxina) dyhrenfurthi. Appearance of Misellina	
Lower Permian	Yahtashian	Chalaroschwagerina vulgaris	
		Chalaroschwagerina solita	
	Sakmarian	Robustoschwagerina, Paraschwagerina	
	Asselian	Schwagerina sphaerica-Pseudofusulina firma	
		Schwagerina moelleri-Pseudofusulina fecunda	
		Schwagerina vulgaris-S.fusiformis	

Table 3. Correlation of the Permian of East Asia.

USSR Leven 1981	CHINA Sheng *et al.* 1982	JAPAN Minato *et al.* 1978	VIET NAM Liem 1982,1983	THAILAND	MALAYSIA	SUMATRA		USA
? ? DORASHAMIAN	CHANGHSINGIAN	TOYOMA SERIES	Palaeofusulina-zone= Dongdangian ?	NGAO	ARING			OCHOAN
DZHULFIAN	WUCHIAPINGIAN							
MIDIAN	MAOKU		Lepidolina zone= Sisophonian	SRA KAEO	B. KEPAYANG Jengka pass			
MURGABIAN		KANOKURA SERIES	Neoschwagerina-zone			PADANG HIGHLANDS		GUADALU-PIAN
KUBERGANDIAN			CANCELLINA-ZONE	SARABURI LIMESTONES				
BOLORIAN	CHIHSIA		MISELLINA ZONE		LEE MINE SUMALAYANG		JAMBI PROVINCE	
YAHTAHSIAN		SAKAMOTOZAWA	ROBUSTOSCHWA- GERINA-ZONE		CHUPING			LEONAR-DIAN
SAKMARIAN		SERIES		THAM NAM MAHO-LAN	CHEMOR			WOLFCAM-PIAN
ASSELIAN	MAPING		SCHWAGERINA ZONE					

Table 4. Radiometric ages of the Permian.

TRIASSIC		
		245 M years
UPPER PERMIAN	Dorashamian	
	Dzhulfian	250
	Midian to Kubergandian	255
MIDDLE PERMIAN		260
		265
	Artinskian	
		273
LOWER PERMIAN	Sakmarian	
		280
	Asselian	
		290
CARBONIFEROUS		

some detailed improvements. The lower boundary of the Permian is the base of the *Schwagerina vulgaris–S. fusiformis* zone. Another assemblage with *Occidentoschwagerina fusulinoides, O. alpina, Daixina bosbytauensis, D. robusta, Rugosochusenella paragregaris* and other species, can also be used; but it appears a little earlier than *Schwagerina vulgaris* and *S. fusiformis.* The upper boundary of the Permian corresponds to the base of the *Otoceras woodwardi* zone.

The type sections of the Lower Permian are in the southern part of the Ural Mountains (Asselian and Sakmarian) and in Southwest Darwaz (Yahtashian).

The base of the Middle Permian corresponds to the appearance of the first Verbeekinaceae represented by the genus *Misellina.* The stratotypes of the Middle Permian stages are in Southwest Darwaz (Bolorian) and in Southeast Pamir (Kubergandian and Murgabian).

From the Asselian to the Murgabian, there is no major problem of stratigraphical correlation between southern USSR and Southeast Asia.

The type sections of the Upper Permian are located in Transcaucasus. The base of the Upper Permian is marked by the appearance of the *Yabeina–Lepidolina* assemblage and corresponds to the base of the *Chusenella abichi* zone. At the end of the Upper Permian, the fusulinids lose their leading importance in Transcaucasus. Hence, the two upper stages of the Upper Permian are defined by ammonoid zones. In South China and Viet Nam, fusulinids are present throughout the Upper Permian with the exception of a few meters at the top of the Permian. In China, the Wuchiapingian contains abundant fusulinids and they are correlated with the Dzhulfian. The Changhsingian (or Changxigian), which has yielded abundant conodonts belonging to *Gondolella subcarinata*, appears to include younger horizons than the Dorashamian (Zhao *et al.*, 1978; Sheng *et al.*, 1984). The extreme top of the Dorashamian consists of red clay.

For the Upper Permian, the stratigraphical correlations are partly controversial and references to South China should be better than references to southern USSR.

The division of the Permian based on the fusulinids has been greatly improved during the last forty years; reading Gubler (1934) or Fromaget (1934), it is easy to assess this improvement.

STRATIGRAPHICAL LEXICON

In literature, some names of stratigraphic units are said to be informal and represent an easy way to map an area where our knowledge is incomplete, especially when rocks are poorly dated. Later on, those names are mentioned in other papers. What will be their future ? It is not clear. They may turn out to be formal. Accordingly, these units are mentioned in the following lines because geologists working in Southeast Asia need to know them. Many stratigraphic unit names are not based on properly studied sections. Some of them must be abandoned, but it is not the aim of this paper to select what must be kept and to replace the national stratigraphic committees in their long and exacting task. Stratigraphic units will be firmly established through the efforts of numerous geologists working independently.

<u>Adaman Group</u> (Mantajit, 1979, Tantiwanit *et al.*, 1983) —Peninsular Thailand— Term introduced to replace the terms "Phuket Group" or "Kaeng Krachan Group". Type locality along the western coast of the Phuket Island and Phang Nga. Reason to coin this new term is minor (*Fig. 16*).

<u>Aer Kuning Beds</u> (Zwierzycki, 1935)—Sumatra—See Djambi series.

<u>Alas Formation</u> (Cameron *et al.*, 1980)—Sumatra—Formation of North Sumatra, exposed west of Medan. Consisting of limestone, shale and sandstone. Assigned to the Lower Permian because of a hornshape coral without dissepiments identified as *Allotropiophyllum sinense*. In fact, this coral is related to *Zaphrentites* (Fontaine and Vachard, 1983) and is associated with Early Carboniferous (Late Visean) conodonts (Metcalfe, 1983).

<u>Aring Formation</u> (Aw, 1972)—Southeast Kelantan east of Gua Musang, Peninsular Malaysia—Two type localities along Sungai Nuar and Sungai Relai (Tributaries of the Sungai Lebir). Composed of tuffs and minor flows of andesitic to rhyodacitic composition, with a few interbeds of argillite, limestone and dolomite (*Fig. 11*, kindly prepared by Dr. P. C. Aw for this paper). About 3000 m thick. Ranges from the

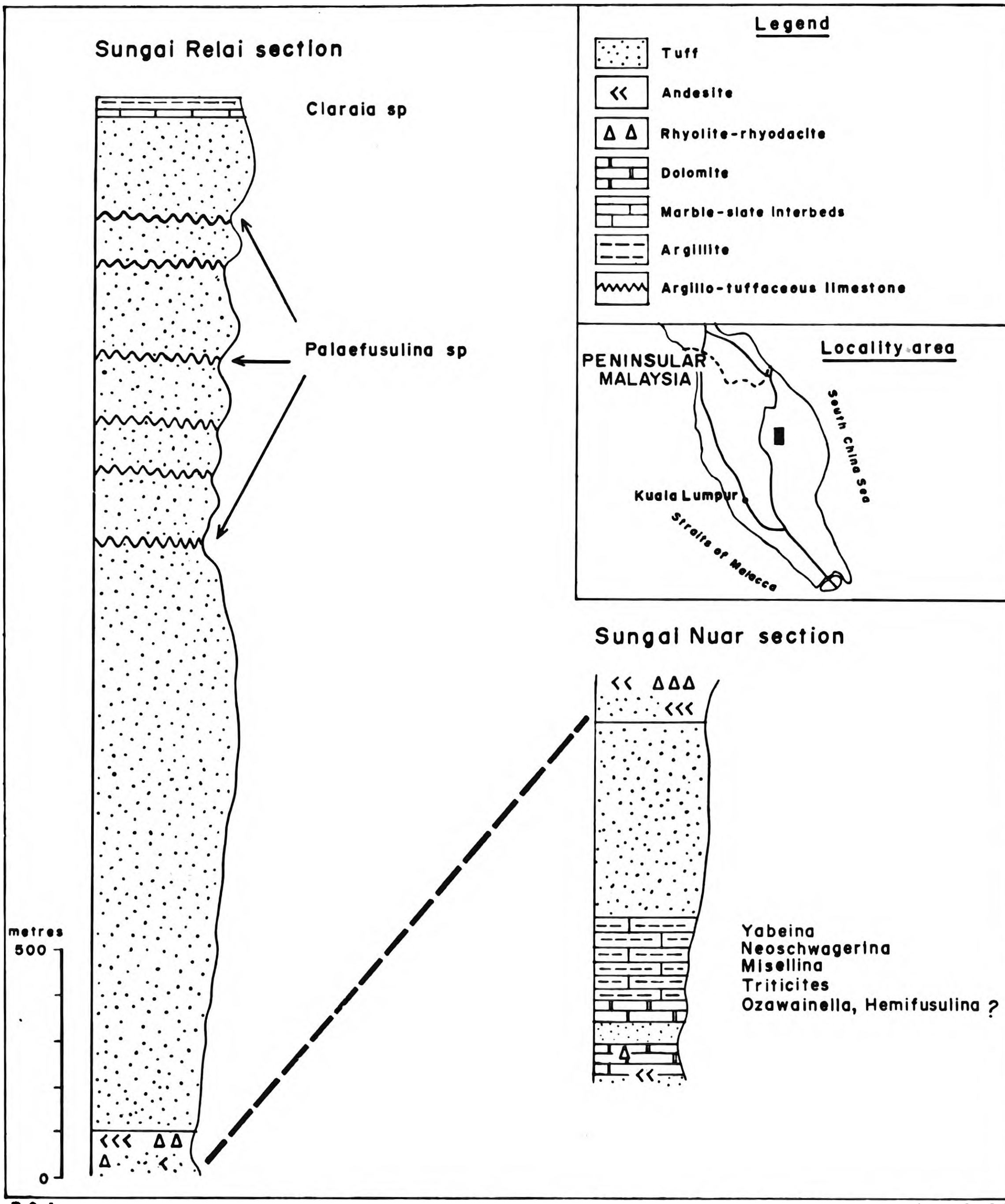


Figure 11. Litho-stratigraphic section of the Aring Formation.

Middle Carboniferous (Moscovian, Kashirian to Podolskian) to Early Triassic in age, according to the studies of brachiopods (Yanagida and Aw, 1979) and foraminifera (Aw *et al.*, 1977; Yanagida and Aw, 1979). Marine fossils occur sporadically throughout the formation. Equivalent of the Gua Musang Formation. The Aring Formation represents the oldest rocks of the Southeast Kelantan studied by P. C. Aw (1972). It is overlain by the Telong Formation, but the relationships between the two formations is not clear at their contact and they partly overlap. See Geological Map of scale 1 : 63, 360, sheet 46 and part of sheet 58 Sungai Aring, published in 1978.

<u>Bac Son Series</u> (Liêm *et al.*, 1975)—North Viet Nam—Visean to Permian in age. Name used to replace older terms, namely "Upper Palaeozoic", "Anthracolithic", "*Productus* Limestone", "Fusulinids Limestone", and others. Those series, mainly composed of carbonate, are 1500–2500 m thick. Rich in fossils, they have been divided into 12 horizons (*Fig. 7*).

<u>Bacuit Formation</u> (Hashimoto and Sato, 1973)—Philippines—Consists of sandstone, tuffs and slate. Conformably underlying the Minilog Formation. Exposed at the Manmegmeg Bay south of Bacuit in northwest Palawan Island. Contains conodonts Middle–Upper Permian in age (*Fig. 13*).

<u>Ban Ai Horizon</u> (Toriyama, 1944)—North Thailand—Limestone with *Pseudoschwagerina* exposed at the top of the pass between Ban Doi Hoatao and Ban Ai, about 80 km north-northeast of Chiang Mai. No stratigraphical section has been described. Asselian in age (Toriyama, 1984).

<u>Bangak Metasediments</u> (Khoo, 1977 in Annual Report)—East of Kuala Lipis, Pahang, Peninsular Malaysia—No fossil–Considered Permian in age.

<u>Bang Phra Limestone</u> (Bunopas, 1983)—Southeast Thailand—Exposure east of Sri Racha at Khao Liewadi near a dam site; it is only a limestone lens in shale, less than 1 m thick. It has provided algae and foraminifera, Kubergandian–Murgabian in age (Bunopas *et al.*, 1983; Fontaine and Mainguy, 1983).

<u>Bohorok Formation</u> (Cameron *et al.*, 1980)—North Sumatra—Composed of pebbly

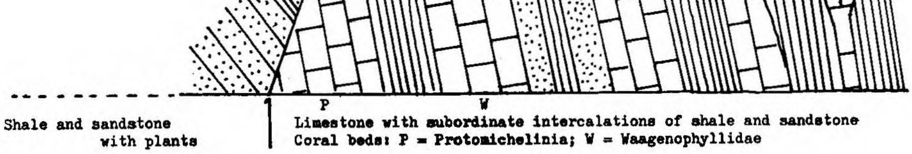


Figure 12. Eastern part of the road cut at the Jengka Pass. Position of the coral beds.

mudstones, i.e. non bedded medium to coarse-grained breccio-conglomeratic wackes. Subordinate interbeds of siltstone, sandstone and rarely limestone. Clasts are angular to subrounded, from 1 mm to 5 cm in diameter, but reaching 75 cm in East Aceh. The Bohorok Formation and the Kluet Formation are interdigitating lateral equivalents, the Kluet Formation representing the distal facies of the Bohorok Formation. The size and the proportion of coarse clasts increase northeastwards. Carboniferous–Lower Permian in age, but no fossil has been identified.

Calcaires à Productus (Mansuy, 1913)—Kampuchea, Laos, Viet Nam—In old times, name used to designate Permo–Carboniferous limestones.

Calcareous Series (Richardson, 1947, 1950)—North Pahang, Peninsular Malaysia—Also previously called "Calcareous Formation" (Richardson, 1939). Inappropriate terms only based on lithology and used by Richardson (1950), Fitch (1952), Ingham and Bradford (1960), and others for different regions and sections. For many years, it was assumed that all the limestone formations of Malaya were of Carboniferous and Permian age. Richardson (1950) mentioned fossils at a few localities, but none of the fossils was identified. During the study of E. H. Yin (1965) in the same area, an increasing number of fossil localities was found, and some with Triassic fossils. The name "Gua Musang Formation" was introduced and included volcanics that Richardson (1950) grouped into the "Pahang Volcanic Series".

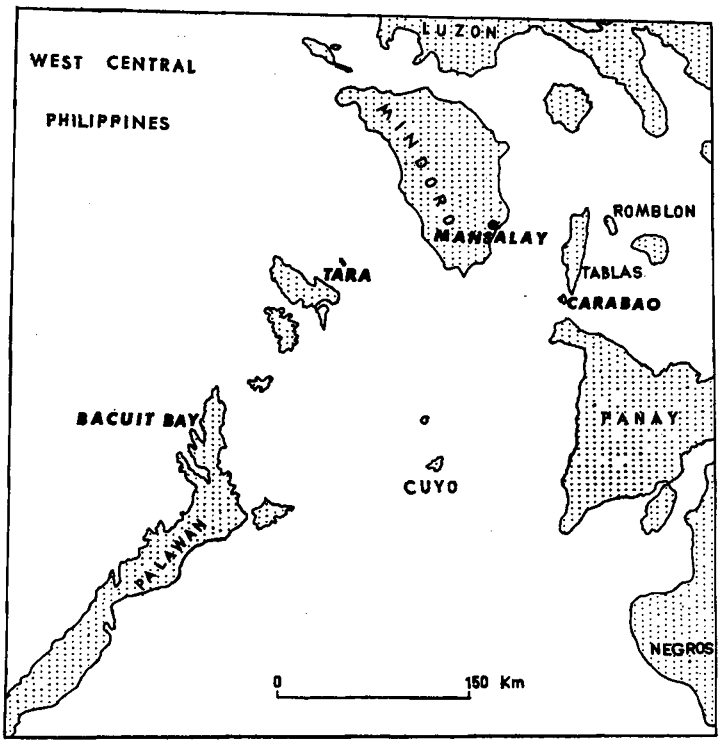


Figure 13. Localities with Permian Fossils of West Central Philippines.

Carabao Limestone (Bureau of Mines and Geosciences, 1981)—Philippines—Limestone containing fusulinids, Murgabian in age (Andal, 1966; Fontaine, David and Tiên, 1983). *Neoschwagerina haydeni* is the most reliable species among the identified foraminifera. Limestone exposed in the southeastern part of the small Carabao Island which is located offshore northwest Panay (*Fig. 13*).

Chuping Limestone (Jones, 1966)—Langkawi Islands, Perlis and Kedah, northwest Peninsular Malaysia—Type locality; Chuping Hill in Central Perlis–Generally massive limestone, locally fossiliferous. Algae (*Mizzia*, *Gymnocodium*, *Permocalculus*, *Anthracoporella* and others) are present. Fusulinids, Artinskian to Lower Murgabian in age (Toriyama *et al.*, 1975), have been found. Corals belong to tabulata and solitary tetracorallia (Jones, 1973). Permian conodonts have been identified in the vicinity of Kodiang, as well as Triassic conodonts. The Chuping Limestone and the Kodiang Limestone were considered a single unit by Jones who considered them as intercalations in the top of the Singa and Kubang Pasu Formations, except at the Langkawi Islands where he placed the Chuping Limestone above the Singa Formation (See captions of the geological maps). Since the discovery of Upper Permian conodonts in the Kodiang Limestone (Metcalfe, 1981), the idea of a single unit prevails again and the Chuping Limestone is supposed to be in continuity with the Kodiang Limestone (See "Upper boundary of the Permian" in this paper). In Pulau Langkawi, the Chuping Limestone is estimated to be 1,065 m thick while in Perlis it is about 600 m thick (Annual Report, 1980; Geological Map 1: 63,360, sheet 150 Pulau Langkawi, 1966).

A current study suggests the presence of Triassic fossils at the Chuping Hill.

Djambi (=Jambi) Series (Zwierzycki, 1935; Marks, 1956)—Sumatra, Indonesia—Thick sequence of shale, sandstone and volcanics with a few intercalations of limestone. Divided into three units, from base to top:

Karin beds: shale, sandstone, dacitic tuff. Containing the famous Jambi Flora. A limestone intercalation at Telok Gedang (Merangin River) is rich in Early Permian fusulinids (Thompson, 1936; Fontaine and Vachard, 1983).

Salamuku beds: mainly volcanic beds. A Limestone intercalation at Batu Impi contains corals and Early Permian fusulinids (Fontaine and vachard, 1983; Fontaine, 1984).

Aer Kuning beds: volcanic beds with two limestone intercalations containing early Permian fusulinids (Fontaine and Vachard, 1983).

Dohol Formation (Rajah, 1969)—East Johore, Peninsular Malaysia—Argillaceous sequence with minor beds of sandstone, limestone and volcanics, 900 m thick. It contains the oldest rocks of the area studied by S. S. Rajah (1969). Within this sequence, a thick-bedded limestone contains Permian fusulinids (*Pseudofusulina* and *Misellina* zones) and is 122 m thick, it is called Sumalayang Limestone Member. No fossil was found outside this limestone. The Dohol Formation is overlain by the Linggiu Formation, probably with an unconformable relationship. In some places, it shows metamorphism, due to the Lenggor granite. See Geological Map of scale 1:

63,360, sheet 125 Gunong Belumut, published in 1976.

Doi Musur Group (Bunopas, 1982)—West Central Thailand—Type section along the Tak–Mae Sot Highway between km 28.5 and km 62.5 i.e., between Doi Musur and Pha Woh. Triassic fossils (*Halobia*) have recently been discovered at km 50. According to the definition by Bunopas, Triassic should not belong to the Doi Musur Group, which has already a long stratigraphical range and may represent Silurian, Devonian, Carboniferous and Lower Permian. The uppermost part of the group (i.e. the upper part of the "Mae Ya U Siltstone") contains abundant bryozoa and

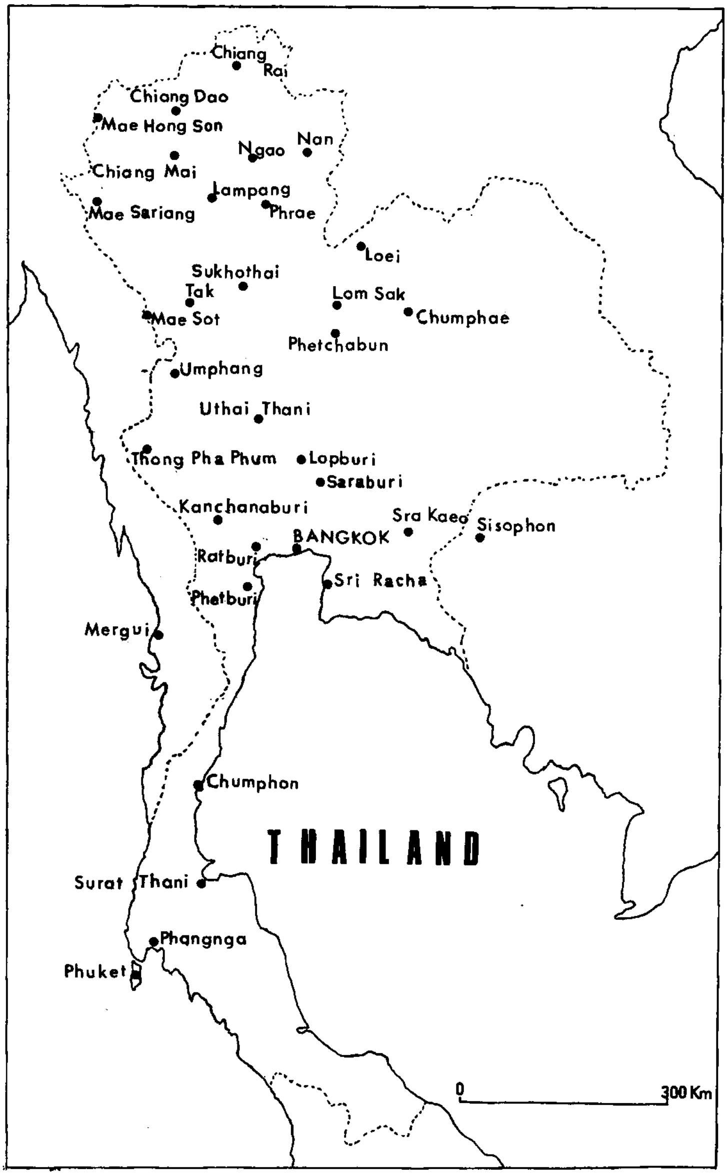


Figure 14. Locality map, Thailand.

brachiopods, not identified yet and probably Carboniferous–Early Permian in age. A limestone crops out at km 55 (Pha Raka) and seems to be intercalated in the "Mae Ya U Siltstone". It is dolomitic and has not yet yielded any fossils. The palaeontology of the Doi Musur Group needs to be studied more precisely. This group is overlain by the Pha Woh Limestone.

Dong Dang Formation (Liêm, 1967)—Lang Son area, North Viet Nam—See Dongdangian.

Dongdangian (Liêm, 1982)—Stratotype at Dong Dang and surroundings in Lang Son area, North Viet Nam—Consists of limestone with intercalations of shale, siltstone and sandstone. Corresponds to the interval between the *Yabeina–Lepidolina* zone and the *Otoceras–Ophiceras* zone. Contains *Palaeofusulina–Colaniella* fauna and *Nankinella–Staffella* fauna.

Gayong Volcanics (Foo, 1970)—South Pahang, Peninsular Malaysia-Fine-grained,

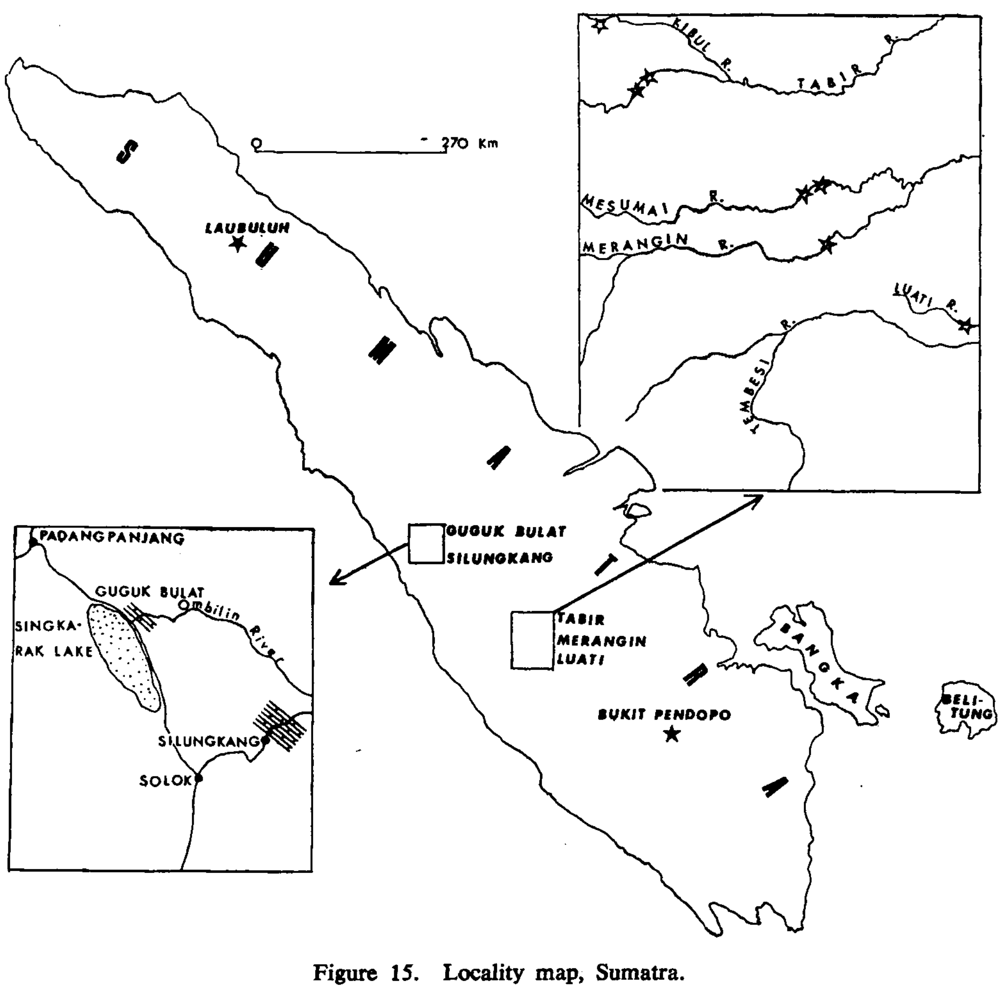


Figure 15. Locality map, Sumatra.

acidic tuffs with isolated and rare occurrences of agglomerates, lapilli tuff, tuff–lavas and porphyries. Welded tuffs or ignimbrite are common; they are considered the results of repeated and short-lived ejections and accumulated largely from explosive incandescent clouds. The Gayong Volcanics unconformably overlie the Sawak Metasediments and are overlain by a sequence of Jurassic–Cretaceous rocks.

Gua Musang Formation (Yin, 1965 and Yin in Kobayashi *et al.*, 1967)—South Kelantan, Peninsular Malaysia—Limestone, shales, sandstones and volcanics (rhyolitic to andesitic in composition). Shale with *Leptodus* at Sungai Jemeru about 14 km south-southeast of Kuala Lipis. *Claraia* discovered at Sungai Peranggan near Kuala Lipis and at five other localities of South Kelantan and North Pahang (Tamura, 1968). Ammonoids, middle Early Triassic in age, found at Gua Panjang (Hada, 1966). Visean fossils collected west-northwest of Kuala Lipis (Gobbett and Hutchison, 1973). Gua Musang is thus Carboniferous to Triassic in age. Equivalent to the Aring Formation which is pyroclastic. Unconformably overlain by the Gunong Rabong Formation (Yin, 1965) which is Middle Triassic to Jurassic in age.

Gunong Sinyum Formation (Chong and Yong, 1968)—Between Temerloh and Jerantut, Pahang, Peninsular Malaysia—Andesitic agglomerate with limestone fragments, sandstone, shale and limestone. Only small foraminifera (*Palaeotextularia, Monogenerina, Tetrataxis*) were identified at Gunong Sinyum and considered Permian in age. A current study of D. Vachard is showing that limestones of that area are, at least partly, Triassic in age.

Shale contains plant remains and brachiopods. It is the oldest rocks in the Gunong Sinyum (1594 feet high) area and belongs to the Raub Group of Alexander (1958).

Gelubi Formation (Wong, 1980)—Southwest Perak, Peninsular Malaysia—Unfossiliferous pelites that seem to be equivalent to the Kim Loong no. 3 Beds of Suntharalingam (1967); see Nam Loong Beds and *Figure 17*.

Huai Na Kham Formation (Chonglakmani and Sattayarak, 1978)—Northeast Thailand—Along the Lom Sak–Chum Phae Highway, at about 84 km from Lom Sak. Thick sequence of clastics believed to overlap the Pha Nok Khao Formation which consists of shallow marine carbonates and is exposed northeast of the Huai Na Kham Formation. The Huai Na Kham Formation is not strongly deformed. Sheet Changwat Phetchabun of the Geological Map of scale 1: 250,000.

Jong Limestone (Foo, 1964)—Langkawi Islands, Northwest Peninsular Malaysia—Limestone containing corals (*Caninia* cf. *liangshanensis* Huang, *Sinophyllum pendulum* Grabau), brachiopods, bryozoa (Sakagami, 1964; four bryozoa species indicating a lower Middle Permian). Is part of the Chuping Limestone; horizontally bedded at Pulau Jong.

Kaeng Krachan Group (Javanaphet, 1969; Piyasin, 1975 unpublished)—Phetburi area, Peninsular Thailand—Type section exposed southwest of Phetburi, divided into three units, from top to bottom: Khao Chao Formation (shale with intercalations of sandstone; more than 850 m thick), Khao Phra Formation (pebbly mudstone, shale and siltstone; more than 600 m thick; with a few fossiliferous horizons), Huai Phu Noi Formation (carbonaceous shale with intercalations of pebbly shale; locally fossiliferous with Carboniferous brachiopods; more than 480 m thick). No fossil has been firmly identified in this group which is equivalent to the Phuket Group (See below). Considered Carboniferous–Lower Permian in age.

Karing Beds (Zwiezycki, 1935)—Sumatra—See Djambi Series.

Kati Formation (Foo, 1968)—Northwest Perak, Peninsular Malaysia—Areno–argillaceous formation correlated with the Kubang Pasu Formation. Band stretching just west of the Perak River. Poorly exposed. Without volcanics. Unfossiliferous. Represents a lateral facies change from the more calcareous facies of the Salak Series. Exposed southwards until Bukit Tunggal and farther south plunging under Cenozoic sediments (Wong, 1980).

Kenny Hill Formation (Yin, 1963)—Kuala Lumpur area, Peninsular Malaysia—Monotonous alternating sandstones and shales. No datable fossils. Almost unmetamorphosed. 300 m to 1200 m thick according to the authors. Unconformably overlying the Kajang Formation consisting mainly of sandstone with minor intercalations of argillaceous and calcareous beds. The Kajang Formation is also unfossiliferous and overlies Silurian limestone. Following the deposition of the Kenny Hill sediments was a period of folding. The Kenny Hill Formation is deprived of volcanics. In the surroundings of Kuala Lumpur, there is no indication of volcanic activity in the past; emplacement of granite is the only igneous activity. The Kenny Hill Formation might be Carboniferous-Permian in age and corresponds to the Kubang Pasu Formation; it extends from Kuala Lumpur town southward through the suburbs of Petaling and Petaling Jaya and farther southward for at least 30 km. Gently folded and forming a broad syncline.

Kepis Formation (Khoo, 1979)—Negeri Sembilan, Peninsular Malaysia—Carboniferous shales, siltstones, sandstones, mudstones, with limestone lenses. Thickness estimated to about 3700 m. Brachiopods, corals (solitary hornshape tetracorallia looking like an hapsiphyllid), nautiloids, fusulinids, wood and plant fragments have been found, but have not been carefully studied. Carboniferous-Lower Permian in age. Unconformably overlying the Pilah Schists. Unconformably overlain by the Gemas Formation, Middle to Upper Triassic in age. Volcanic activity. Geological Maps of scale 1 : 63,360, sheet 104 Kuala Pilah, to be published.

Khao Plukmu Limestone (Bunopas, 1976)—West Thailand—Permian limestone exposed in a hill 40 km north of Bo Phloi or about 75 km north of Kanchanaburi. Isolated limestone, Murgabian in age, with *Neoschwagerina*, *Sumatrina*, *Verbeekina*. The base has a gradational contact with the underlying well-bedded non-calcareous grey shale (Mae Plung Shale, Carboniferous).

Khao Chakan Limestone (Bunopas, 1983)—Southeast Thailand—Limestone exposed east and South of Sra Kaeo, Lower Permian to Midian in age (Pitakpaivan and Ingavat, 1980; Sugiyama and Toriyama, 1981; Fontaine and Mainguy, 1983).

Kinta Limestone (Rastall, 1927)—Kinta Valley (10 to 17 km wide), Peninsular Malaysia—Limestone with subordinate shale and sandstone. Fossiliferous in a few places. Silurian to early Middle Permian. The oldest fossils have been found in the vicinity of Chemor (northern part of the Kinta Valley); Lower Middle Silurian in age, they consist of corals and graptolites (Thomas and Scrutton, 1969; Berry and Boucot, 1972). No volcanics. Nam Loong Beds and Lee Mine Beds are the upper part of the Kinta Limestone.

Klaeng Limestone (Bunopas, 1983)—Southeast Thailand—Limestone exposed in two subparallel ridges north of Klaeng. Considered Permian in age for a long time up to 1983 (Bunopas). Actually Scytho-Anisian to Ladinian (Fontaine and Vachard, 1981; Fontaine and Mainguy, 1983).

Kluet Formation (Cameron *et al.*, 1980)—North Sumatra—Thick sequence of sandstones, mudstones and siltstones. Poorly sorted, conglomeratic wackes occasionally occurring within the finer sediments. Interbeds of green volcanics are locally present in East Aceh and Riau; but in general, there is little evidence of contemporary volcanism. Detrital limestones and calcareous horizons (Pangururan Beds) are occasionally found. Carboniferous and Lower Permian by lithologic correlation with the Phuket Group in Thailand. Lateral facies of the Bohorok Formation. Discovery of Triassic conodonts (Metcalfe, 1984) around the Toba Lake and in the Pangururan Beds requires re-interpretation of this formation.

Kuantan Group (Alexander, 1959)—East Peninsular Malaysia—Argillaceous and calcareous strata, Upper Paleozoic in age. Exposed in the Kuantan area (Fitch, 1952), then occurring in the eastern zone of the Malay Peninsula from Kelantan to Johore (Foo, 1983). Shale is dominant with subordinate limestone, sandstone and volcanics. Early Carboniferous to Late Permian.

Kubang Pasu Formation (Jones, 1967)—Perlis, North Kedah, Peninsular Malaysia—Basal grey and red mudstone with Upper Devonian–Lower Carboniferous fossils (Hamada, 1969), overlain by thick–bedded sandstones, shales and mudstones. About 1500 m thick. Equivalent to the Singa Formation (See in the following pages of this paper). Foo (1983) proposed to abandon the name of Singa Formation in favour of the Kubang Pasu Formation. Arenaceous component is more developed in the Kubang Pasu Formation. Upper Devonian to Lower Permian in age. At Bukit Temiang in Perlis, the top of the formation contains algae, bryozoa, brachiopods and gastropods, just below the Chuping Limestone (The basal red beds of the Singa–Kubang Pasu Formations have been called "the Langgun Red Beds" by Kobayashi

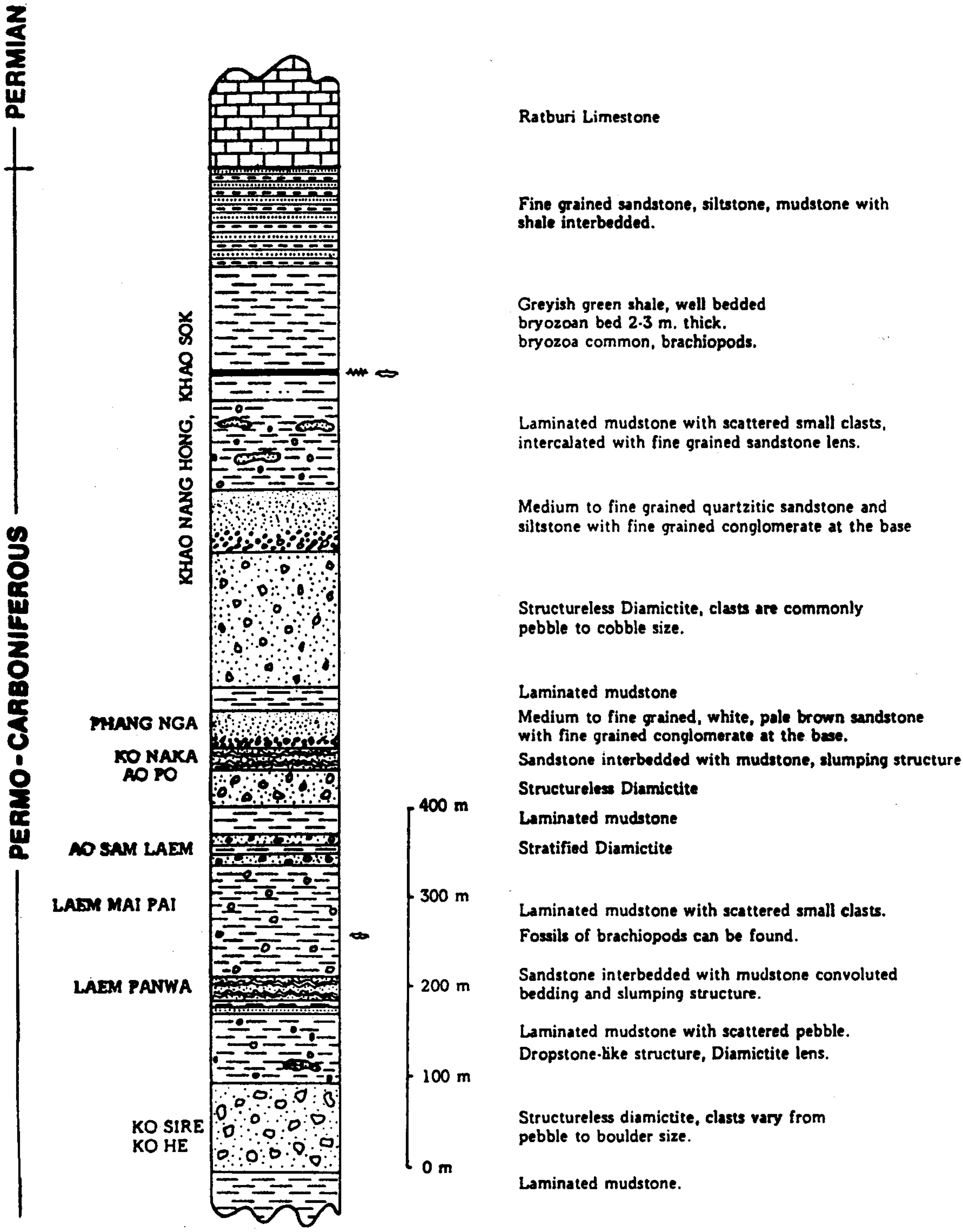


Figure 16A. Stratigraphic sequence of the Phuket Formation (Tantiwanit *et al.*, 1983).

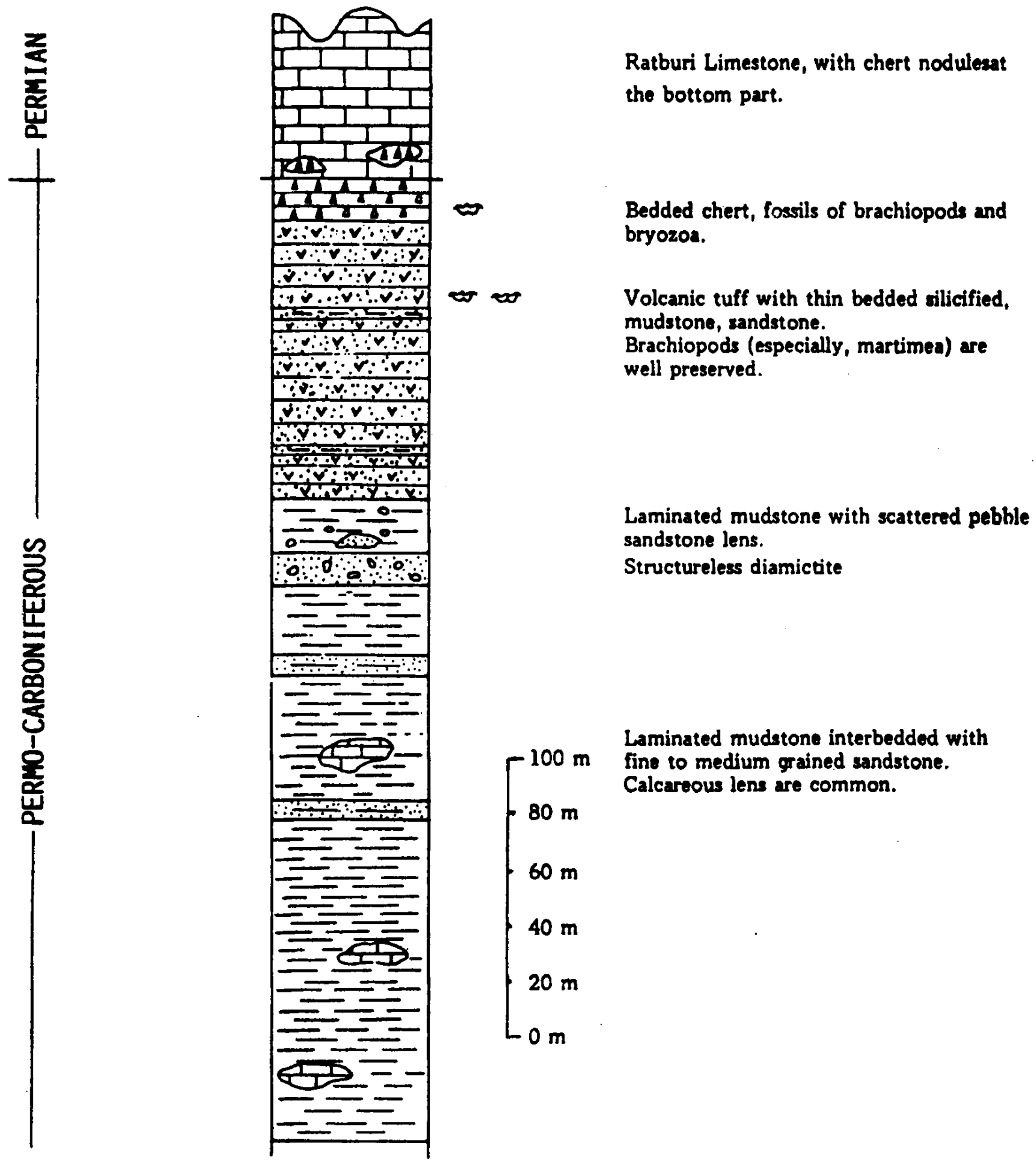


Figure 16B. Stratigraphic sequence at Ko Yao Noi (Tantiwanit *et al.*, 1983).

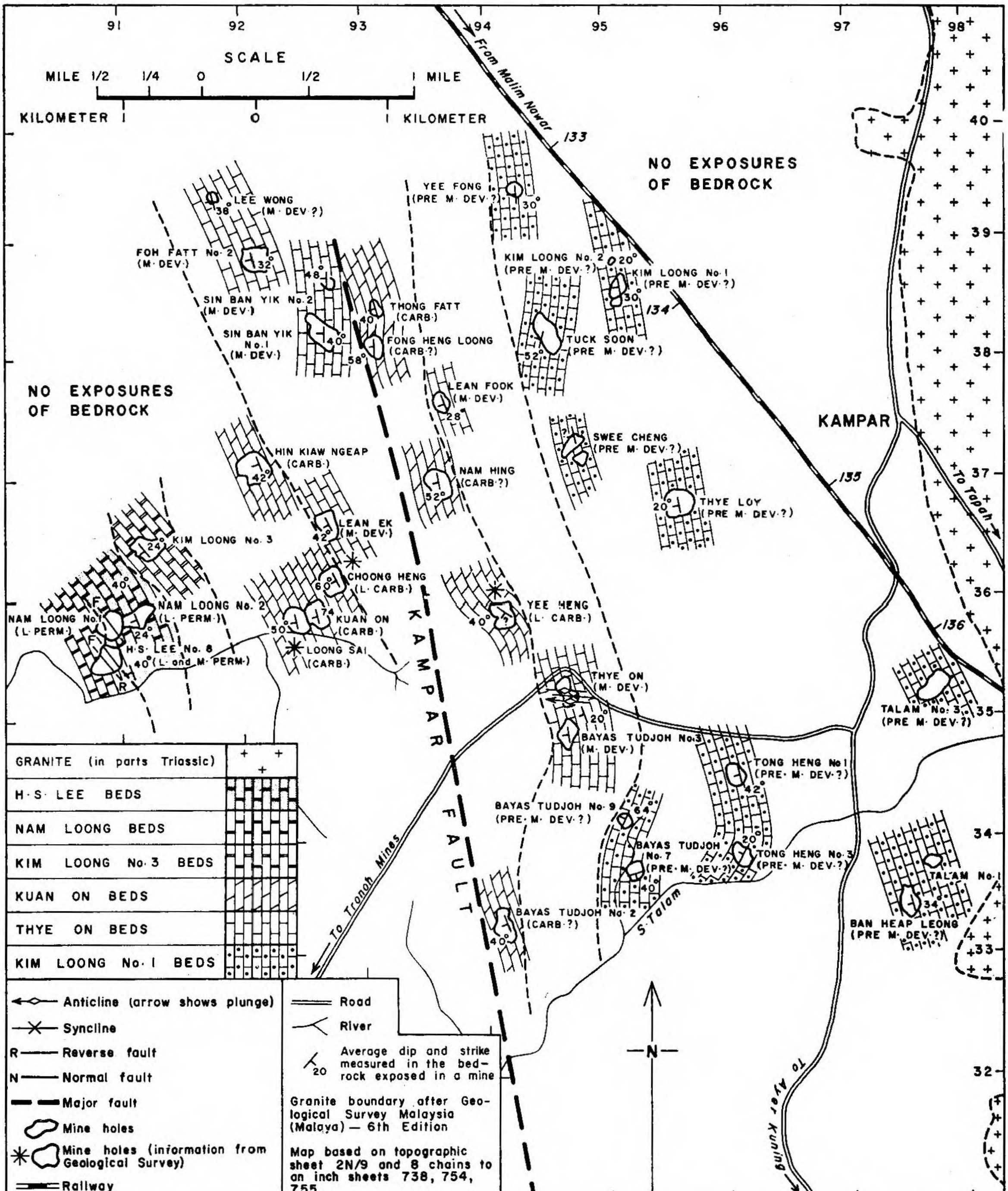


Figure 17. Geology of the bedrock west of Kampar, Perak State, Peninsular Malaysia (Suntharalingam, 1968).

1973; because it has not been shown that the typical Singa–Kubang Pasu rocks overlie them, Halim Abdul Samad (1982) has maintained this term).

Lebir Formation (Rajah, 1972)—South Kelantan, Peninsular Malaysia—Consists of sandstone, shale, limestone and volcanics. Oldest rocks of the borderlands of the States of Trengganu, Kelantan and Pahang (Sheet 47 and part of 48). Name introduced in an annual report. No palaeontological information. Permian in age.

H. S. Lee Mine Beds (Suntharalingam, 1967)—West of Kampar, Kinta Valley, Peninsular Malaysia—Limestone, about 20 m thick, containing *Pseudofusulina kraffti* at its base and *Misellina claudiae* in its upper part (Ishii, 1966). The upper part with *Misellina claudiae* is rich in fossils: solitary Waagenophyllidae (? *Iranophyllum, Pavastehphyllum* (*Sakamotosawanella*) *permicum*), gastropods (Batten, 1972), pelecypods (Runnegar and Gobbett, 1975; Yancey and Boyd, 1983) and ammonoids: *Adrianites, Prostacheoceras* and *Neocrimites* (Lee, 1980). Fauna is prolific, but depositional environment was not reefal (*Fig. 17*).

Linggiu Formation (Rajah, 1969)—South Johore, Peninsular Malaysia—Overlies the Dohol Formation, probably with an unconformity. Composed of sandstone, conglomerate, siltstone, chert, shale and contemporaneous tuff and lava (acid to intermediate). Thickness estimated to be not more than 700 m. The arenaceous component is better developed and some conglomeratic beds are locally prominent. Plant fossils (= Linggiu Flora, see chapter on palaeontology) indicate a Late Permian age (Konno *et al.*, 1970). See Geological Map of scale 1 : 63,360, sheet 125 Gunong Belumut published in 1976.

Mae tho Formation (Bunopas, 1976)—West Thailand—Near the Tak–Mae Sot Highway close to the Lansang National Park. Section composed of sandy limestone, recrytallized limestone, tuffaceous shale and sandstone, shale. Lower Permian in age, with *Monodiexodina shiptoni* Dunbar (Ingavat and Douglas, 1981).

Matsi Formation (Burton, 1978)—Peninsular Thailand—Type section at Khao Matsi, Ban Pak Nam, 10 km southeast of Chumphon. Consists mainly of sandstone with intercalations of conglomerate, limestone, shale and mudstone; many beds are red in color. This formation extends in a prominent band widening southwards and following the east coast of Peninsular Thailand from the southern part of the Phra Chuab Province into the Surat Thani Province. Interdigitated with the Ratburi Limestone and the upper part of the Phuket Group according to Burton (1978), but overlying the Ratburi Limestone and Mesozoic in age for many other geologists. A Mesozoic age had already been suggested by an Early Jurassic bivalve (*Eomiodon*) collected near Chumphon (Hamada, 1960); this has been recently confirmed by the discovery of ammonites, also near Chumphon. These ammonites have been tentatively identified as Jurassic ammonites by the Department of Mineral Resources (Bangkok).

Mergui Series (Oldham, 1856; Brown and Heron, 1923; Clegg, 1953)—Tenasserim, Southeast Burma—Thick sequence of shales and pebbly mudstones ("Pebble" size smaller than a grain of wheat with an occasional pebble as large as a hazel nut; very few rounded pieces) with subordinate sandstone and limestone. Overlain by the "Moulmein Limestone". Assumed to be more than 3,000 m thick. Volcanic rocks occur in the Mergui Archipelago of South Burma; they are considered Carboniferous in age. The Mergui Series, possibly Ordovician to Lower Permian in age according to Bender *et al.* (1983), should be the continuation of the Singa–Kubang Pasu Formations of Malaysia, of the Phuket–Kaeng Krachan Formations of Thailand, and of the Bohorok–Kluet Formations of Sumatra.

Minilog Formation (Hashimoto and Sato, 1973)—Philippines—Limestone more or less recrystallized, partly bedded and oolithic, exposed in small islands of the Bacuit Bay in Northwest Palawan Island. Contains fusulinids indicating a Middle Permian age.

Nam Duk Formation (Chonglakmani and Sattayarak, 1978)—Huai Nam Duk between Lom Sak and Chum Phae, Northeast Thailand—Sequence exposed along the Lom Sak–Chum Phae Highway (Km 18 to 34 from Lom Sak) and consisting of allodapic limestone, a flyschoid alternation of shale and sandstone, chert, and some shallow marine sediments corresponding to the molasse of Hemcke and Kraikhong (1982). Usually intensively folded and faulted. Lower-Middle Permian in age.

Nam Duk Group (Altermann *et al.*, 1983)—Northeast Thailand—Since the Nam Duk Formation corresponds to a long time interval of deposition and covers different orogenic stages, it is proposed to regard it as a whole "Group".

Nam Loong Beds (Suntharalingam, 1967)—West of Kampar, Kinta Valley, West Malaysia—Bioclastic limestones with crinoids, brachiopods and molluscs; bedded or massive. About 150 m thick. Considered Lower Permian in age after identification of some brachiopods. A large normal fault separates the Nam Loong Beds from the H. S. Lee Mine Beds. The Nam Loong Beds overlie the Kim Loong No. 3 beds consisting of shales and sandstones which are deprived of fossils and probably Late Carboniferous to Early Permian in age (*Fig. 17*).

Ngao Group (Bunopas, 1982)—North Thailand—Exposed in the Lampang—Ngao area and composed of three units, from top to bottom: Huai Thak Formation (Piyasin, 1972), Pha Huat Formation (Piyasin, 1972) and Kiu Lom Formation (Piyasin, 1972).

The Kiu Lom Formation consists of shale and sandstone with intercalations of limestone which is locally very rich in fusulinids. A few limestone samples were collected by the author at the Kiu Lom Irrigation Dam on the Yom River 30 km north of Lampang; they were studied by D. Vachard who identified:

Algae: *Koivaella permiensis*, *Anchicodium* sp.

Small foraminifera: *Climacammina* sp., *Bradyina* sp., *Geinitzina* sp., *Tetrataxis* sp., *Hedraites* sp., *Tuberitina collosa.*

Fusulinoids: *Schubertella* cf. *giraudi*, *Biwaella* aff. *americana*, *Boultonia willsi*, *Darvasites* aff. *ordinatus*, *Pseudofusulina* ex gr. *ellipsoides*, *Robustoschwagerina* cf. *schellwieni*.

These fossils are included in a bioclastic wackestone with fragments of pelecypods, ostracods, trilobites and brachiopods; they indicate a Late Asselian–Early Sakmarian age. Environment was subtidal.

The Pha Huat Formation is at Pha Huat, a high limestone hill 10 km south of Ngao. It contains *Neoschwagerina* (Piyasin, 1972). The author did not visit that locality, but went to Chae Hom north of Lampang where a "similar" limestone was indicated by the geological map (scale 1 : 250,000). The Chae Hom limestone contains many pisolithes and appear to be Triassic in age.

The Huai Thak Formation crops out at the Huai Thak west Ban Pang Kho 20 km south of Ngao. It consists of sandstone and shale with a few intercalations of limestone. It is rich in sponges, bryozoa, brachiopods (*Leptodus* . . .), pelecypods, and contains a few small foraminifera: *Hemigordius*, *Geinitzina* (Identified by D. Vachard). Two other exposures were visited; they belong to the Huai Thak Formation. Near Ban Cham Kha north of Lampang, a limestone is exposed along the road to Ngao. It contains corals (*Liangshanophyllum*), algae (*Tubiphytes obscurus*), small foraminifera (*Neoendothyra* sp., *Climacammina* sp., *Paraglobivalvulina mira*, *Pachyphloia* sp., *Frondina permica*, *Colaniella* sp., *Calcitornella* sp., *Glomospira* sp.), fusulinoids (*Codonofusiella* sp., *Paradoxiella* sp.). These fossils indicate a Late Midian age; *Liangshanophyllum* is characteristic of the Wuchiapingian. At Phra That Muang Kham east–southeast of Lampang, a bioclastic wackestone–packstone contains corals (*Liangshanophyllum*), algae (*Koivaella permiensis*, *Tubiphytes obscurus*, *Solenopora* cf. *centurionis*, *Bacinella* sp.), pseudoalgae (*Eflugelia johnsoni*), small foraminifera (*Neoendothyra* sp., *Dagmarita* sp., *Frondina permica*, *Pseudocolaniella* sp., *Colaniella* sp., *Geinitzina* sp., *Diplosphaerina inaequalis*), fusulinoids (*Reichelina*) sp., *Staffella* (*Nankinella*) sp., *Codonofusiella* sp. These fossils suggest an age similar to that of Ban Cham Kha. The Phra That Muang Kham Limestone had been previously assigned to the base of the Triassic.

In conclusion, the Ngao Group ranges, at least, from the Upper Asselian to the Dzhulfian; 10 km southeast of Ngao, *Palaeofusulina* has been found (Sakagami and Hatta, 1982).

Nilam Marble (Aw, 1972)—Southeast Kelantan, Peninsular Malaysia—See Telong Formation.

Pahang Volcanics (Scrivenor, 1904)—Peninsular Malaysia—Term that has little more significance than Malayan Volcanics. Obsolete.

Pai Limestone (Konishi, 1953)—North Thailand—Limestone exposed near Pai in the Mae Hong Son area, i.e. 110 km northwest of Chiang Mai. Containing algae (*Epimastopora*) and fusulinids (*Boultonia*, *Triticites*, *Schwagerina*). Overlain by sandstone and slate with intercalations of limestone lenses, chert and reddish marl. This sequence is unconformably overlain by a reddish conglomerate. Belongs to the

Pseudoschwagerina zone.

Pangururan Beds (Cameron *et al.*, 1980)—North Sumatra—Shallow water limestones and calcareous siltstones rather rich in crinoids, algae, brachiopods and abundant fenestellid bryozoans. Exposed on the west shore of Lake Toba. Considered similar to the bryozoan beds near the top of the Phuket Group in Thailand, the Pangururan Beds were included in the top of the Kluet Formation. Recently, Triassic conodonts have been discovered in those beds (Metcalfe, 1984). However, fenestellids disappeared at the end of the Permian and a problem remains.

Pawa Limestone (Heim and Hirschi, 1939)—West Thailand—Same as Pha Woh Limestone or Phra Woh Limestone; it is a question of transcription. Heim and Hirschi (1939) did not find any fossil at Pha Woh because the rock was too much recrystallized. However they were inclined to regard this rock as corresponding to the limestone with fusulinids known elsewhere in Thailand.

Permocarboniferous Limestone (Hagen and Kemper, 1976)—Thailand—Name proposed for all Thailand. Re-introducing an old term, because limestone accumulated from the Upper Carboniferous to the Permian without discontinuity in the northern part of Thailand.

Pha Nok Khao Formation (Chonglakmani and Sattayarak, 1978)—Northeast Thailand—Massive or thick bedded limestone exposed along the Chum Phae–Loei Highway around 40 km from Chum Phae. Locally rich in fusulinids, it is Early to Middle Permian in age. Sheet Changwat Phetchabun, Geological map of scale 1 : 250,000.

Pelepat Formation (Rosidi *et al.*, 1976)—South Sumatra—Mainly lavas and tuffs; composition is usually andesitic, locally basaltic or rhyolitic. This formation contains intercalations of siltstone, shale and limestone. Brachiopods and fusulinids have been collected from the limestone. The thickness reaches 1100 m. Called "Diabas Formation" by Tobler (1919).

Pha Woh Limestone (Bunopas, 1982)—West Central Thailand—Limestone exposed from Km 62.5 to Km 66.1 of the Tak–Mae Sot Highway, i.e. from 13.9 to 17.5 km from Mae Sot. It is a massive dolomitic limestone with rare intercalations of chert. It builds up prominent karstic hills and overlies the Doi Musur Group. No fossils have been identified in the limestone which is considered Middle to Late Permian in age. Ten kilometers north–northwest of Pha Woh near the waterfall of Doi Mae Ka Sa, a bedded limestone with sedimentary figures of slumpings is overlain by a calcareous sandstone flooded with *Monodiexodina shiptoni* (Ingavat and Douglas, 1981); because they are different in facies, the Pha Woh Limestone and the Mae Ka Sa Limestone are maybe different in age. Does the Pha Woh Limestone represent the youngest Permian beds ?—It is not sure, because it appears to be overlain by some clastic beds with a dolomitic limestone at their top (exposed from Km 66.1 to Km 67.7 along the highway); there is no proof that it is in fault contact with those clastic beds (which contain a coal seam 1 m thick). A thin section from the limestone exposed near the microwave station (Km 67) contains *Afghanella* or *Sumatrina* and *Ungdarella*, indicating a Middle-Late Murgabian age.

Phrae Group (Bunopas, 1982)—North Thailand—Sedimentary sequence, 4000 m thick, consisting of chert, agglomerates and conglomerates (Mae Sai Formation), greywacke, argilite and limestone (Rong Kwang Formation). It forms the greater part of the mountain range extending from Sukhotai in the south to Nan in the north. It ranges from Carboniferous to Permian in age.

Phuket Group (Mitchell *et al.*, 1970)—Phuket area, Peninsular Thailand—The upper part of the Phuket Group is equivalent to the Kaeng Krachan Group; thus, some geologists favor abadoning the name "Phuket Group". The Phuket Group displays a lithology somewhat different from that of the Kaeng Krachan Group, for example in pebbly mudstones, rock fragments are larger (up to 90 cm across) in the Phuket area than in the Kaeng Krachan area where they are less than 3 cm in diameter. Early Permian brachiopods have been found in the upper part of the Phuket Group at Ko Ya Noi northeast of Phuket and near Krabi. They occur just below the Ratburi Limestone and mostly above pebbly beds. They indicate a probable Sakmarian age (Waterhouse, Pitakpaivan and Mantajit, 1981). Cold-water fauna has been mentioned by Waterhouse (1982) at Ko Muk and Ko Phi Phi islands southeast of Phuket. Moreover, fossil plants with *Walchia* have been discovered 15 m below the Ratburi Limestone. Stauffer and Lee (1984) strongly support a glacial marine origin for this group. Diamonds have been discovered in alluvium in southern Thailand; they could be derived from the Phuket Series (Aranyakanond, 1955). They have been used to substantiate the glacial origin (*Fig. 16*).

Pondok Limestone (Foo, 1968)—Northwest Perak, Peninsular Malaysia—Massive limestone, recrystallized, unfossiliferous. Upper Palaeozoic in age because it is closely associated with the Kati Formation. See Kati Formation and Salak Series from the same region.

Ratburi Group (Javanaphet, 1969)—Central Thailand—Exposures in the Ratburi area, about 100 km west-southwest of Bangkok. Isolated limestone hills scattered in a Quaternary plain. They do not provide a very important section of the Permian. Even though they are known for a long time, their fusulines have not been extensively studied. A few of them were identified and had been collected from three localities (Khao Prik, Khao Chong Krachok and Khao Ta Mong Rai). They were considered to be Early Artinskian (Khrao Phrik) and Sakmarian (Khao Chong Krachok and Khao Ta Mong Rai) in age (Sakagami, 1969). From that three localities, some bryozoa were also studied (Sakagami, 1968). On the contrary, Brachiopods have received more attention and have been considered Middle Permian in age (Late Artinskian by Grant, 1976; Kungurian by Waterhouse, 1981). In spite of our fragmentary knowledge, the names "Ratburi Limestone" or "Ratburi Group" have been used for all the Permian exposures of Thailand consisting of limestone and associated clastic sediments. For instance, Pitakpaivan (1965) studied some "Fusulines of the Rat Buri Limestone", but his samples were collected from localities of Central Thailand (Saraburi, Lopburi, Nakhonsawan, Phetchabun and Loei), i.e. very far from Ratburi. No type section has been designated. Toriyama (1967) discussed proposals for abandoning the name Ratburi as inappropriate. Grant (1976) was inclined to confine the name Ratburi to Limestones in the vicinity of Ratburi and limestones elsewhere with similar faunas. The name "Ratburi Limestone" or "Ratburi Group" were restricted to Peninsular Thailand by Bunopas (1981). *Shanita*, a peculiar foraminifera, has been newly found at Khao Tha Mo southwest of Phetburi and indicates a relatively high Permian (See appendix 5).

Ratburi Limestone (Brown *et al.*, 1951)—See Ratburi Group.

Raub Group (Alexander, 1958, 1968)—Continuous belt stretching from Kelantan southwards to Bentong in South Pahang, Malaysia—Calcareous and argillaceous shales with lenticular masses of limestone and with intercalations of pyroclastic rocks and occasional small lava flows. Thickness not greater than 2500 m. The volcanic rocks, andesitic and rhyolitic, have been included in the "Pahang Volcanics" which are Triassic to Carboniferous in age according to Alexander (1968). They make the difference between the Raub Group and the non volcanic Kinta Limestone, Kati Formation and Kenny Hill Formation. Volcanism increases to a maximum intensity in the upper part of the Raub Group. Few fossils have been identified. Late Carboniferous–Permian in age. Also called the "Calcareous Series" (Raub is 30 miles southwest of Kuala Lipis).

Redang Beds (Soon, 1977)—Pulau Redang offshore Northeast Malaya—Conglomerates with interbeds of shale and sandstone. Contain fossil plants. Associated with unfossiliferous sandstone (Pinang Beds).

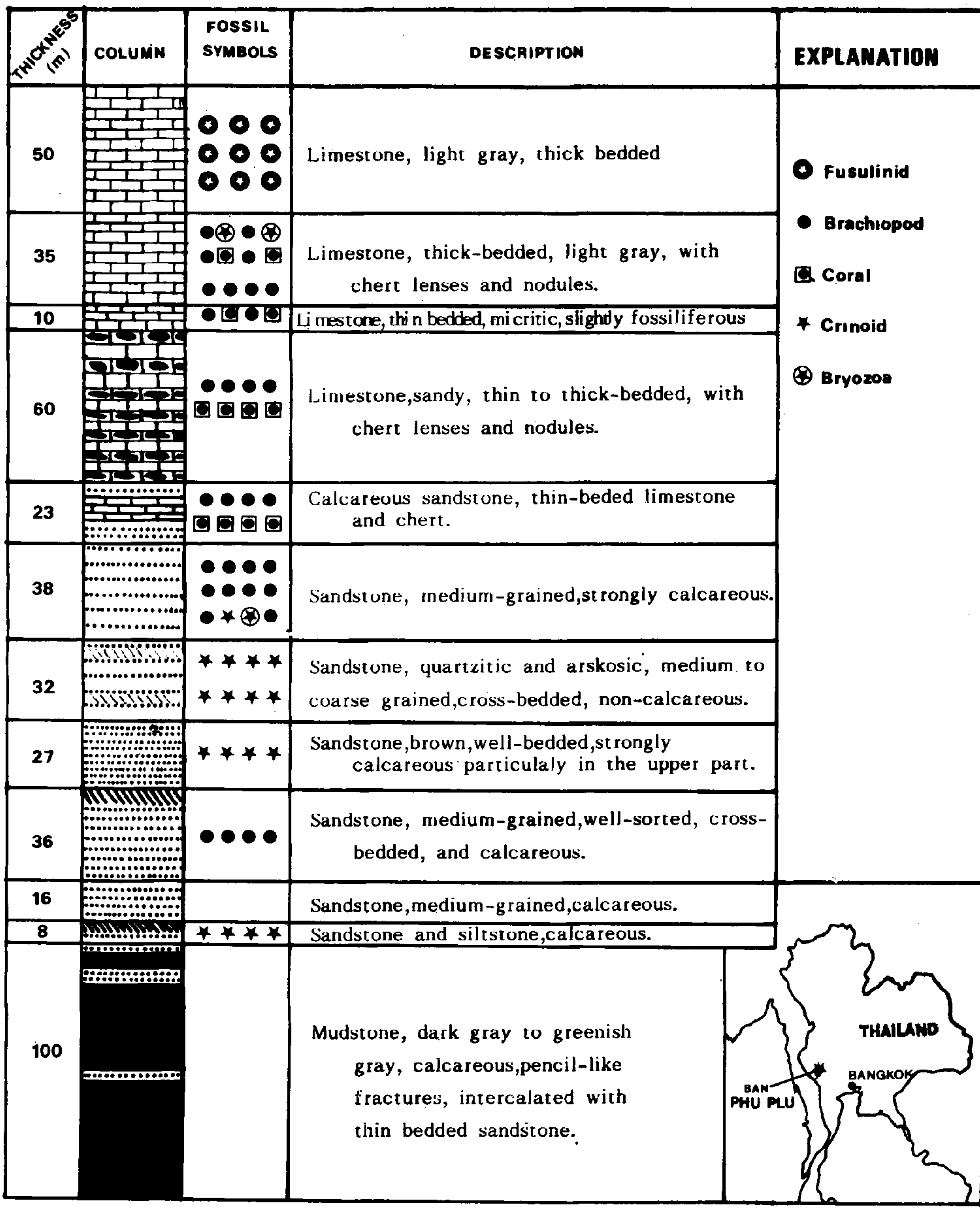
Sai Yok Group (Bunopas, 1982)—West Central Thailand—The Sai Yok Group is exposed to the west of Kanchanaburi in the Three Pagodas Fault zone. It consists of three units, from top to bottom; the Tha Madua Sandstone, the Sai Yok Limestone and the Khao Muang Khrut Sandstone. A few branchiopods and fusulines from the Khao Muang Khrut Sandstone and Sai Yok Limestone were identified and gave the general age from Early Permian to early Late Permian (Bunopas, 1982).

At Ban Phu Plu near the road from Kanchanaburi to Sai Yok, a limestone unit (commonly wackestone associated with some packstone) is rich in fossils. They are algae, pseudoalgae, bryozoa, brachiopods, corals (solitary tetracorallia without dissepiments, tabulata), pelecypods and crinoids. Algae, pseudoalgae and foraminifera have been identified by D. Vachard, corals by H. Fontaine.

Algae: "*Permumbella*" sp.

Pseudoalgae: *Ungdarella uralica.*

Small foraminifera: *Diplosphaerina* sp., *Tuberitina collosa*, "*Earlandia*" sp., *Climmacammina* sp., *Tetrataxis* sp., *Abadehella* sp., *Globivalvulina* sp., *Multidiscus padangensis*, *Bradyina* sp., *Geinitzina* sp., *Langella* sp.



A. MEESOOK & V. SUTEETORN ***GEOLOGICAL SURVEY DIVISION, DMR, THAILAND. (1984)***

Figure 18. Generalized stratigraphic column of Permian rocks of the Ban Phu Plu area, Amphoe Saiyok, Chanqwat Kanchanaburi.

Fusulinoids: *Sichonetella* cf. *orientalis* Toumanskaia, *Minojapanella* sp., *Parafusulina padangensis*, *Schubertella* sp., *Yangchienia* sp., *Eopolydiexodina megasphaerica* (*E. bithynica*).

Corals: *Pseudoromingeria* sp., *Sinophyllum pendulum*, Polycoeliidae.

Subtidal environment. Murgabian to Midian in age. The Ban Phu Plu Limestone is rich in bryozoans and crinoids; it contains polydiexodinids. Fusulinid fauna is not varied in species and dasycladacean flora appears to be almost absent. It is usually fine-grained (micrite). All these characters correspond to a Permian limestone of the Thong Pha Phum surroundings described by Hagen and Kemper (1976). The Ban Phu Plu Limestone and the Thong Pha Phum Limestone were probably deposited on a shelf in a rather deep water (however less than 200 m deep) and they represent mud mounds built up by bryozoa, crinoids and small foraminifera.

Salak Series (Foo, 1968)—Northwest Perak, Peninsular Malaysia—Succession of carbonaceous shale with subordinate sandstone and calcareous rocks. Unfossiliferous. No volcanic rock. Probably Upper Palaeozoic in age. See Kati Formation and Pondok Limestone from the same region.

Salamuku Beds (Zwierzycki, 1935)—Sumatra—See Djambi Series.

Saraburi Group (Bunopas, 1982)—Central Thailand—Western edge of the Khorat Plateau from Loei south to Saraburi. This group is divided into three units, namely Dan Sai Shale, Saraburi Limestone, Khao Luak Formation in the ascending order. Many fossiliferous outcrops are included in this group which is the best known from a palaeontological point of view.

Sawak Metasediments (Foo, 1970)—South Pahang, Peninsular Malaysia—Oldest rocks of the area, composed of schists and phyllites with subordinate argillites and quartzites. Unfossiliferous, but older than the Middle Triassic well-dated rocks of south Pahang and East Negeri Sembilan (Gemas Beds). Considered Permian in age. Low grade metamorphism.

Sedili Volcanic Formation (Rajah, 1969)—Johore, Peninsular Malaysia—Tuff, agglomerate, lava and volcanic ash ranging from rhyolitic to sandesitic in composition. Ignimbrite is the most abundant variety and rhyolite forms the bulk of the lava flows. The presence of ignimbrite makes a difference with the pyroclastic Aring Formation which contains no welded tuff. Perhaps contemporaneous with the Linggiu Formation, i.e. Upper Permian in age. Producing some outstanding topographical features (Gunong Chemendong attaining a height of 2777 feet).

Silungkang Formation (Klompé *et al.*, 1961)—Central Sumatra—Formation built up by limestone, shale and volcanics. It is divided into two series, namely a lower volcanic series and an upper calcareous series. Exposed along the road from Silungkang to Sawahlunto near Silungkang. Along the road from Silungkang to the microwave station, Hahn and Weber (1981) have found fusulinids in the lower limestone

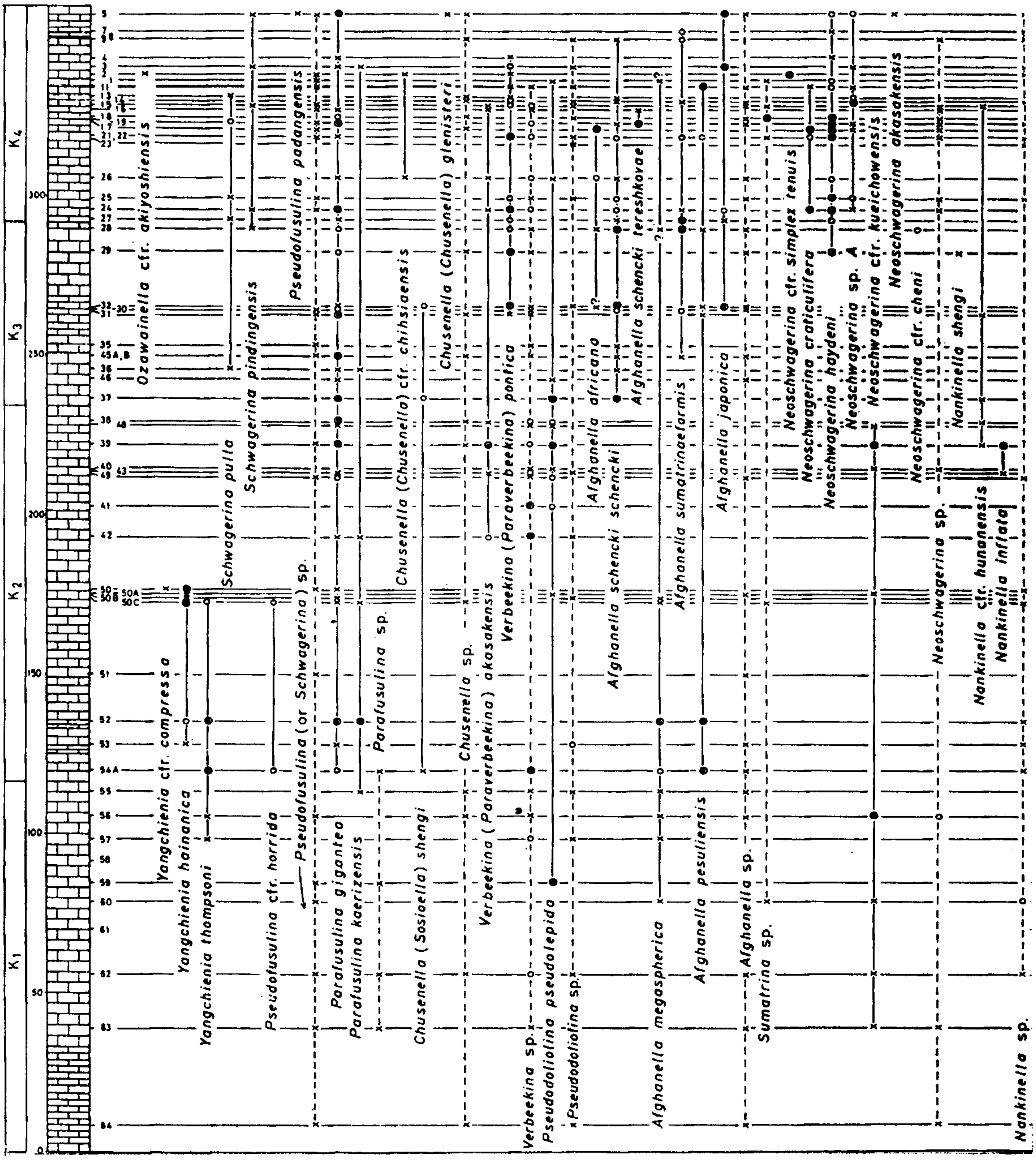


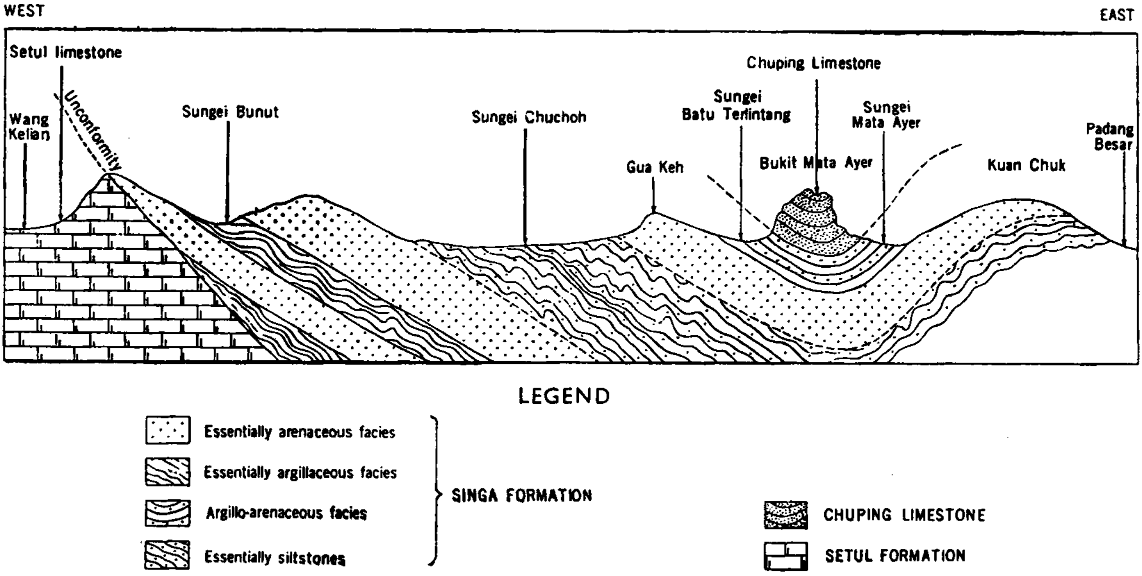
Figure 19. Section of the Khao Khao limestone (Toriyama and Kanmera, 1979). Khao Khao is a hill located near Km 129 of the highway 5, i.e. between Saraburi and Lopburi.

Table 5. Two sections of the Saraburi Limestones, after Toriyama and Kanmera, 1979.

Khao Khao	Khao Phlong Phrab
K4 Neoschwagerina haydeni	
K3 Afghanella schencki schencki	
K2 Afghanella pesuliensis Pseudodoliolina pseudolepida	B7 Presumatrina schellwieni
K1 Afghanella megasphaerica Neoschwagerina cf. kueichowensis	B6 Neoschwagerina simplex
	B5 Maklaya sethaputhi
	B4 Maklaya pamirica
	B3 Maklaya saraburiensis
	B2 Misellina confragaspira
	B1 Misellina otai Misellina cf. termieri

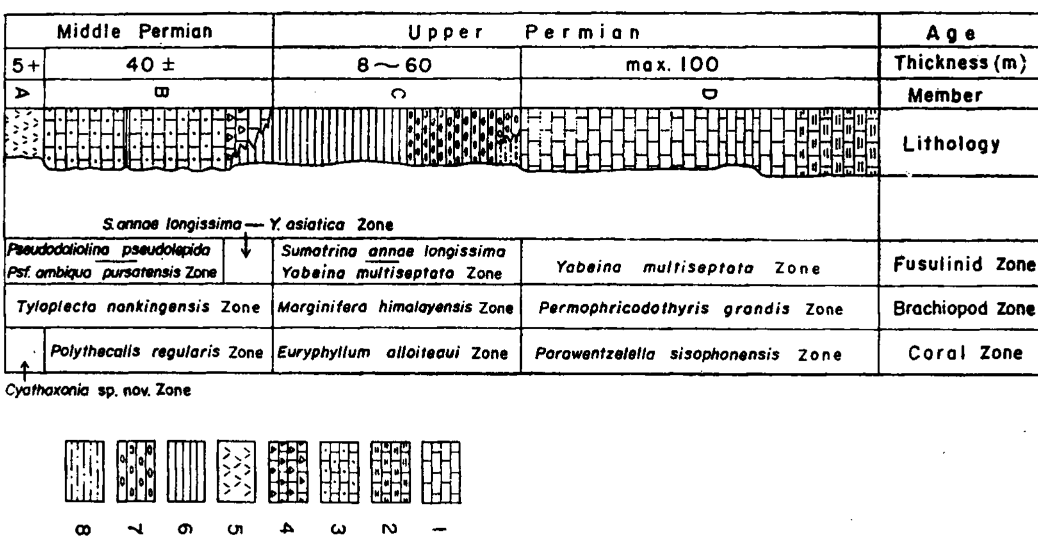
beds: *Pseudofusulina valida* Lee, *P. vulgaris* Schellwien, *Rugososchwagerina yabei* Staff, *Minojapanella* sp., *Mesoschubertella* sp., fusulinids indicating an Artinskian age. Fontaine (1983) described some solitary corals from higher beds. The Guguk Bulat Limestone which is Upper Murgabian in age and crops out about 30 km northwest of Silungkang is also assigned to the Silungkang Formation (*Fig. 15*).

Singa Formation (Jones unpublished; Foo, 1964; Jones, 1966)—Langkawi Islands, West Malaysia—Succession of alternating carbonaceous siltstone, mudstone, pebbly mudstone (pebbles angular to rounded, a few mm to 20 cm in diameter; occurrence of an isolated trondhjemite boulder at Pulau Tepor; Precambrian in age according to Stauffer and Snelling, 1977), and sandstone. About 2100 m thick. Upper Devonian to Lower Permian in age. Equivalent to the Kubang Pasu Formation. Foo (1983) suggested to abandon this name in favour of the Kubang Pasu Formation which is better exposed. See Geological Map of scale 1 : 63,360, sheet 150 Pulau Langkawi, published in 1966. On other sheets (sheet 2 E/5 Perlis 1967; sheet 2 E/6 Perlis / Kedah 1967; sheet 2 E/9 Kangar 1967; sheet 2 E/10 Jitra 1967), the Kubang Pasu



Diagrammatic section across North Perlis showing the structural distribution of the different facies of the Singa Formation

Figure 20. Singa Formation near the Thai border in Northwest Peninsular Malaysia (Jones, 1978).



Generalized columnar section of the Permian of west Cambodia.

1: bedded limestone, 2: muddy limestone or micritic limestone, 3: crinoidal limestone, 4: limestone breccias, 5: tuff breccias or tuff, 6: reddish shale, 7: reddish brownish calcareous mudstone with calcareous nodules, 8: drusy coating skeletal limestone (grainstone)

Figure 21. Section of the Sisophon area (Ishii *et al.*, 1969).

and the Singa Formations are not separated and Jones (1973) treated them under the same chapter heading. The pebbly mudstones are a product of mass movement for some authors; they have a glacial marine origin for other authors (Stauffer and Lee, 1984) (*Fig. 20*).

Sisophonian (Liêm, 1983)—Stratotype in the vicinity of Sisophon, Western Kampuchea—Upper part of the section exposed in the hills near Sisophon and containing *Lepidolina multiseptata*, *Sumatrina longissima* and *Yabeina asiatica.* Limestones with a minor intercalation of shale and mudstone. Abundant and varied fossils (*Fig. 21*).

Sumalayang Limestone Member (Rajah, 1969)—Johore, Peninsular Malaysia—See Dohol Formation. Upper part of the Lower Permian and lower part of the Middle Permian with *Cuniculinella globosa* Deprat, *C. zulumartensis* Leven, *Monodiexodina shiptoni* Dunbar, *M. kattaensis* Schwager, *Parafusulina dronovi* Leven, *P. dutkevitchi* Leven, *P. granumavenae* Roemer, *P. murotbekovi* Leven, and others (Igo *et al.*, 1979). Another limestone containing fenestellids and crinoids crops out about 30 km north–northwest of Gunong Sumalayang close to the Sungai Lenggor; it may represent another depositional environment of the Permian (Rajah, 1969).

Taku schists (Savage, 1925; McDonald, 1967)—South and west Kota Baharu, Peninsular Malaysia—Elongate body, 80 km long, 8 to 22 km wide, stretching from the Thai border near Tanah Merah to Central East Kelantan near Manik Urai. Considered to be the metamorphosed equivalents of sedimentary rocks occurring in the area (Savage, 1925) and accordingly in part Permian in age. This hypothesis is still accepted by Chung and Yin (1976), Rajah and Yin (1980) and Foo (1983). Considered the oldest rocks of the area and possibly pre-Carboniferous in age by other authors (Aw, 1964, McDonald, 1967) or at least pre-Permian in age (Khoo and Tan, 1983). The relationship between the schists and adjoining sedimentary rocks at their contact has nowhere been clearly observed and remains rather problematical. Micas from the Taku Schists gave a Late Triassic K-Ar age which Bignell and Snelling (1977) interpreted as cooling or resetting age and which throws no light on the age of the main metamorphism undergone by the Taku Schists. This Late Triassic age just sets a younger limit to the possible age of the Taku Schists. Apophyses of the Kemahang Granite extend into the Taku Schists.

Ta Thiet Limestone (Liêm, 1983)—Binh Long area, South Viet Nam: 106°26′40″, 11°42′40″—Limestones exposed in the Saigon River at the Kampuchean border, 200 m thick. Separated by an unobserved interval of 10 m from the Lower Triassic with *Otoceras-Ophiceras.* Limestones containing *Palaeofusulina*, *Colaniella*, *Reichelina*, *Neoendothyra.* Relationship with the *Lepidolina–Yabeina* and *Neoschwagerina* faunas are unknown.

Tawar Formation (Courtier, 1974)—East of Penang, Peninsular Malaysia—Interbedded shale and chert, unconformably overlain by the Semanggol Formation (Triassic). Unfossiliferous. Tentatively, assigned to the Permo-Carboniferous. See

Geological Map of scale 1 : 63,360, sheet 21/10 and part of sheet 21/11 Province Wellesley / South Kedah, published in 1973.

Telong Formation (Aw, 1972)—South Kelantan, Malaysia—Exposed in the Sungai Aring area. Consists mainly of argillite with minor volcanics and with intercalations of limestone (Nilam Marble). About 1 km thick. Shale contains pelecypods with occasional ammonites, of Carnian or "Upper Triassic" age. Limestone displays more or less recrystallized fossils. This formation ranges in age from the Late Permian to the Upper Triassic with a hiatus in the Middle Triassic (Aw, 1973). The lower part of the Telong Formation grades laterally in the east into the upper part of the Aring

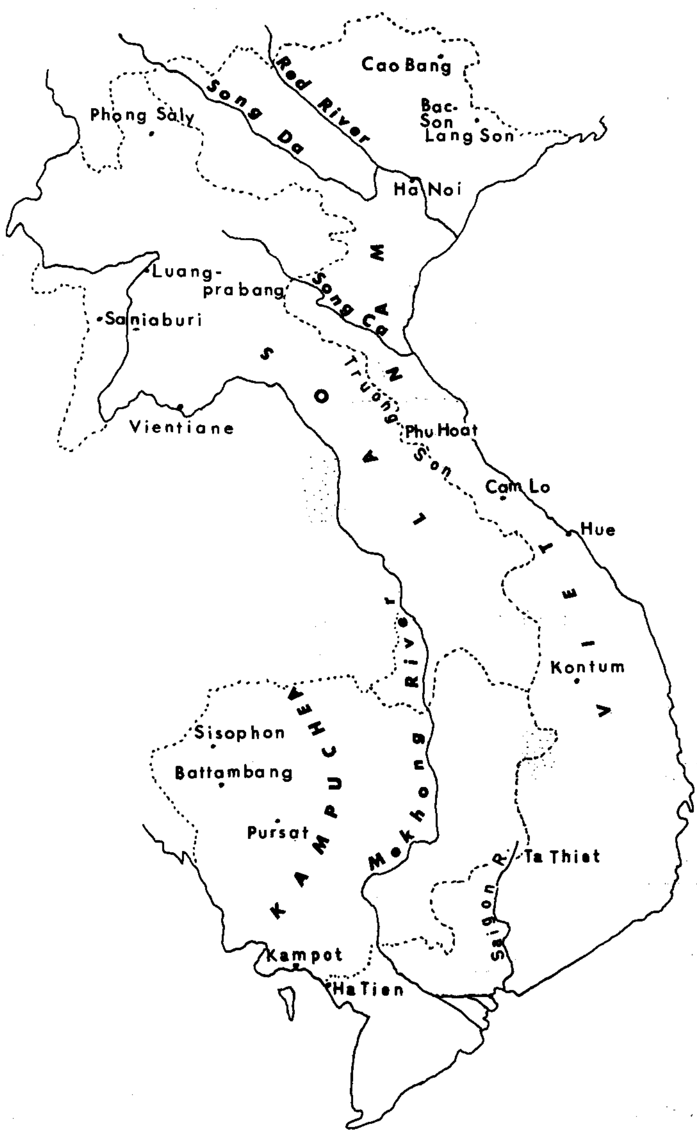


Figure 22. Locality map, Vietnam, Kampuchea.

Formation. See Geological Map of scale 1 : 63,360, sheet 46 and part of sheet 58 Sungai Aring, published in 1978.

Terbat Formation (Haile, 1954)—Terbat, south-southeast of Kuching, West Sarawak—Succession of fusuline limestones, chert and shale. Thickness: more than 1000 m. Fusulines from the first collected samples were Lower Permian in age (Liechti *et al.*, 1960; Cummings, 1962); later on, other samples gave a Carboniferous (Bashkirian) age (Sanderson, 1966). Thus, the Terbat Formation is Carboniferous and Permian in age. Overlain unconformably by the Sadong Formation (Upper Triassic). Cummings (1962) found no other Permian foraminifera than Lower Permian ones: *Pseudoschwagerina uber*, *Paraschwagerina* (*Zellia*) cf. *heritschi*, *P.* cf. *gigantea*, *Schwagerina* sp., *Nummulostegina* cf. *velebitana*, and other smaller foraminifera.

Tolo Harbour Formation (Ruxton, 1960)—New Territories, Hong Kong—Oldest sedimentary formation of Hong Kong consisting of shales and siltstones, 400 m thick. Unconmably overlain by volcanic rocks (Ignimbrites are dominant). Containing a few brachiopods (mainly *Dictyoclostus*), some fenestellids and solitary hornshape corals (Yin *et al.*, 1981). Plant remains are abundant at the top of the formation.

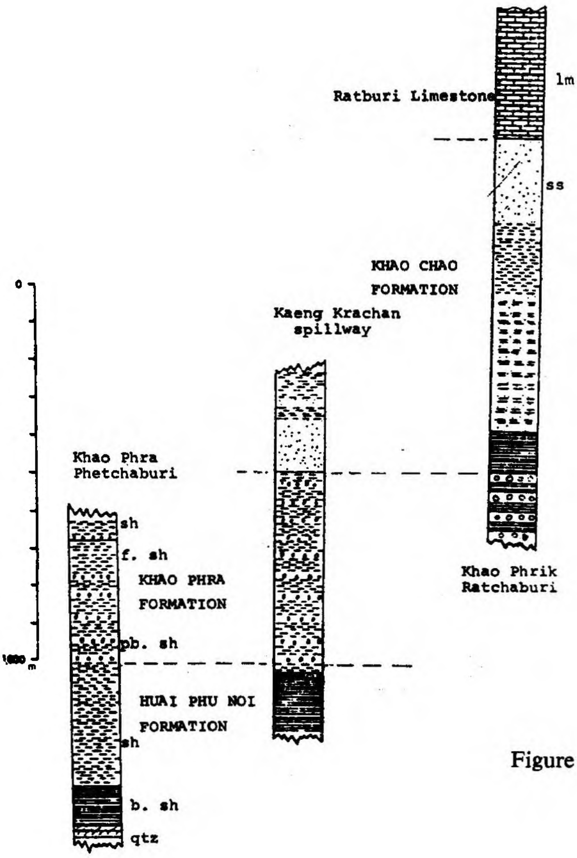


Figure 23. Stratigraphic columns of the Kaeng Krachan Group in North Peninsular Thailand (Bunopas, 1982).

Tualang Limestone (or Tanjong Tualang Limestone) (Wong, 1980)—Southwest Perak, Peninsular Malaysia—Southwest exposure of the Kinta Limestone.

Uthai Thani Limestone (Bunopas, 1982)—Central Thailand—The best section is between Uthai Thani and Umphang, 70 km west of Uthai Thani; fossils not identified. A few fusulinids were isolated from other outcrops between Uthai Thani and Ban Rai and indicated a Lower Middle Permian age (Ingavat *et al.*, 1975).

CHAPTER III

GEOCHEMISTRY

A great number of chemical analyses have been performed on Permian limestones by government agencies or by private companies because those limestones are used by cement plants (see chapter on "Mineral Resources" of this paper). They are limited to the determination of CaO and MgO contents. To date, very few geochemical studies have been carried out on Permian rocks.

CHEMICAL AND MINERALOGICAL CHARACTERISTICS OF THE PERMIAN LIMESTONES

Limestones crop out in many scattered localities of Southeast Asia. They are of Paleozoic or Mesozoic age in the continent (Viet Nam, Kampuchea, Laos, Thailand and Peninsular Malaysia) and they range from the Ordovician to the Triassic. Jurassic limestones are exposed in Western Thailand. In the Southeast Asia islands, Paleozoic limestones are less important than the Cenozoic limestones which are widespread in Sumatra, Borneo and the Philippines.

Limestones age has usually been based on fossil discovery. In Malaysia, Hutchison (1968) attempted to find a chemical criterion for their differentiation independant of palaeontology. One hundred eighty four limestone specimens were analysed for calcium, magnesium and insoluble residues. Results showed that dolomite localities could not be correlated with age of the formation or with geography. The occurrence of dolomite throughout Peninsular Malaysia is "patchy and sporadic with no easily discernable pattern" (Hutchison, 1968, p. 51). These results are contrary to the old assumption that, in Peninsular Malaysia, Mg content increased with age of the limestones.

In Thailand, Junhavant *et al.* (1984) obtained the highest MgO content in the Permian rocks when they analyzed 29 limestone samples of different ages from North Thailand. A similar result should be obtained for Western Thailand where dolomitic limestones or dolomites, Permian in age, are extensively distributed. However, chemical data cannot be used for stratigraphical purposes.

Phosphate is common as secondary (Cenozoic in age) deposits in the Permian limestone caves of Southeast Asia. In spite of that, phosphorus is only present as trace or in a very small quantity in the limestones.

A study of thin sections cut from Permian Limestones of Malaysia (Chuping Formation, Sumalayang Limestone, H. S. Lee Beds, Jengka Pass Limestone) has been carried out by Prasada Rao (1984) to clarify the major depositional environments and to interpret probable climatic zones during the formation of those limestones. The conclusion of this study is that the Permian Limestones of Malaya were formed under cool temperate (Chuping Formation) and temperate (Sumalayang Limestone) settings and accordingly, it is suggested that the Western Malaysia was probably part of Gondwanaland. It is difficult to harmonize this conclusion with palaeontological data. Fusulinacea, which are absent in the Permian of Australia, appear to have been well adapted to shallow marine environments of warm tropical and subtropical seas (see "Palaeobiology of Fusulinaceans" by Ross 1982, 3d North American Palaeontological Convention). Massive Rugosa are present in Malaysia (see chapter on "Palaeontology" of this paper). Moreover, palaeo-magnetic data have demonstrated that Southeast Asia was situated near the equator in Permian times (McElhinny *et al.*, 1981).

To date, no mineralogical study indicates that regional metamorphism is marked in the Permian limestones. On the contrary, the few clay analyses performed on Permian samples from Thailand and Indonesia show that limestones have not been touched by metamorphism. Palaeontological studies corroborate this conclusion (see chapter on palaeontology). Contact metamorphism is restricted to a narrow zone around granitic intrusions; in the Lopburi area in central Thailand, limestone is marmorized up to a distance of ten or twenty meters from granite and beyond this distance, there is no indication of metamorphism (Bonnet, 1976).

ORGANIC MATTER

Marine faunas (microfauna and macrofauna), marine (algae) and continental floras are very abundant in many Permian exposures. During their life, they thrived under favourable environments where it is natural to assume that many other organisms flourished, but disappeared without being fossilized. Hence, organic matter was deposited in great quantity and has been partly preserved in the sediments. Unfortunately, very few chemical analyses have been performed on the Permian rocks and it is impossible to describe this organic matter in its present state with precision. A few remarks, however, can be made.

Thin coal seams are intercalated in some Permian formations of Viet Nam, Kampuchea, Laos, Thailand, Malaysia and Sumatra. Anthracite has been mentioned in a few places (Saurin, 1954). Its presence suggests a high maturation level of the organic matter and only a possible gas accumulation. However, a sample of limy shale from the vicinity of Silungkang in the Padang Highlands in Central Sumatra contains organic matter, in part sapropelic in nature, with a rather low thermal alteration index suggesting the end of the oil window and the beginning of the gas zone. To this encouraging result, unfortunately isolated, petrographical studies of the Permian limestones of Southeast Asia, which have been important in number, add another interesting characteristic; these limestones are not metamorphosed and appear fresh.

STABLE ISOTOPES

Geochemistry of stable isotopes is making tremendous progress each year. It appears to have become an extremely useful tool for stratigraphic correlation and for information on palaeo-environments. Unfortunately, it has been poorly used in Southeast Asia.

A – Strontium Isotopes

As a global phenomenon, the 87Sr/86Sr ratio of the Permian marine carbonates is low. At the end of the Permian, it increases to reach a maximum during the Triassic. Such a lowstand which is explained by erosion weakness and great carbonate accumulation fits well with the Permian of Southeast Asia. However, the first results from Permian samples of Southeast Asia are puzzling. Limestone samples from two Lower Permian localities of the Jambi Province in Sumatra; Telok Gedang (IN444) at the Merangin River and Pulau Apat (IN452) at the Mesumai River, have shown anomalous values. Namely 0.70861 for IN444 and 0.70855 for IN452. These values should have been about 0.7074 according to the presently proposed model. The meaning of these anomalies is not perfectly understood. Sea water of the Jambi Province was perhaps not in equilibrium with oceanic water during the Early Permian, due to some confinement or it seems more likely that radiogenic strontium has been introduced during or after the limestone deposition by a cause which has not been determined yet.

B – Carbon and Oxygen Isotopes

Study of the carbon and oxygen isotopes present in the Permian rocks of China (Chen *et al.*, 1984) has shown an anomaly in the Upper Permian. In some Changhsingian limestones, the δ13C values vary from 0.1‰ at the base of the stage through 5.1‰ in the middle to 0.1‰ at the top; these values constitute a cycle of variation. They are positive whereas the overlying Triassic formation shows negative values. Hence, δ13C value curves of marine carbonates will probably become a good tool for the stratigraphy of China.

In Thailand and Sumatra, a few analyses of the carbon and oxygen isotopes have been carried out to understand the evolution degree of the Permian sediments. Those sediments are not metamorphosed. The sample IN276, collected near the Semangko Fault, is the most evolved according to clay analysis. It is probably touched by incipient anchimetamorphism. Its age, Permian according to the geological map (scale 1 : 250,000), is not ascertained by fossils, especially by fusulinids that seem to be entirely absent.

Table 6. Carbon and oxygen isotopes contained in the organic matter and the carbonate of a few Permian limestones.

Sample	Locality	age	δ 13C Kerogen	δ 13C Carbonate	δ 18C Carbonat
T 108	Khao Pan Ek (Saraburi area, Thailand)	Middle Permian	−21.60		
T 452	South of Khao Pang Sawong (Pak Chong area, Thailand)	Lower Permian	−29.46		
IN 276	6 km of Alahan Panjang (Sumatra) in the Semangko Fault zone	Permian ?	−25.35	− 1.57	−14.5

UPPER BOUNDARY OF THE PERMIAN

In Southeast Asia, gaps in sedimentation are frequent at the top of the Permian. In the few areas where the Upper Permian is continuous with the Lower Triassic, detailed geochemical studies have sō far never been carried out and we do not know if there is a geochemical anomaly similar to that of the Late Cretaceous. At the close of the Cretaceous, a layer was enriched in iridium, osmium, gold and platinum. This has been known as a global phenomenon. The reason for this anomaly remains controversial; instantaneous catastrophe due to an extraterrestrial body impact or emissions from peculiar volcanoes (Science No. 4628, 1983); a meteorite impact seems to be proved by shock metamorphism features of the minerals (Science No. 4651, 1984).

Another iridium anomaly has been noticed at the Eocene-Oligocene boundary. Those iridium anomalies are coeval with extinctions in the fossil record. This fact is not a law. Iridium anomaly seems to be absent at the end of the Cambrian when abrupt extinction of tribolites is marked within a few centimeters of section (*Science* No. 4632, 1984); however, this remark is based on results restricted to one sampling site and it needs to be corroborated by other results at distant locations.

The extinction pattern at the close of the Permian appears as rather a gradual transition, not as a catastrophic turnover. On the other hand, volcanism was important at the end of the Permian in large areas of Southeast Asia (See the chapter on "Igneous activity" in this paper).

EVAPORITES – CLIMATE

Although evaporite deposition was important during the Permian in some parts of the world, Permian evaporites are so far unknown in Southeast Asia. This absence of evaporite deposits appears to correspond with a high level of humidity. Coal seams are present in the Permian beds of Southeast Asia. Although they are not strongly developed, they indicate also a somewhat humid climate together with the rich floras discovered up to now. Bauxitic deposits of Viet Nam and Kampuchea are indicators of a humid and warm climate. Corals and thick carbonate sediments put emphasis on a warm climate.

CHAPTER IV

IGNEOUS ACTIVITIES

Igneous activities were not very strong during the Permian in Southeast Asia. Nevertheless, volcanism was important in a few areas, especially during the Late Permian.

PLUTONIC ACTIVITY

Radiometric datings of plutonic rocks, mainly by potassium-argon and rubidium-strontium methods, have been largely used in Southeast Asia where it is commonly difficult to give an accurate age to intrusive bodies just by geological mapping. In many places, intrusive bodies are dated only as younger than the intruded rocks and there is no means to give upper limits to their ages.

Whereas the Permian lasted from 290 to 245 Ma before present, many dates obtained in Southeast Asia fall in the Triassic (245 to 205 Ma). This fact is clear in many results obtained in all the countries of Southeast Asia (Webb, 1982 for the Mae Sariang granite in Thailand; Priem and Bon 1982 for granites of Bangka and Belitung in Indonesia; Geochronology Laboratory of Bandung 1981 for granites of Sumatra at Sibolga, Sisawah in the vicinity of Solok; Pongsapich *et al.*, 1983, for several granites for Thailand; Trung and Bao, 1984 for granites of South Viet Nam; Lasserre *et al.*, 1968 for the granite of Bo Khâm in East Kampuchea; Bignell and Snelling, 1977 for some granites of Malaysia). A granodiorite with amphibole crops out near Dusun Baru in the Jambi Province (Sumatra). This body apparently intruded into the Lower Permian strata exposed along the Merangin River. A sample (IN446) of this granodiorite collected at Sungai Sadeh, a tributary of the Merangin River has indicated an age corresponding to the boundary between the Triassic and the Jurassic according to analyses performed by the laboratories of Elf-Aquitaine in 1984 on whole rock (200 Ma), on amphibole (200 Ma) and on feldspars (210 Ma).

In Southeast Asia, few radiometric datings indicate Permian times.

Many age determinations have been carried out in Peninsular Malaysia and have been the subject of a major paper of Bignell and Snelling (1977). The conclusion of these authors is; "The granites of the East Coast region were intruded in two episodes at 250 Ma and 220 Ma (Rb–Sr isochrons), K–Ar ages on micas are generally concordant with the appropriate Rb–Sr isochron age. . . . The Main Range batholith is composed of granites of Late Carboniferous (about 280 Ma) and Late Triassic (about 230 Ma and 200 Ma) age. Potassium-argon ages on micas from the southern part of the batholith often show evidence of considerable argon loss. Evidence of the 280 Ma intrusive event has been completely erased and most K–Ar apparent ages fall in the range 80 Ma to 200 Ma—A Devonian intrusive event (about 360 Ma) has been tentatively inferred from an isochron based on the analysis of widely dispersed samples from the Main Range batholith in Perak and Kedah—A revision of the ages of those granites (to be published) indicates that the Main Range granites belong to the boundary between the Triassic and the Jurassic whereas the granites of the East Coast are Permian to Triassic in age. The granite of Kuantan (East Coast) appears to be as old as the Carboniferous–Permian boundary with a Rb-Sr age of 292 ± 12 Ma (Yap, 1984). Available Rb-Sr whole rock and zircon U-Pb data indicate that the granites of Penang Island (West of the Main Range granites) were probably emplaced in the Late Triassic between 220 Ma and 207 Ma (Kwan and Yap, 1984). These new results give a clear picture of a subduction with a final collision (See chapter on paleogeographic evolution); however, their simplicity leaves us perplexed. The granites of the Main Range are S-type whereas the East Coast granites are a mixture of S-type and I-type granites. Compared with granites, other

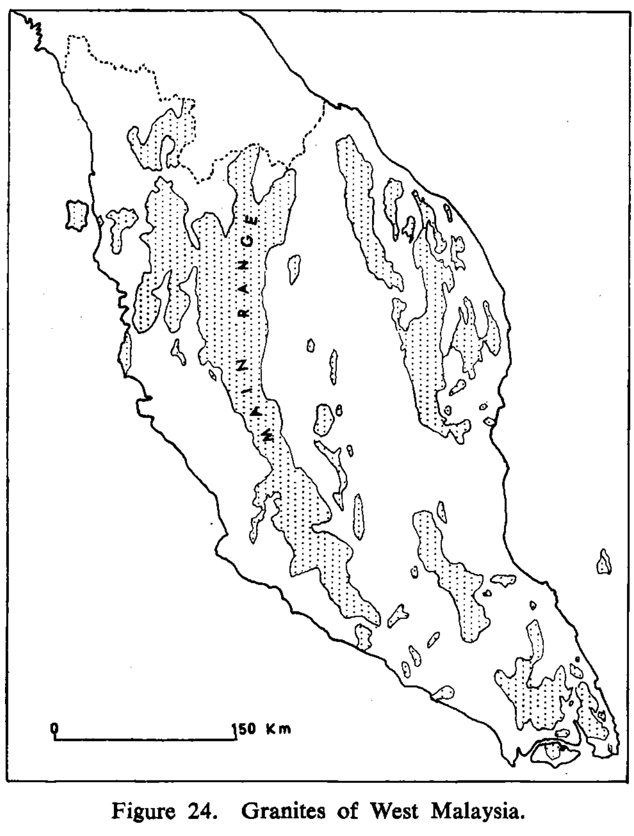


Figure 24. Granites of West Malaysia.

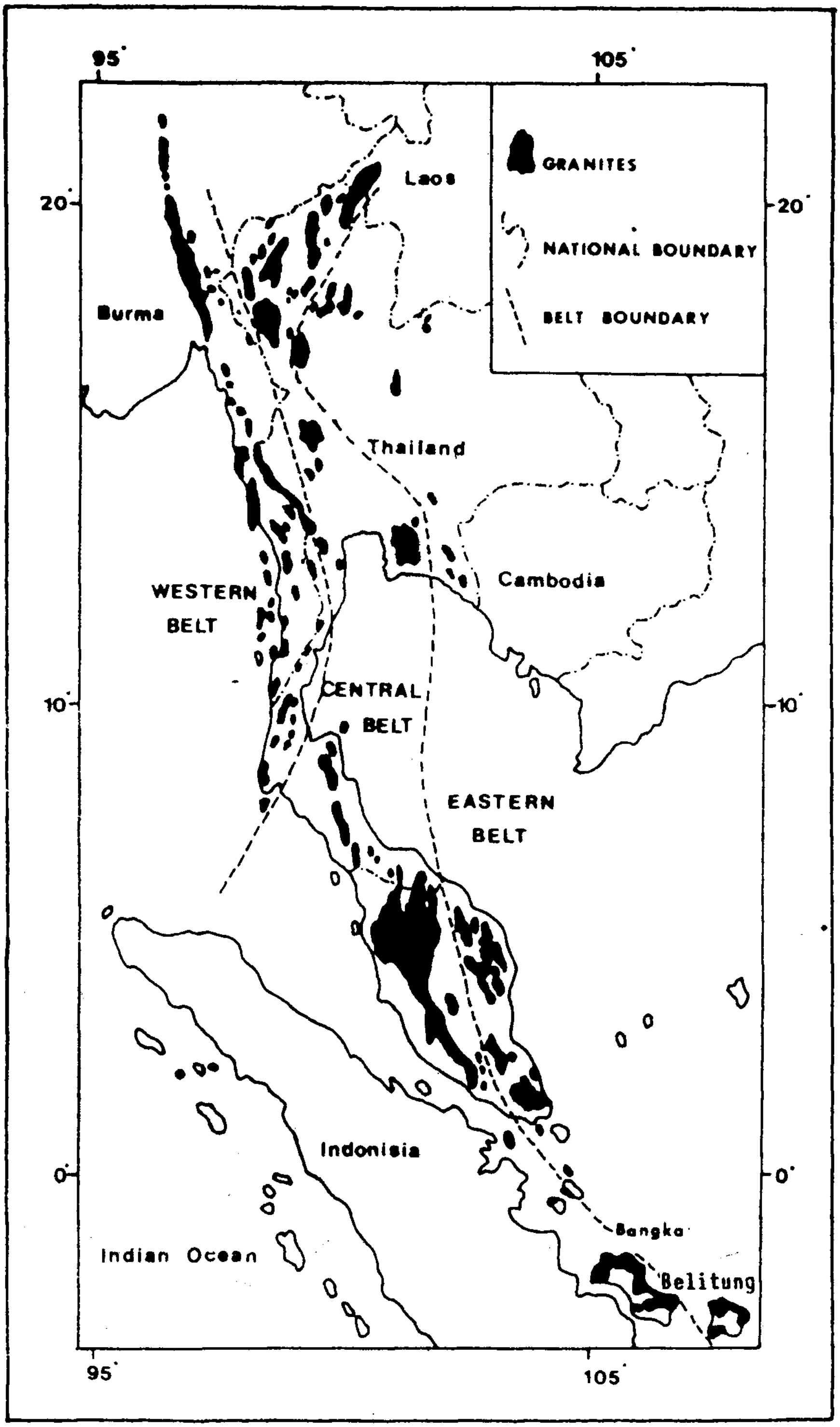


Figure 25. Distribution of granites in Thailand and Peninsular Malaysia, according to Pongsapich *et al.*, 1983.

plutonic igneous rocks are insignificant in Peninsular Malaysia.

Granitic rocks of Thailand have been divided into three main parallel belts namely, the Eastern, the Central and the Western Belts. A number of Rb-Sr radiometric ages of the Western Belts, which is located along the Burmese border, suggest, but not conclusively, that the granites of that belt are Cretaceous in age even though data from a few samples correspond to older ages. The Eastern Belt appears as a continuation of the eastern part of Peninsular Malaysia (=Eastern and Central Belts of Malaysia); it is characterized by plutonic rocks Permian to Triassic in age (mainly Triassic): Chiang Khan granite of the Loei Province (230 Ma), Tak Batholith (255 Ma, 212 Ma, 208 Ma) which is a I-type granite, granites of the Chanthaburi area. The Central Belt of Thailand, Triassic in age, comprises a great part of the granitoids of Thailand. Those granitoids are S-type in nature; they are exposed in the Chiang Rai area, west of Chiang Mai-Tak, in the western part of the Uthai Thani Province, in the Chonburi-Rayong area and south of Surat Thani in Peninsular Thailand. A few Permian Rb-Sr ages have been obtained in the Rayong-Chonburi area (290 Ma, 273 Ma, 272 Ma) and in Peninsular Thailand (297 Ma and 258 Ma south of Yala; 252 Ma east of Narathiwat). The Central Belt of Thailand is equivalent to the Main Range granite of Peninsular Malaysia.

In Laos near Sanakham, small granodiorite bodies have been dated 255 Ma and 264 Ma by the K-Ar method on amphiboles (Lasserre *et al.*, 1972). Sanakham is a village of the northern bank of the Mekhong River less than 2 km north-northeast of Chiang Khan in Thailand; it is 140 km upstream of Vientiane. Whereas results fall in Permian times for the Sanakham granodiorite, they belong to the beginning of the Triassic for the Chiang Khan granite inThailand.

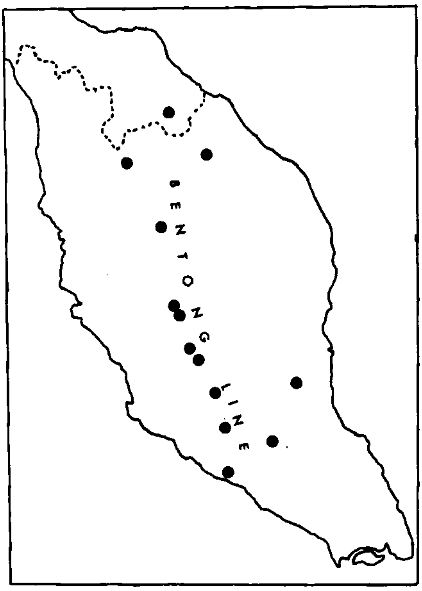


Figure 26A. Serpentinised ultramafics from Peninsular Malaysia and Southern Thailand.

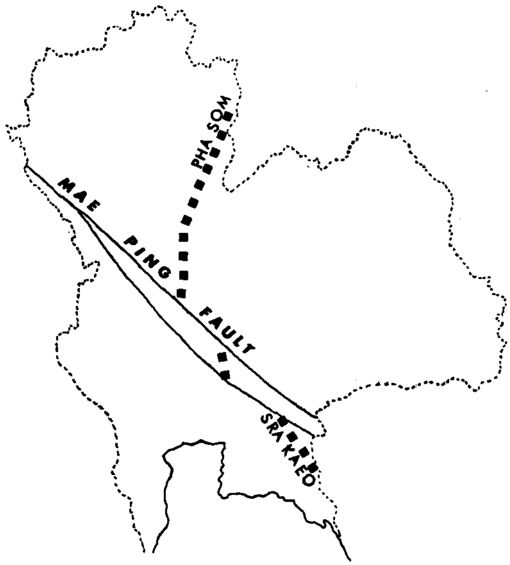


Figure 26B. Distribution of ultramafics in Northern Thailand.

In Kampuchea, there is no indication of Permian igneous activity. The Bo Khâm Granite in Northeast Kampuchea is about 230 Ma old, thus a little younger than the Permian-Triassic boundary.

In Viet Nam, Ge *et al.* (1979) have mentioned magmatism in the Late Paleozoic. They considered that some granitoids of the Dien Bien Phu Group exposed in North and Central Viet Nam were probably of Middle Permian age. Outside the Dien Bien Phu area, the diorites of the Quang Tri region in Central Viet Nam (Lang Bung and Dong Ti Massifs) were inferred to be post-Early Devonian because of their geological setting. The potassium-argon ages of these diorite were 236 Ma and 249 Ma. Since these rocks are highly dynamometamorphosed, their ages are somewhat rejuvenated and are considered as corresponding to the Middle Permian. The Po Sen Massif, located west of Lao Cai, is also composed of highly metamorphosed rocks with potassium-argon ages of 236 Ma and 242 Ma. A Permian age (263 Ma) has been established for the Ngan Son Massif in North Viet Nam. Hence, Permian magmatism was suggested. However, a strong magmatism is more clearly evidenced in the Triassic. During the Permian, magmatism remains ambiguous and it is probably better to keep a Late Permian to Late Triassic age for the magmatism as it was proposed by Tri *et al.*, 1977.

ULTRAMAFICS REGARDED AS OPHIOLITES

Ultramafic bodies, possibly belonging to the Permian (at least partially), crop out in three areas; Pha Som in Northeast Thailand, Sra Kaeo in Southeast Thailand and along the Bentong Line (*Fig. 26A, B*) in Central Peninsular Malaysia. They are supposed to form a continuous line. They are composed of gabbro, dunite, hornblende peridolite and serpentinite. The time of their emplacement is not accurately known. It is thought to be Late Permian in Northeast Thailand (Bunopas, 1982).

In the Uttaradit area (Northeast Thailand), the Pha Som Ultramafics are in contact by fault with sedimentary rocks, commonly metamorphosed to greenschist facies, considered Silurian–Devonian in age. In Southeast Thailand, the Sra Kaeo Ultramafics display pillow structures with maximum dimensions of up to 1 m. They appear to be overlain by Murgabian-Midian limestone. They are associated with a melange-like formation. In Peninsular Malaysia, the Bentong Ultramafics are closely associated with rocks so different in age, structure and metamorphic type that Tan and Khoo (1983) considered them to be intrusive bodies. In Southern Peninsular Thailand (Narathiwat Province), gabbroic rocks and serpentinised peridotite seem to be a continuation of the Bentong line of ultramafics.

The existence of a paleo-suture along the Pha Som–Sra Kaeo–Bentong line is still speculative; it should be the result of the "Indosinian Orogeny". This line is not a simple line because of the strike-slip displacements on the Mae Ping and Three Pagodas Fault zones (*Figs. 2, 30*).

VOLCANIC ACTIVITY

Volcanic rocks are very abundant in the Permian of Southeast Asia, but not everywhere. They occupy large areas in well-defined zones.

In Peninsular Malaysia, volcanic rocks are common in the Central Belt (Pahang, Kelantan, West Johor); they have been called "Pahang Volcanics" because they were first studied in Pahang in 1904. They occur more extensively from Central Pahang to North Kelantan. In the Eastern Belt (Trengganu, East Pahang, East Johor), volcanic rocks are less frequent. Accordingly in Central and North Trengganu (Chung, 1962), minor tuffs, dacite and andesites occur in a very localized area. In the Western Belt (See in the Stratigraphic lexicon: Chuping Limestone, Singa Formation, Kubang Pasu Formation, Kinta Limestone, Kenny Hill Formation and Kepis Formation or the southernmost extension of the Permian), volcanic rocks are absent.

Hence, the volcanic activity in Peninsular Malaysia was strong in the Central Belt; it decreased towards the east and was non-existent to the west. This distribution suggests a subduction dipping towards the east (not westward as mentioned by Hutchison, 1973; Bignell and Snelling, 1977).

Pyroclastic rocks, of which tuff predominates, are extensive whereas lava flows are minor. Tuffs, massive or thinly -stratified, are usually finely laminated, hard when fresh and soft and friable when weathered. They are commonly interbedded with shale and limestone. Locally, they are very thick (See Aring Formation). Near Kampong Awah in Central Pahang, a very fossiliferous limestone with fusulinids (Igo, 1967), bryozoa (Sakagami, 1973) and corals (This paper; see chapter on Palaeontology) is intercalated in an andesite agglomerate. Shale is more commonly associated with the pyroclastic rocks than limestone. It has yielded relatively few fossils probably because of intense and deep weathering.

Volcanic rocks are rhyolitic to andesitic in composition. Rhyolites, dacites, trachytes and andesites have been found, but rhyolites are more common even though trachytes and andesites are more abundant in some areas. Dacites and trachytes are of restricted distribution.

Differences in composition might have evolved with time. Some volcanoes first produced material dominantly of rhyolitic composition and later they furnished material ranging in composition from trachyte to andesite.

Lavas are associated with neritic sediments in some places and tuffs contain marine fossils. Thus, volcanism was submarine or at least in marine areas. In Trengganu (Chung, 1962), an andesite is interbedded with Permian sediments with no apparent break between them and no pillow-lavas. The Aring Formation in Kelantan is a typical volcano-sedimentary sequence. The products of volcanic eruptions fell into the basin of sedimentation and were intimately mingled with the calcareous and argillaceous sediments. Tuffaceous limestone contains fusulinids.

The Aring section (*Fig. 11*) shows that volcanism was intense during the Late Permian. A tuffaceous shale has been described in Pahang which extends from Ulu Sungai Meledu into the headwaters of the Sungai Selor. It has strongly colored bands with seams, 3 mm thick. It is whitish when composed of rhyolite tuff and black when consisting of a carbonaceous shale.

A more peculiar rock (ignimbrite) is present in Southeast Malaysia and has been studied in Johor (Rajah, 1969) and in South Pahang (Foo, 1970). In south Pahang, it is part of the "Gayong Volcanics" (See stratigraphic lexicon). In Kelantan, the Temangan Ignimbrite that forms a prominent ridge 24 km long and 0.8 km wide is considered intrusive in nature and younger than the ignimbrites of Southeast Malaysia, i.e., Triassic in age.

In Southeast Malaya (Central Johor), ignimbrite is predominant in the Sungai Sedili-Sungai Tempenis area (See Sedili Volcanic Formation in stratigraphic lexicon). It is associated with subordinate lava flows, agglomerates and volcanic ash. The welding varies from poor to intense.

Volcanism has been dated in a few places. At Kampong Awah in Pahang, there is a close association of Permian limestone and pyroclastic andesite. This complexity results from explosive submarine activity in a sea of limestone deposition. In Trengganu, andesite is intercalated with Permian limestone. The pyroclastic Aring Formation has yielded Moscovian fossils at its base and Upper Permian–Lower Triassic fossils at its top. In the Gua Musang area, tuffs, lavas and agglomerates are interfingering with sedimentary rocks, Permian and Lower Triassic in age. Commenting on the results of his investigation in Kelantan and Trengganu, McDonald (1967) wrote "All degrees of interbedding are present and contacts shown on the map between predominantly volcanic rocks and predominantly sedimentary rocks are arbitrary, and indicate, except in the case of the andesites, a gradation from one to the other rather than a sharp break." The ages of many volcanic rocks have not been determined and it is difficult to accurately separate Permian volcanic rocks from older (Carboniferous) or younger (Triassic) ones. The volcanic activity ranged from the Carboniferous to the Triassic and was very strong towards the end of the Permian. In the Sungai Aring area (*Fig. 11*), volcanism was weak from the Moscovian to the top of the Murgabian, but it was very active during the Late Permian and more than two thousand meters of tuffs were deposited in about ten millions years.

In Sumatra, volcano-sedimentary sequences, called Silungkang Formation or Pelepat Formation (See the chapter on stratigraphy), have been described in the Jambi Province (Tobler, 1919) and in the Padang Highlands (Klompé *et al.*, 1961; Katili, 1969; Rosidi *et al.*, 1976). They are a continuation of the formations known in Peninsular Malaysia. In North Sumatra, the Peusangan Group contains volcanic rocks (Cameron *et al.*, 1980) which are considered to be Permian and Triassic in age, but they have not been firmly dated in several areas (See chapter on paleogeographic evolution). In the vicinity of Silungkang, lavas and pyroclastics are interbedded with limestones and shales that contain also some pyroclastic material. This fact demonstrates the fact that the volcanic activity was sometimes continuous though less intensive at certain intervals. West of Bangko in the Jambi Province, one can notice the same fact. Tuffs are more frequent than lavas. In the Silungkang area, volcanic rocks are associated with Middle Permian sediments whereas they are associated with Lower to Middle Permian sediments in the Jambi Province. In the

Silungkang area, volcanic activity decreases in the upper part of the section with the appearance of relatively more lavas. There is no definite proof that submarine volcanic activity occurred in Sumatra during the Permian. In the Jambi Province, the presence of oolothic limestone (v.g. Muara Selajau at the Kibul River, a tributary of the Tabir River), the occurrence of abundant plant remains (leaf impressions and fossil woods) and the discovery of tree trunks still in their living position suggest shallow marine to continental environments. Thus volcanic layers were deposited in coastal areas, probably on and near islands.

In West Borneo, a "Permo-Carboniferous" volcanism has been mentioned, but not described in detail (Klompé *et al.*, 1961).

According to the distribution of the various types of volcanic deposits and their chemical composition Klompé *et al.* (1961) assumed that there were two volcanic arcs in Malaysia and Western Indonesia during the Permian. One passing through Peninsular Malaysia and Borneo and characterized by acid to intermediate nature; the other in the south passing through Sumatra and displaying rocks of intermediate to basic in composition. The existence of these two arcs is not proven and it does not fit with the structural lines of Peninsular Malaysia.

In Kampuchea, rhyolites are widespread. They lie upon fossiliferous Permian limestones in the Battambang area. Many of them were assigned to the Triassic by Gubler (1935) and were considered Jurassic–Cretaceous in age by the BRGM geologists (See sheets of the geological map of scale 1 : 250,000 : Pouthisat, Sisophon, Kampong Chhnang, Phom Penh) with a few possible exceptions, for example the Thmar Meas rhyolite (Sisophon Sheet) might belong to the end of the Permian. Andesites and andesitic tuffs are exposed in several areas of Kampuchea and crops out in many localities of the Battambang Province. They are less common than the rhyolites. They were considered older or younger than the Permian by Gubler (1935). In fact, they are difficult to date in many places. Some of them are Permian in age because they appear as interbedded with Permian sediments (BRGM, Sisophon and Phouthisat Sheets).

In Laos, some andesites are assigned to the Permian, they are exposed in the upper reaches of the Nam Lik about 150 km northwest of Vientiane and in the vicinity of Saniaburi 80 km southwest of Luang Prabang. Near Ban Nam Nga 60 km north-northeast of Luang Prabang, a Permian limestone is intercalated in andesites. In the Pak Lay area, Bourret (1925) mentioned andesitic pebbles in the Triassic "Red Beds" and considered andesites as Permian or Early Triassic in age. He indicated a thickness of 500 m for the volcanic deposits and a large geographic distribution, especially southwest of Pak Lay. Some dacites croping out in the valleys of the Nam Beng and the Nam Tha Rivers are also assigned to the Permian by Saurin (1950). All these andesites and dacites belong to the western part of North Laos.

In western Thailand and eastern Burma, volcanism is absent in the Permian. During the Carboniferous, it was locally strong in the area of the Mergui Archipelago (Burma) where tuffs and agglomerates are intercalated in the Mergui Series and are associated with large masses of rhyolite and porphyry.

In central Thailand roughly between Long. 99°30′ and Long. 101°30′, a strong volcanism appeared during the Permian. Its products are exposed at Denchai, Phrae,

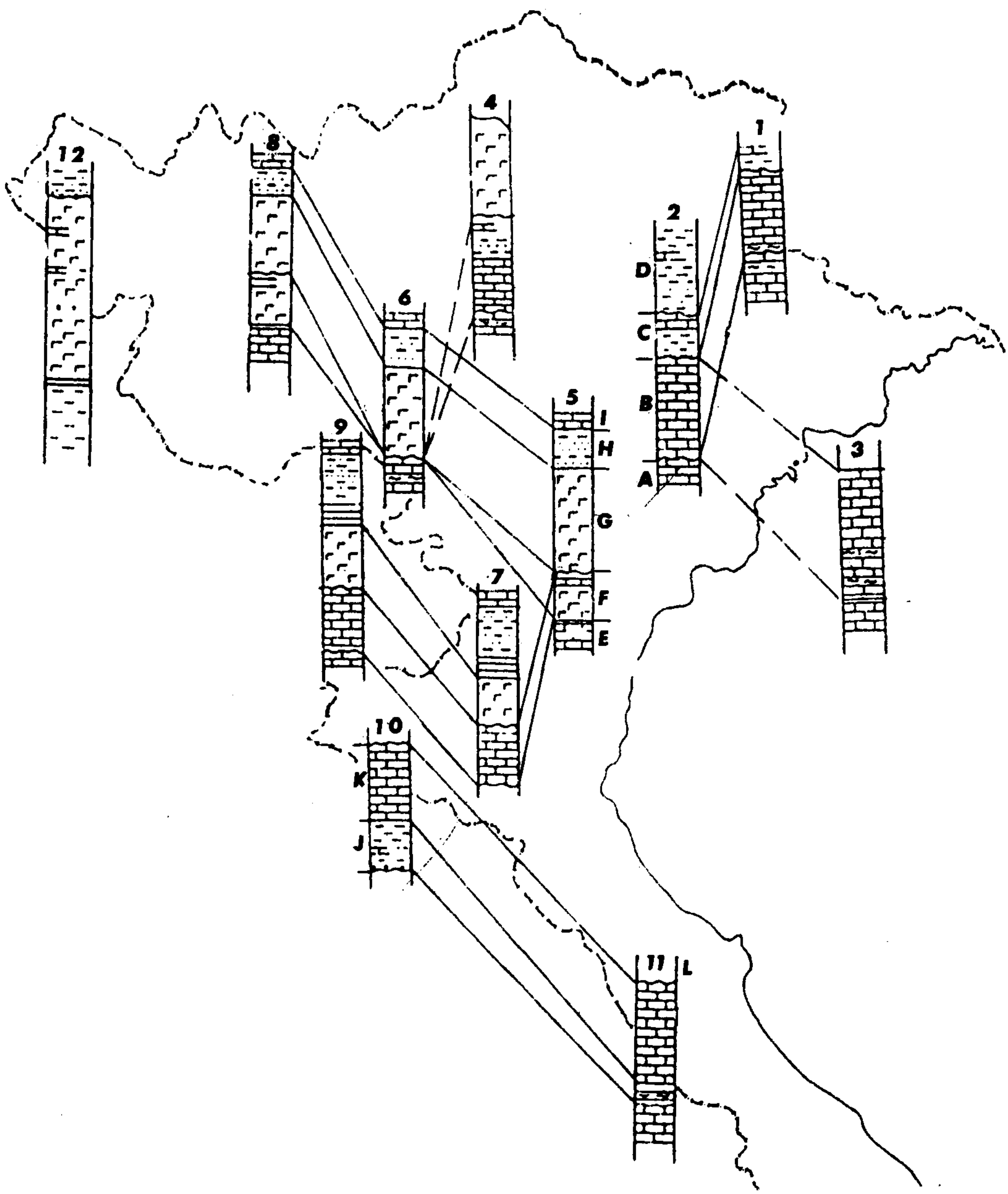


Figure 27. Upper Palaeozoic sections of North Viet Nam, showing the geographic distribution of the Permian volcanic rocks.

1–Toc That; 2–Bac Son; 3–Cat Ba. A=Devonian; B=Bac Son Series; C=Dong Dang Formation; D=Lang Son Formation or Lower Triassic.

4–Ban Cai; 5–Hoa Binh; 6–Ta Khoa; 7–Thanh Hoa; 8–Tam Duong; 9–Son La. E=Devonian; F=Bac Son Series; G=Volcanic rocks; H=Upper Permian; I=Lower Triassic.

10–Muong Xen; 11–Qui Dat. J=Tournaisian; K=Muong Long F.; L=Khe Giua F. 12–Muong Te

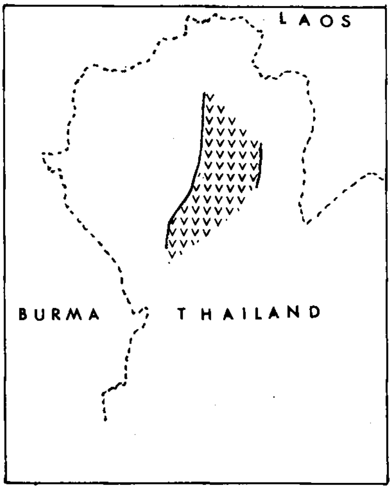


Figure 28A. Carboniferous - Early Permian volcanism in North Thailand (Bunopas and Vella, 1978). In fact, only possible volcanic activity during the Lower Permian marked by probable presence of tuffaceous rocks (Bunopas, 1982)

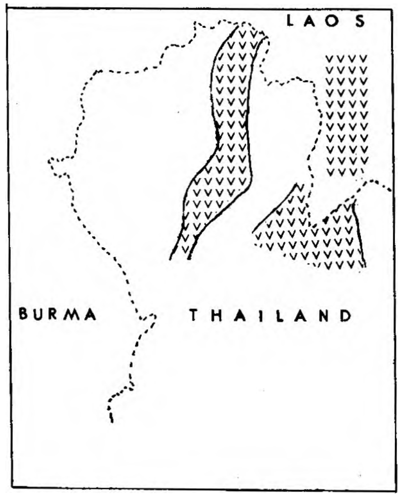


Figure 28B. Late Permian - Early Triassic volcanism in North Thailand, according to Bunopas and Vella (1978). The western belt belongs to a volcanic arc with a long history. The eastern belt had a short existence; it continued into Laos.

Chiang Mai, Lampang, Sirikit (= Pha Som) Dam, Lom Sak, Phetchabun, Ban Tha Kham and Sra Kaeo. They include extensive flows and pyroclastics. At several places, they overlie shale with *Leptodus* or limestone with *Neoschwagerina.* Some chemical analyses of flows and tuffaceous samples have been reported by Bunopas (1982, p. 587). This volcanism started during the Upper Permian and continued to at least the Early Triassic. It is impossible to distinguish between Upper Permian and Lower Triassic volcanics. In North Thailand, some tuffaceous sandstones and shales are Lower Permian in age (Bunopas, 1982). They are restricted to a small area (See chapter on Palaeogeography).

In Viet Nam, Permian volcanism is restricted to the Black River (= Song Da) region (*Fig. 27*). It is basaltic in nature. It belongs to a thick volcanic–sedimentary sequence ranging in age from the end of the Middle Permian to the Late Triassic and with thicknesses ranging from 3,500 to 6,000 m. In the Ha Tien area (South Viet Nam), a rhyolite has been assigned to the Permian (Saurin, 1971).

In the Philippines, no lava flow has been so far discovered in the Permian strata. A few tuffaceous beds have been noted in North Palawan; they are weathered (Hashimoto and Sato, 1973).

VOLCANISM AND LIFE

In Southeast Asia, the activity of lava flows were restricted and was not very important during the Permian. They were not actually destructive to life. During this time, however, major volcanic outbursts ejected huge quantities of ash and debris over wide areas, especially in the surrounding seas. Moreover, those explosions probably released abundant toxic gases. But the effects of this volcanism were not very profound on plants and animals. Although they were important in some parts, they were restricted to relatively small areas. Fossils are abundant below and above volcanic deposits. The evidences of pollution by anomalous concentrations of trace metals in sea water has not been found so far. Fossils are even present in the tuffs. Volcanism cannot explain selective deaths. In the same way, the death of a large quantity of corals in 1983 in the Chiriqui Gulf west of Panama could not be connected with the eruption of the Chicon Volcano 1982.

The side-effect of the Permian volcanism on the upper atmosphere and the climate is difficult to be determined. For comparison, the eruption of Tambora in Indonesia in 1815, probably bigger than that of Krakatoa, caused imperceptible change in the climate. Only long episodes of volcanic activity might be directly linked with major changes of climate.

In Southeast Asia, volcanism occurred from Permian to Late Triassic, but its effects are not actually apparent. Is the disappearance of corals and fusulinids at the end of the Permian to be connected with a global cooling due to volcanism?

CHAPTER V

PALAEOGEOGRAPHIC EVOLUTION

Before dealing with the palaeogeographic units of Southeast Asia, it is useful to assess the influence of the oscillation of sea levels during the Permian in Southeast Asia, and then, to mention some geologic features that are to be understood before palaeogeographic reconstruction.

The general acceptance of the plate tectonics concept has led to considerable speculations about the presence of possible collision sutures in Southeast Asia. A few tectonic blocks that were definitely welded during the Late Triassic have been delineated by occasional melanges and bodies of serpentinite (usually small) classified as dismembered ophiolites.

Three main blocks have been recognized by several authors (Gatinski *et al.*, 1978; Bunopas and Vella, 1978; Mitchell, 1981; Helmcke, 1982; Bunopas, 1982; and others), namely the South China Block, the Indochina Block and the Shan-Thai Block. A few authors have added the "East Malaya Block" to these three blocks. For Stauffer (1973), the East Malaya Block is an intervening band between the Shan-Thai Block and the Indochina Block. Ridd (1980) and Metcalfe (1983) reduced that block to East Peninsular Malaysia and the Gulf of Thailand. Achache *et al.* (1983) indicated a puzzling position for East Malaya during the Late Cretaceous. East

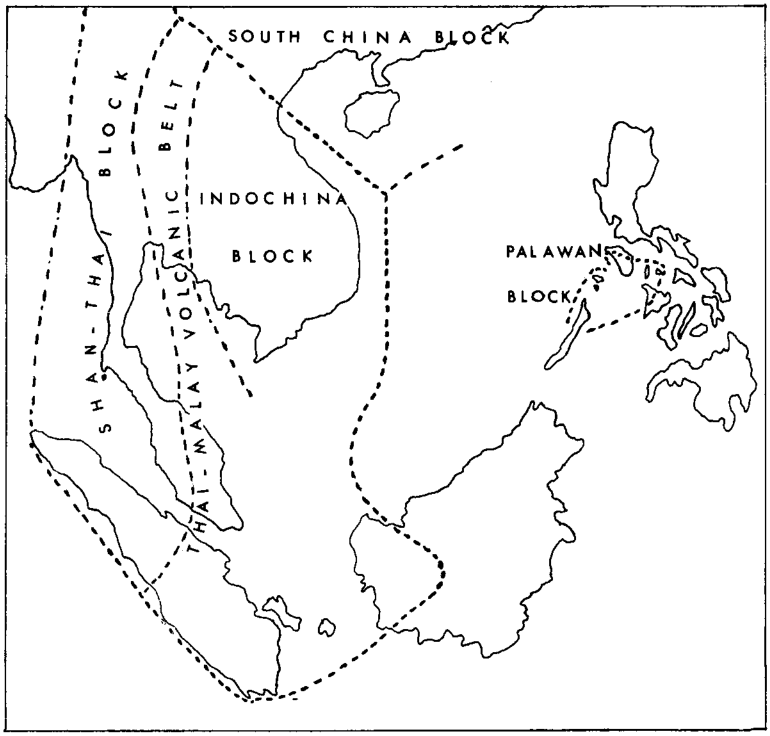


Figure 29. Tectonic blocks of Southeast Asia.

Malaya would be still separated and far from West Malaya by that time.

The Palawan Block which corresponds to a part of the Western Philippines is considered a block rifted off from South China by the opening of the South China Sea.

To unravel the palaeogeographic evolution of Southeast Asia during the Permian is a very complex undertaking. Much of the information gathered to date is not detailed enough and the conclusions arrived at are still open for discussion and speculation. This paper will deal with the three blocks; Shan-Thai Block, Indochina Block and South China Block, and their boundary zones, namely the Thai-Malay Volcanic Belt and the Rifting Zone of the Da River. A few words will mention the Permian of the Palawan Block.

EUSTATIC SEA LEVELS

During the Permian, the sea level stood high during the Asselian and the Sakmarian, it fell abruptly during the Yahtashian, it stood low from the Middle Murgabian to the Midian, and it fell drastically at the end of the Permian. This oscillation of the sea level, which is accepted as a global phenomenon, can help to partially understand the depositional sequences of Southeast Asia.

In the Ngao area of northern Thailand, the Huai Thak Formation overlies the Pha Huat Limestone with a sharp lithological change at the contact. It is composed of terrigenous clastic detritus. Sedimentation, tending to be confined to individual basins, implies that some uplift took place during the Upper Permian. A fall in sea level seems a likely explanation (Bunopas, 1982).

Wielchowsky and Young (1983) have also used sea level oscillation in northeastern Thailand to explain a significant clastic influx, a diminution of carbonate accumulation and the appearance of dolomites during the Artinskian–Kubergandian. In the same way, they have explained the carbonate development during the Murgabian and the Midian on their "Khao Khwang platform" by the high sea level. However, they observed that, at the same time, terrigenous clastic deposition overwhelmed the carbonates on the "Pha Nok Khao platform". They suggest tectonic movements in the Pha Nok Khao area.

It is also true that eustatic sea levels cannot explain all the Permian sediments. The Permian beds of Western Kampuchea belong to the Upper Murgabian and the Midian. Hence, they correspond to a highstand of the sea level. Such a nice correlation is no more valid for the Lower Permian. The Asselian and the Sakmarian are absent in Western Kampuchea. Accordingly, sediment deposition was controlled not only by eustatic sea level, but also by tectonics.

A FEW GEOLOGICAL FEATURES OF SOUTHEAST ASIA

The Alpidic structures occur to the west of the area under discussion. They cover West Burma and continue south of Sumatra into the present well-known zone of subduction. Southeast Asia was a continental block welded to South China by the time of the India-Asia collision starting probably at the Eocene.

If Southeast Asia was not directly touched by the Himalayan Orogeny, the area was subjected to stress from the repercussion of the Himalayan movements. Strike-slip faults trending northwest appear to have been peculiarly active. The main faults are; Red River Fault, Mae Ping Fault, Three Pagodas Fault and Semangko Fault (*Fig. 30*). They must be taken into account for palaeogeographic reconstruction.

Sinistral displacement is suggested for the Mae Ping and the Three Pagodas Faults whereas a dextral displacement is assigned to the Semangko Fault (An 1892 earthquake in North Sumatra along the Semangko Fault was accompanied by 2 m of right lateral strike slip). Along the Red River Fault, an important extrusion of Indochina has been suggested (Tapponier *et al.*, 1982). Although the sense of strike-slip displacement is presently dextral along the Red River Fault, palaeomagnetic results suggest that it may have been mostly sinistral in the past. An important block between the Mae Ping Fault and the Three Pagodas Fault has been shifted towards the East. The Semangko Fault seems to be the southern boundary of the Permian exposures. The Permian outcrops mentioned by previous authors southwest of the Semangko Fault have been recently visited near Padang and Tapaktuan; they have yielded Jurassic corals.

North-south faults have controlled the formation of the Gulf of Thailand and many small Tertiary basins in Thailand. These faults, however, appear not to be important for our subject as well as the northeast-trending faults.

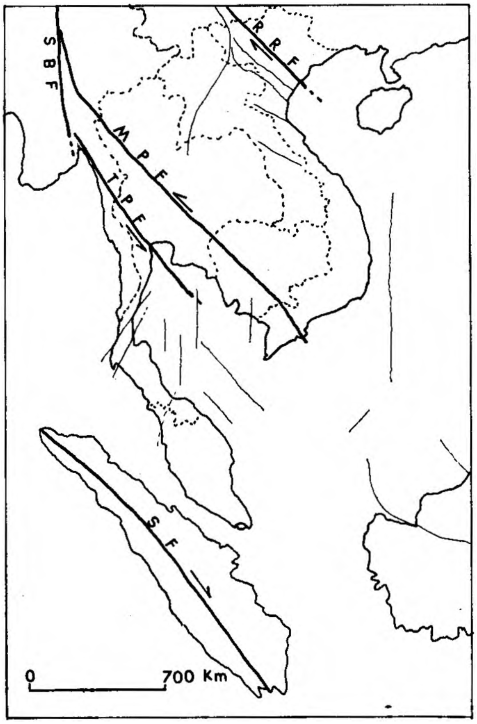


Figure 30. Some faults of Southeast Asia. SBF=Shan Boundary Fault; RRF=Red River Fault; MPF=Mae Ping Fault; TPF=Three Pagodas Fault; SF=Semangko Fault

During the Cenozoic, openings of the South China Sea and the Adaman Sea are related to the Himalayan movements and appear to be a simple kinematic consequence of the extrusion of Indochina during the collision between India and Asia (Tapponnier *et al.*, 1982). In the Gulf of Thailand, rifting and brief ocean-floor spreading are supposed to have taken place during the Late Cretaceous and/or the Cenozoic (Bunopas, 1982).

SHAN-THAI BLOCK

The Shan-Thai Block, a name coined by Bunopas and Vella (1978), is a continental block that was mostly submerged from the Cambrian to the Middle Mesozoic. It has been designated by several names; Sino-Burmanian Plate, Sino-Burman Ranges, Kachin-Shan-Tenasserim Highlands, West Malaya Block, Shan-Thai Microcontinent, Mergui Platelet and others. It is composed of East Burma, West Thailand, West Peninsular Malaysia and, perhaps, Northwest Sumatra. It displays some unique characteristics concerning volcanism, stratigraphy and sedimentology such as volcanic deposits are almost absent in the Upper Palaeozoic and the Mesozoic sedimentary piles; tectonic movements did not strongly affect the greater part of the Shan-Thai Block; marine sediments are Cambrian to Triassic and locally Upper Jurassic in age; Carboniferous-Lower Permian pebbly shales are present in Burma (Mergui Series), Thailand (Kaeng Krachan and Phuket Groups), Malaysia (Singa Formation) and Sumatra (Bokorok Formation). The origin of these pebbly shales is controversial.

The evidence of Permian flora in this block is only a few plant fragments which are characterized by *Walchia* (See the chapter on Palaeontology). Further research is necessary before drawing cogent conclusions. A sequence of shale and sandstone of the Martaban Beds widely exposed near Martaban North of Moulmein, Burma contains plant remains that should be interesting to study.

Coral reefs are very scarce. Massive Waagenophyllidae are known in two places, namely at Khao Tham Sua southwest of Phetburi, Thailand and near Kyauktaung northwest of Tharabwin in the Mergui area, Burma. Some have been collected at a locality 80 km north-northeast of Chiang Mai in Thailand (Minato, 1944) and near Pindaya northwest of Taunggyin in Burma (Smith, 1941). The Genus *Wentzelella,* which is present in Central Tibet (= between the Indus suture and the Banggong-Nujiang suture) as well as in Sinkiang and is absent in South China, has been found in Peninsular Thailand (Fontaine *et al.*, 1979).

If coral reefs were scarce, mud mounds were probably largely developed. They are indicated by the abundance of bryozoa, the scarcity of big fusulinids, the presence of large lenses of micritic limestone.

The Permian sediments of the Shan-Thai Block are rich in dolomitic limestones and dolomites that are widespread in Burma and West Thailand. Locally, like south of Umphang in Thailand, dolomite is friable and very porous; hence, it is covered by a dry soil with a meagre vegetation.

Permian limestones are a little less widespread than it was previously thought. Some Mesozoic fossils have been recently described in Burma and Thailand. Other Mesozoic fossils (corals) have been collected in 1984 from limestones of Umphang area and are currently studied.

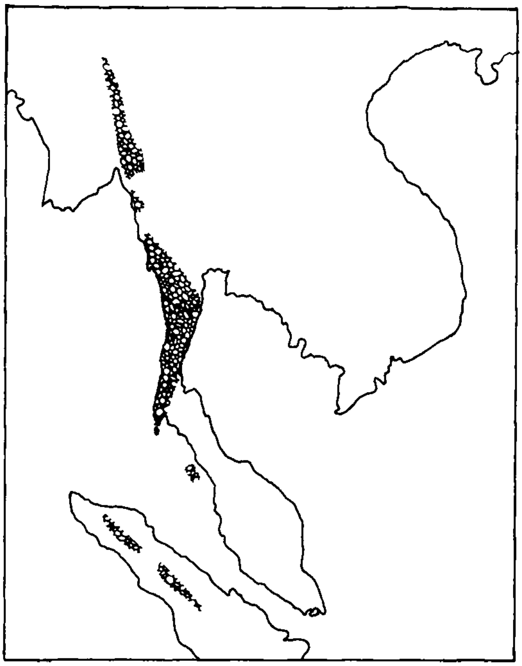


Figure 31. Pebbly mudstones.

In the Shan-Thai Block, the presence of the Upper Permian (with the exception of the Midian) and of the Scythian (Early Triassic) has been poorly evidenced.

Poorly sorted clastic sediments, Carboniferous to Early Permian in age, are exposed from Burma through West Thailand and Peninsular Malaysia to Sumatra. Hence, they have an extent of at least 2,000 km (*Fig. 30*). Usually called "pebbly mudstones", they contain scattered pebbles, angular to rounded, and bigger clasts. Large clasts, from 10 cm to 1 m in diameter, are very rare and have been found only in a few places; Phuket Island and Ko Pa Yam in Ranong Province (Peninsular Thailand), Langkawi Island area (Northwest Peninsular Malaysia) and East Aceh (Sumatra). The common size of the clasts is from 1 mm to 10 cm in diameter. Size analysis of a sample of pebbly mudstone from Peninsular Thailand showed that about 9% of the volume was clasts larger than 2 mm while about 21% was sand and 70% silt and clay (Tantiwanit *et al.*, 1983). Clast lithologies indicate a continental source; quartzite, arkose, limestone, sandstone, siltstone, quartz, granite, gneiss and one trondhjemite boulder from Northwest Peninsular Malaysia (Stauffer and Snelling, 1977).

Diamonds have been found in tin placers near the pebbly mudstones in Peninsular Thailand (Aranyakanond, 1955) and in North Sumatra (Cameron *et al.*, 1980). The pebbly mudstones are interbedded with grey argillites, fine sandstones and graded alternating sandstones and mudstones. They have been considered the product of mass movements on a submarine slope west of a shelf and deep-water suspension deposits (Mitchell *et al.*, 1970; Stauffer and Gobbet, 1972; Ahmad Bin Jantan, 1973; Garson *et al.*, 1975; Sawata *et al.*, 1975; Helmcke, 1982; Bunopas, 1982; Bender *et al.*, 1983). They have been also seen as glacial deposits (Burton, 1969; Stauffer and Snelling, 1977; Cameron *et al.*, 1980; Mitchell, 1981; Waterhouse, 1982; Bunopas, 1982, accepting mass transport and, for some exotic clasts, ice-rafting; Stauffer and Lee, 1984) because they contain exotic clasts such as the trondhjemite of the Langkawi Islands or the diamonds found in Thailand and Sumatra.

Mitchell (1981) suggests that separation of the Thai-Shan Block from Gondwanaland took place either immediately before or after the deposition of the Upper Permian to Lower Triassic carbonates. If this hypothesis is more or less substantiated by the mineralogical study of Prasada Rao (1984), it does not fit with the presence of massive corals and of fusulinids as well as with the great thickness of the carbonates in the Shan-Thai Block. Bunopas (1982) proposed a Carboniferous age for the separation. Because pebbles appear to have been dropped into the mud from above rather than rolled down a slope and because it is unlikely that they were ice rafted, they may have been carried in floating masses of vegetation (Gobbett and Hutchison, 1973).

If the Cambro-Ordovician faunas of the Shan-Thai Block have a very close relationship to those of Australia and if an amazing similar stratigraphic gap existed during the late half of the Ordovician in Australia and in the Shan-Thai Block (Burrett and Stait, 1984), the Permian faunas of East Burma, West Thailand and West Peninsular Malaysia are not actually similar to those of Australia. On the contrary, they display strong affinities to those of the Indochina and South China Blocks. The Permian flora (*Walchia* flora) belongs to the northern hemisphere. It

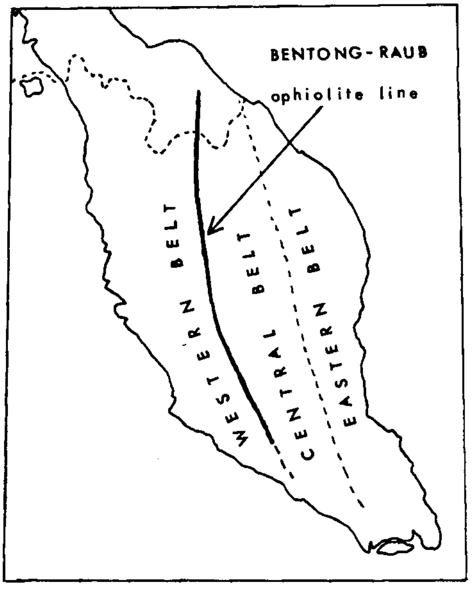


Figure 32. Three fold division of Peninsular Malaysia, as it is accepted by many authors.

is difficult to accept the separation of the Shan-Thai Block from Gondwanaland as late as the Permian or the Early Triassic, as proposed by Mitchell (1981). On the other hand, the Shan-Thai Block could not have been very far from the Indochina and South China Blocks during the Permian.

The southern part of Sumatra does not belong to the Shan-Thai Block. It has a Cathaysian flora. Massive Rugose corals are present as early as the Lower Permian. Volcanic rocks are abundant. The Permian of the northern part of Sumatra is poorly known. Some Permian exposures of the geological map (Scale of 1 : 250,000) are now considered Lower Carboniferous in age (Metcalfe, 1983; Fontaine and Vachard, 1984) or Triassic in age (Metcalfe, 1984). Near Laubuluh 60 km southwest of Medan and 13 km north of Tigabinanga, Permian limestone is poor in fossils and was deposited on a shelf in a relatively great water depth (current study). Until fuller information is available, the northern part of Sumatra is considered part of the Shan-Thai Block and the Bohorok and Kluet Formation are thought to be the equivalent of the Singa Formation in Malaysia and the Phuket beds in Southern Thailand.

The Shan-Thai Block is considered a tectonic unit similar to the Central Tibet (=Southern Tibet of some authors or the part of Tibet located between the Indus and the Banggong-Nujiang suture) and the two units formed a "Southern Tibet-Western SE Asia Block" (Mitchell, 1981).

In the Shan-Thai Block, the Permian beds dip at rather shallow angles in many areas.

In conclusion, the Shan-Thai Block is well characterized by palaeontological, sedimentological, stratigraphic and tectonic features. It was a stable continental shelf probably fringed with a slope to the west. This block was not very distant from the Indochina and the South China Blocks; all these blocks were at relatively similar

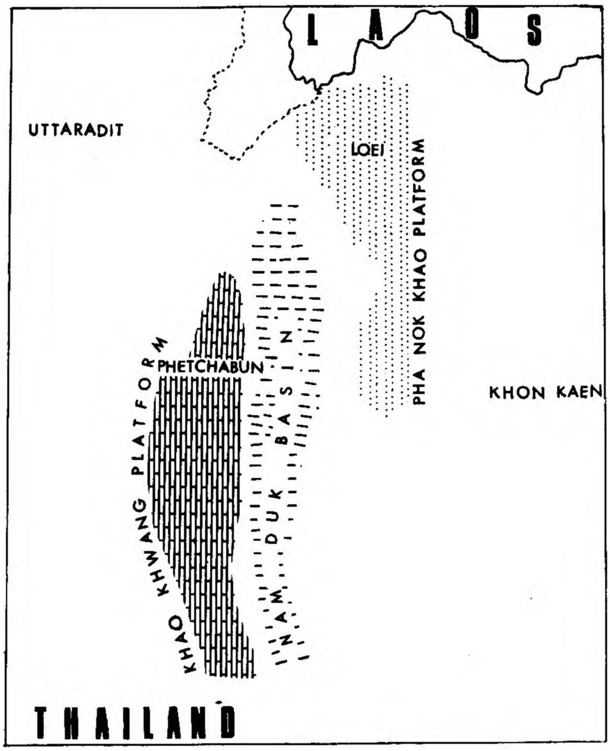


Figure 33. Nam Duk basin.

latitudes during the Permian. Palaeomagnetic data seem to substantiate this point of view (McElhinny *et al.*, 1981). Moreover, the Shan-Thai Block displays some affinities with Central Tibet.

THAI-MALAY VOLCANIC BELT

The Thai-Malay Volcanic Belt is a very interesting zone. Unfortunately, it is not well-known. It extends from North Thailand to Sumatra and is divided into three parts by the Mae Ping and Three Pagodas Faults, and maybe into four parts by a third fault in the Malacca Strait. It is characterized by a strong volcanism especially from the Late Permian to the Triassic.

In the Thai-Malay Volcanic Belt, Stauffer (1973) placed an island arc and several authors have suggested a volcanic arc setting for some mineralizations from Sumatra to Thailand, but not necessarily during the Permian. A collision between the Shan-Thai Block and the Indochina Block has been mentioned by many authors and several tectonic models have been proposed.

In North Thailand, "remnants of a volcanic arc", extending from Chiang Rai to Chiang Mai, have been studied by Macdonald and Barr (1978), who considered it to be Carboniferous in age. They are, however, more likely to be Late Permian-Early Triassic in age (Bunopas, 1982). They consist of basalts, porphyritic basalts, basaltic porphyries and gabbros; agglomerates are by far the most abundant rocks. The results of chemical analyses indicate the rocks to be ranging from ultramafic to intermediate, but they are mostly mafic. The rock suite is tholeiitic; it appears to belong to an island-arc, built on oceanic crust and subsequently welded to the Shan-Thai Block (Macdonald and Barr, 1978). These rocks are dykes and perhaps sills which intruded into Carboniferous sediments and were emplaced as a result of back-arc spreading in Late Permian–Triassic time. They lie west of the true volcanic arc facies (Bunopas, 1982). The "true volcanic arc" has not been extensively studied. It forms a north-south trending zone north of the Chao Phraya Plain. It fringed the Shan-Thai Block. Rocks are basaltic or andesitic–basaltic in composition. In front of this arc, a fore-arc basin should be represented by chert, phyllite and greywacke of unknown but great thickness, ranging from Silurian to Middle-Late Triassic in age. The volcanic arc with its back-arc and fore-arc basins belongs to the "Sukhothai Fold Belt" (Bunopas, 1982).

In Northeast Thailand, another band of volcanic rocks has the same north-south trend; northwards, it continues into Laos (*Fig. 28B*). The rocks include tuffs, agglomerates and flows; they are andesitic and rhyolitic in composition. They have not been the object of any petrographical or chemical study. They belong to another symmetric fold belt, the "Loei Fold Belt" (Bunopas, 1982). The volcanic rocks are associated with sediments deposited on a shelf on which some deeper grabens were present, for instance the basin east of Lom Sak (=Nam Duk Basin, *Fig. 33*) where the lower part of the Permian consists of allodapic limestone, flysch and chert. These sediments are overlain by shallow marine beds, Murgabian in age. "The first unit of rocks comprises mainly cherts, shales and allodapic limestones. The cherts are usually banded... The shales vary from grey to greenish. Limestones are frequent..., (produced) by turbidites in near reef sedimentary basins... In the second unit of rocks greywackes alternate with shales. In the greywackes all features of the Bouma-cycle can be found, characterizing them as turbidites... The third unit of rocks comprises a very thick sequence of clastic rocks, mainly sandstones and shales...rich in fossils...laid down rapidly in a subsiding marine basin which became more and more shallow" (Helmcke and Lindenberg, 1983). This basin or "Nam Duk Basin" intervened between the "Khao Khwang Platform" to the west and the "Pha Nok Khao Platform" to the east (Wielchowsky and Young, 1983). Because source of terrigenous clastic sediments was to the east, the Nam Duk Basin acted as a vacuity barrier and terrigenous clastics are not developed on the Khao Khwang Platform (*Fig. 33*). Wielchowsky and Young (1983) suggest a possible thrusting during the Murgabian in the Nam Duk Basin area.

Between the Sukhothai Fold Belt and the Loei Fold Belt that followed independant histories until the Triassic, are the Pha Som Ultramafics, considered to be ophiolite. To the south, these ultramafics disappear below Quaternary deposits of the Chao Phraya Plain; their continuation is indicated by a gravity anomaly (Bunopas, 1982).

The two volcanic arcs of North and Northeast Thailand may be present in Southeast Thailand and West Kampuchea. The western arc should be represented by andesite, tuff and agglomerate, poorly exposed between Rayong and Chanthaburi, not accurately dated. The eastern arc would correspond to a few volcanics known in West Kampuchea and in Southeast Thailand near the Kampuchean border. Between those volcanic arcs, are the Sra Kaeo ultramafics.

In Thailand, Bunopas (1982) proposed a double subduction with two separate volcanic arcs (*Fig. 34*); one belonging to the "Sukhothai Fold Belt" and the other to the "Loei Fold Belt", the two belts being separated by a line with discontinuous outcrops of ultramafics, namely the "Uttaradit" or "Pha Som" Suture in North

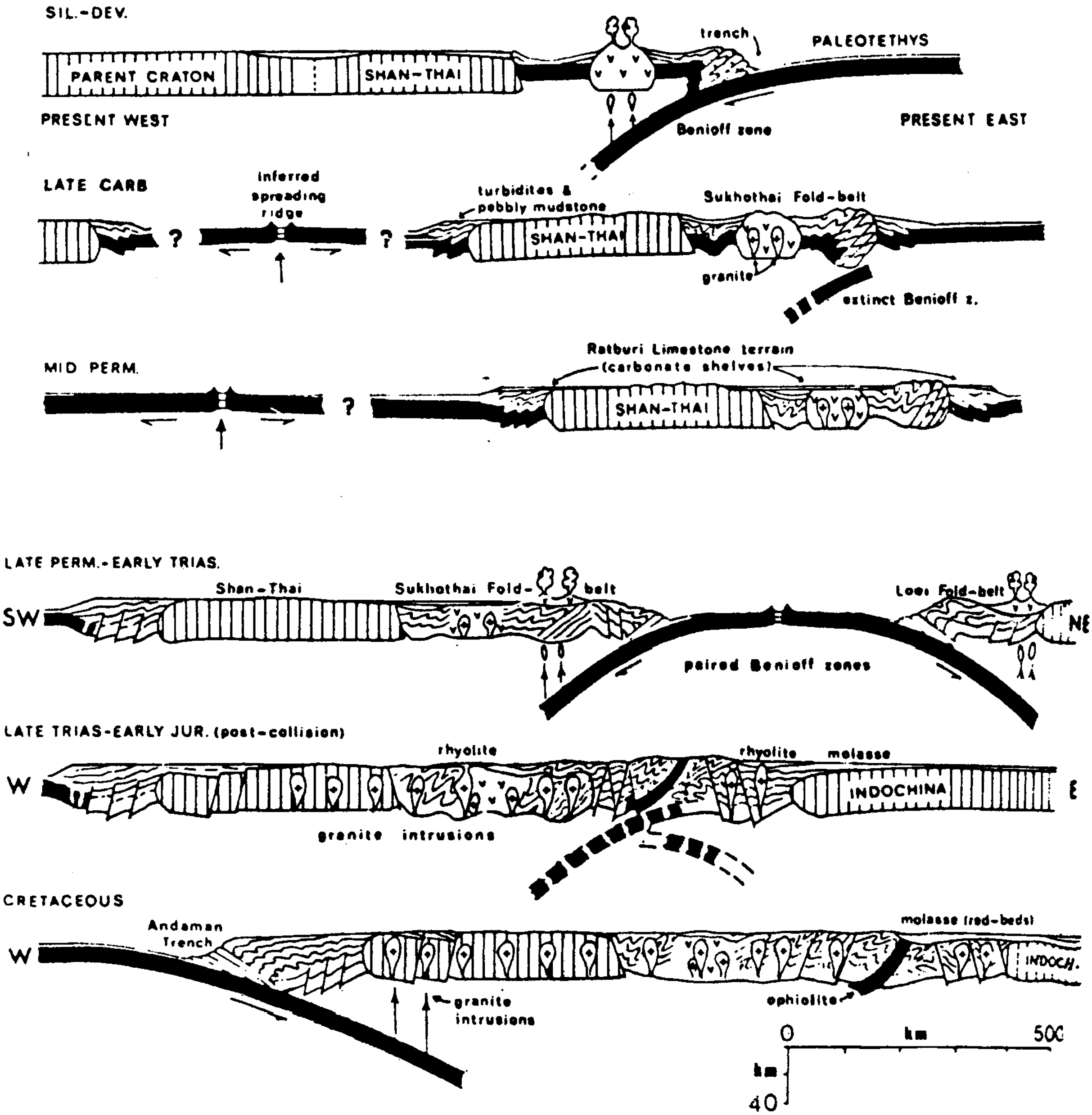


Figure 34. Plate tectonics history of Shan-Thai and western Indochina (Bunopas, 1982).

Thailand continued by the Sra Kaeo ultramafics in Southeast Thailand. For Bunopas (1982), "a spreading ridge appeared in the ocean separating Shan-Thai and Indochina late in the Permian, and subduction commenced simultaneously along the Shan-Thai and Indochina margins". The two separate volcanic arcs were generated on the one side by subduction dipping west beneath Shan-Thai, and on the other side by subduction dipping eastward beneath Indochina. The east-dipping subduction beneath Indochina probably ceased in the Middle or Late Triassic whereas the effects of the westward dipping subduction beneath Shan-Thai persisted through Late Triassic into Early Jurassic by granite injection and rhyolitic volcanism.

In Peninsular Malaysia, small exposures of ultramafic rocks have been used to define the "Bentong-Raub ophiolite line" and a paleo-subduction zone. At first, a westward subduction was recognized; later on, an eastward subduction was preferred. According to Khoo and Tan (1983), field relationship of the ultramafics favours an intrusive rather than a thrust emplacement. Moreover, these ultramafic bodies are only partly distributed along a line. These rocks must have been derived from deep-seated sources possibly the upper part of the mantle. No major occurrences of chromium have been reported. A rift related to fracturing of the crust could provide avenues for the upward migration of the serpentinized ultramafics (Khoo and Tan, 1983). Accordingly, the "Central Belt" is shown as a downfaulted and spreading graben. Hence, two tectonic schemes are proposed for Peninsular Malaysia.

If we take into account the displacement due to the strike-slip faults (Mae Ping and Three Pagodas), there is an apparent continuity of the ophiolites from North Thailand to Malaysia, presuming a collision that took place during the Late Triassic. From some paleomagnetic data, the Shan-Thai Block rotated rapidly clockwise between the Permian and the Triassic, and "this rotation is best accounted for by supposing that the Malay Peninsular end of Shan-Thai closed first with Indochina, and the rest then swung like a log floating in a river when one end suddenly becomes grounded. The west Malay Peninsula (Southern Shan-Thai) may have closed with the east Malay Peninsula (Southern Indochina) relatively early (Permian?) and the rest of Shan-Thai may have sutured progressively to Indochina from south to north, like a zipper being drawn up "(Bunopas, 1982, p. 598–599).

In Peninsular Malaysia, Permian volcanism is strong in the "Central Belt" and gradually decreases towards the east in the "Eastern Belt" (*Fig. 32*; the three fold division of Peninsular Malaysia was proposed by Scrivenor in 1928 when he observed that the Western and the Eastern Belts were mineralized in tin whereas the Central Belt was characterized by gold. The basis of this division is still recognized valid by Rajah and Yin in 1980).

From North Thailand to Sumatra, volcanism is andesitic to rhyolitic in nature. Sediments interfingering with the volcanic rocks are commonly shallow marine to continental.

In marine facies, fossils are abundant and massive corals are present locally, colithic limestones and grainstones sporadically occur and indicate high energy environments. In the eastern part of the Thai-Malay Volcanic Belt, paralic sediments contain rich floras from North Laos to Sumatra; these floras, Early to Late Permian in age and Cathaysian in affinity, are represented by the floras of North Laos, Phet-

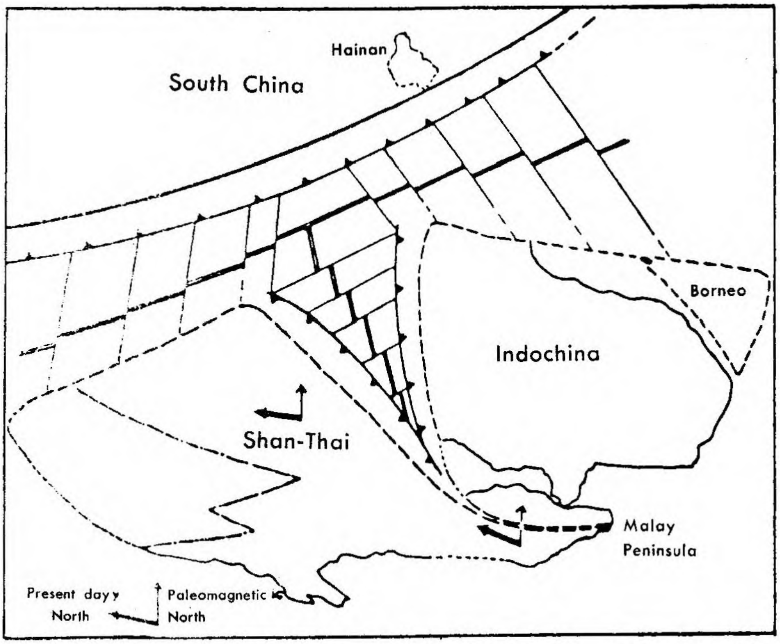


Figure 35. Palinspatic map of Southeast Asia immediately prior to the Indosinian Orogeny (Bunopas, 1982).

chabun area in Thailand, Sisophon in Kampuchea, East Peninsular Malaysia, and Jambi in Sumatra.

In the Bangka and Belintung Islands, Permian sediments are fine-grained, thinly bedded and associated with radiolarian cherts; they are considered deep sea deposits. They may belong to a basin similar to that of the Lom Sak area in Thailand.

INDOCHINA BLOCK

During the collision with the Shan-Thai Block, the western part of the Indochina Block was warped down and transformed into depressions that were subsequently filled with continental clastic sediments, Upper Triassic to Cretaceous in age, widely exposed in Northeast Thailand (Khorat Plateau) and surroundings areas of Laos, in Kampuchea (Cardamomes and Elephant Mountains), and in Malaysia (Tembeling and Gagau Formations). Moreover, during the Cenozoic, block faulting gave birth to the Gulf of Thailand. In southern Laos, southern Viet Nam and eastern Kampuchea, an important basin appeared at the beginning of the Triassic and was filled by thick sediments during the Triassic and the Lower Jurassic. Accordingly, Permian strata are concealed by younger sediments in very large areas of the Indochina Block.

During the Permian, a large part of the Indochina Block was an emergent land, or more probably, a few emergent lands separated by shallow marine channels and shallow seas; those lands were permanently emergent (Kontum Massif) or momentarily submerged by sea incursions like in the Cam Lo area north of Hue where the Upper Permian unconformably lies upon the Ordovician. Erosion prevailed in the Kontum

Massif and the surrounding areas; its products were transported and deposited in the seas surrounding that region. In the vicinity of Cam Lo, the Permian beds are composed only of terrigenous sediments indicating proximity of a land. In the same way, clastic sediments are abundant in Eastern Thailand in the so-called Pha Nok Khao Platform (Wielchowsky and Young, 1983). In western Kampuchea, the presence of bauxite and fossil woods in a marine Murgabian-Midian sequence is also indicative of a nearby land. Permian seas were never deep from West Kampuchea (Battambang–Sisophon area) to Southeast Viet Nam (Hatien area), as it is indicated by algae and coral fossils. In the Phu Hoat area (North Central Viet Nam), bauxite is present within the Permian.

The Permian is commonly less than 1000 m thick. In many localities, it is not represented in its entirety. Whereas it is almost complete in the Sra Kaeo area (eastern Thailand), it ranges only from the Upper Murgabian to the Midian in the contiguous areas of Western Kampuchea. In South Kampuchea and in Southeast Viet Nam (Hatien area and upper reaches of the Saigon River), it consists of the Murgabian and the upper part of the Upper Permian (*Palaeofusulina* limestone). The relationship between the Murgabian limestone and the *Palaeofusulina* limestone is unknown, but is probably an unconformity, related to the same phenomenon that produced the disappearance of limestone after the Midian in a great part of Kampuchea.

In Kampuchea and South Viet Nam, the Permian unconformably lies upon older rocks. On the contrary, north of the Kontum Massif in the Truong Son–Song Ca–Phu Hoat areas, it is in continuity with the Carboniferous. The Muong Long Limestone from the Qui Dat area (Truong Son) has a stratigraphic range similar to that of the Bac Son Limestone of North Viet Nam (South China Block). It is also interesting to note that bauxite is so far known only in the Indochina and the South China Blocks. The Upper Permian, absent in the Song Ca area, unconformably lies upon the remainder of the Permian at the Phu Hoat and in the Truong Son area, as it does in North Viet Nam.

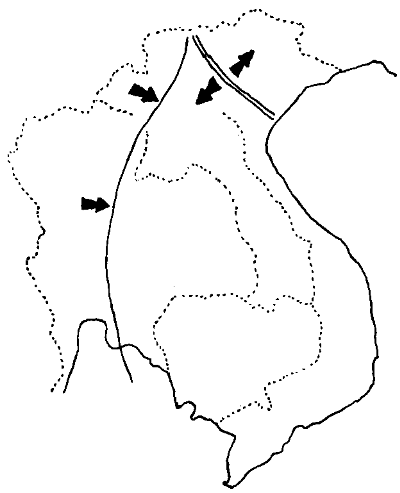


Figure 36. From middle Permian.

SONG DA RIFTING ZONE

In the Late Devonian-Early Carboniferous, the Indochina Block and the South China Block converged and caused folding in the basins between them, resulting in a foldbelt trending NW–SE across North Central Viet Nam. Along this foldbelt, rifting activity mildly appeared in the Late Carboniferous and turned strong from the Late Permian to the Early Triassic. This tension originated probably from the compression due to the subduction acting to the west. Huge volumes of spilite and porphyrite–basalt were formed (*Fig. 27*).

In the Song Da Rifting Zone, the base of the Permian is composed of limestone with intercalations of shale and spilite; the younger horizon of the limestone contains *Neoschwagerina cratulifera* indicating a Middle Murgabian age. Upon these strata, unconformably lies an Upper Permian, 400 to 1200 m thick, composed of carbonaceous shale, siliceous shale, conglomerate, limestone, bauxite, spilite and porphyric basalt. This Upper Permian has provided the *Palaeofusulina–Colaniella* assemblage as well as plant fossils with *Gigantopteris*. Sediment deposition continued from the Late Permian into the Early Triassic without break. From the Late Permian to the Late Triassic, it reached a thickness of 3500–6000 m.

SOUTH CHINA BLOCK

The South China Block is a platform that has undergone repeated subsidence and uplift but relatively little deformation throughout Phanerozoic time. It had been cratonized before the Palaeozoic. Only the southern part of the South China Block, the North Viet Nam, concerns this paper.

Permian strata are widespread in North Viet Nam and commonly consist of limestone with a spectacular karst topography. They are in continuity with the Carboniferous sequences.

The Upper Permian represents a renewed marine transgression and unconformably lies upon the remainder of the Permian. Bauxite is well developed near the Viet Nam-China border and extends over an arc 250 km long and 40–50 km wide.

PALAWAN BLOCK

In the Palawan Block, Permian strata are exposed in the northwestern part (Bacuit area) of the Palawan Island (Hashimoto and Sato, 1973), in the Tara Islands (see appendix 6) and in the Carabao Island (Andal, 1966; Fontaine *et al.*, 1983). Moreover, pebbles of Permian limestone have been found in Southern Mindoro.

This Permian is composed mainly of limestones, locally rich in foraminifera and algae, Middle Permian in age. Moreover, shale and chert of Northwest Palawan Island have provided conodonts, also Middle Permian in age.

CHAPTER VI

MINERAL RESOURCES

BAUXITE

Permian bauxite is known in a few areas of Kampuchea and Viet Nam. It indicates that those areas were emergent lands or near emergent lands during a part of the Permian. Emergence and erosion have been observed at the top of some Permian strata in North Viet Nam at 3 km from Lang Son along the road to Ha Noi. Bauxite is the product of *in situ* tropical weathering. Only those in North Viet Nam have some commercial value in Southeast Asia.

Kampuchea

In the Battambang area (western Kampuchea), bauxite beds are interstratified with Permian limestones. They look like ordinary red beds and not all the red horizons are necessarily bauxitic. Their composition is not regular and the results of the chemical analysis of samples vary widely. These deposits do not appear everywhere as good-quality aluminium ore; the silica content or the iron content, or both, are locally too high. The bauxitic material is made of diaspore and boehmite, with probably predominating diaspore; gibbsite is very low in quantity. Existence of large concealed deposits is possible, but a costly underground exploration is presently difficult to justify because of the poor quality of the ore. Some field investigations carried out by the Mekong Committee have given a figure of 3 million tons of known reserves available for open-cast working, this figure is very low.

Viet Nam

Bauxitic material is present in the Permian strata of several localities of Central and North Viet Nam. The best known deposits are located in the Lang Son area, 150 km northeast of Ha Noi; they were discovered in 1926 and have been intermittently prospected since that time, but more carefully since 1948. They belong to the Dong Dang Formation, Late Permian in age. They appear as lateritic bodies lying on Permian limestone, practically unreworked since their deposition. The present thickness of these bodies varies from a few meters to twenty meters. Chemical analyses indicate the following composition:

SiO_2:	3 to 12%
TiO_2:	1.5 to 4%
Fe_2O_3:	17 to 30%

Al_2O_3: 42 to 57%

Silica is less abundant when the rock is compact and the massive bauxite is commonly 1.5–2 m thick and locally up to more than 4 m thick. A part of the silica was probably brought by impregnation due to hydrothermal solutions after the deposition of the bauxite. The silica and iron contents are more or less oscillating whereas the titanium content is more stable which seems to increase with depth and varies a little laterally. The aluminium content is rather important and the rocks may be called aluminium ores, even though these ores are not uniform in quality. The main minerals are diaspore and boehmite, gibbsite is very minor.

PHOSPHATE

Secondary deposits of phosphate are common in fissures and cavities of the Permian limestones of Southeast Asia. They have been exploited in Kampuchea and in Viet Nam. More extensively in Kampuchea in two areas, namely north of Kampot and south of Battambang. These deposits, Cenozoic in age, are not actually relevant to this paper.

Phosphate deposits are so far unknown in the Permian strata of Southeast Asia. The phosphorus content of the Permian limestones is usually very low. In Malaysia, it exists only as trace in the Jengka Triangle limestones (Chong and Yong, 1968); in limestones of Southeast Kelantan, it is usually less than 0.02% by weight, with erratic values of 0.07 to 0.12% (Aw, 1972); in Northwest Peninsular Malaysia, the P_2O_5 content of the Chuping limestone is less than 0.01% (Jones, 1973). The age of the analyzed samples, considered Permian, is probably Triassic for a part of them. Anyway, no high P_2O_5 content has been observed in other Permian limestones of Southeast Asia. Hence, present data are not encouraging.

The Permian paleoclimate and paleogeography, however, appear to be favourable for some upwellings in the Permian seas of Southeast Asia (Sheldon, 1983), and thus, to marine phosphorite deposition. This working hypothesis is a new approach in the search for phosphate, but it is presently difficult to identify target areas for detailed studies. Phosphate nodules occur in Permian limestones in Southern China (Sheldon, 1983).

LIMESTONE

Permian limestone is very common in Southeast Asia. It is used by cement plants in Viet Nam, Thailand and Malaysia. Because it is usually compact, it is easy to polish and it provides nice commercial "marbles".

BARITE

Some Permian beds contain barite in Thailand and in northern Peninsular Malaysia. The ore bodies are commonly of fissure filling and replacement types.

COAL

Coal deposits are very important in the Permian of China. In Southeast Asia, the Permian strata contain only thin seams of coal without commercial value with the exception of a few areas, especially west and northwest of Vientiane in Laos where coal seams are more than 1 m thick and locally reach 5 m. Coal is bituminous to anthracitic, it is commonly low in volatile matters. Northwest of Vientiane, in the Nam Lik Valley, it is rather high in volatile matters with a content reaching 20%. Mineral matter (ash) is a variable constituent, with a content of 10 to 24% according to a few analyses of surface samples. Age of the coal is Late Permian in Laos at Sop Pong in the Phong Saly Province and in the Luang Prabang area. At Khe Bo in the Song Ca Valley (Viet Nam), it is Upper Permian or possibly Triassic. In Malaysia, the Linggiu Formation (Late Permian) contains carbonaceous shale with plant remains, but apparently no coal seam. West of Vientiane, coal is Upper Carboniferous or Lower Permian. In the Lower Permian of the Jambi Province

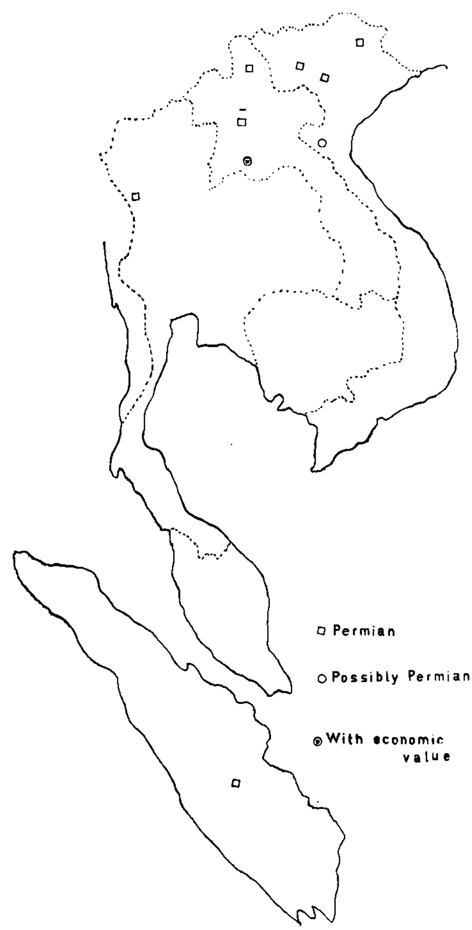


Figure 37. Coal beds.

(Sumatra), coal seams are very thin.

HYDROCARBONS

The causative reasons for hydrocarbon potential in the Permian of Southeast Asia are multiple:

a — Wide geographic distribution of the Permian sediments.

b — Presence of source rocks rich in organic remains.

c — Reservoirs of different kinds; porous dolomitic limestone, karstic limestone, volcanics, sandstone.

d — Adequate closures by unconformities and argillaceous beds.

e — Acessibility to drill in many areas.

To date, search for hydrocarbons in Southeast Asia has been focussed on the Cenozoic strata. The pre-Tertiary has only been considered as an additional objective in the drilling of prospects of Tertiary sediments. Even though there is a production from pre-Tertiary rocks in Indonesia (Tanjung Field in South Kalimantan and Sungai Teras Field in South Sumatra), origin of the hydrocarbons is considered Tertiary in age. However, search for hydrocarbons is slowly moving to older rocks in Thailand and gas has been found in Northeast Thailand by ESSO. Five wells have been drilled. The Nam Phong field discovery well tested 27.6 MMcfgd and an appraisal well, Nam Phong 2, tested between 17 and 18 MMcfgd about two miles to the north. "Although ESSO has not declared the field commercial, reserves of 1.5 tcf have been quoted by other sources" (*World oil*, 1984). The main producing zone is the Permian strata. Gas is 95% methane (*CCOP Newsletter*, vol. 10, no. 1–2). After this discovery, pre-Tertiary prospects, especially the Permian ones, are expected to yield other reserves.

METALLIC ORES

A large variety of mineral deposits occur in Southeast Asia, but metallic ores are not accurately dated. Hence, it is difficult to give a detailed list of those belonging to the Permian.

In North Thailand over latitude 17°30′N, some hydrothermal deposits are assigned to the "Permo-Triassic" (Asnachinda and Chantaramee, 1984).

In Viet Nam, mineralization has been related to rifting activities in the Da River area. It took place from the Late Carboniferous to the Triassic. Spilite and porphyrite-basalts formed huge deposits; they contain high content of titanium and low content of aluminium indicating a mantle-derived material. Sulfide ores of copper and nickel, chromite, ilmenite, pyrite and iron ores are associated with mafic and ultramafic rocks. They represent important mineral resources for Viet Nam. Primary ores of chromite probably have no economic value, nevertheless, they are the source of large placers associated with Quaternary alluvium.

If the ultramafics of Thailand and Peninsular Malaysia are to be considered

Permian in age, we may mention the presence of nickel in the ultramafics of the Sra Kaeo area in Southeast Thailand and of the Raub area in Peninsular Malaysia, as well as the presence of chromite in the Raub area (Peninsular Malaysia), South Narathiwat (Southern Peninsular Thailand) and the Pha Som area (Northeast Thailand). In the Sra Kaeo area, a laterite overlying serpentinite is nickeliferous (Suvanasingha, 1971). In the Narathiwat Province, chromium is higher than 0.5% in soil surrounding the ultramafic body and than 2% in soil over a chromite pocket (Suvanasingha, 1963).

CHAPTER VII

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APPENDIX 1

STUDY OF PERMIAN SAMPLES COLLECTED FROM SUMATRA

By

Henri FONTAINE and Daniel VACHARD

The fossils identified in this paper, were collected by one of us (H. F.) in 1983–1984 with the guidance of M. M. Suharsono and Tatang, geologists at the Geological Research and Development Centre of Bandung. Moreover, a few additional samples come from old collections of the "Museum of Mineralogy and Geology" of the Technische Hogeschool of Delft (Nederland).

This study concerns five localities of the Jambi Province: Mudik Bayur at the Batang Tembesi; Lubuk Cada, Lubuk Kelelawar, Muara Selajau, Batu Tjangap in the Batang Tabir area. Outside the Jambi Province, will be mentioned Talang Glugur in the Gumai Mounts (South. Sumatra) and Laubuluh in the Medan Province (North Sumatra).

Mudik Bayur

Pulau Bayur is an hamlet located at the right bank of the Batang Tembesi. At the hamlet and 700 m upstream of that hamlet, Jurassic limestones have provided many corals. Between those two Jurassic exposures, a small outcrop of Permian limestone exists about 100 m upstream of Pulau Bayur; it was considered thrusted over the Jurassic by Tobler (1922).

This Permian limestone has not been mentioned in previous reports; we have waited for new thin sections to be sure of the age. Two samples (IN531 and IN532) have been studied; they contain algae and foraminifera.

Algae: *Girvanella permica*, *Anthracoporella spectabilis*, *Gyroporella nipponica*, *Permocalculus*.

Small foraminifera: *Diplosphaerina*, *Globivalvulina*, *Geinitzina*.

Fusulinids: *Darvasites* aff. *fornicatus*, *Nankinella*, *Schubertella*.

A Permian age is confirmed and this limestone must be assigned to the Asselian. Asselian limestones have been previously mentioned (Fontaine and Vachard, 1984) at the Mesumai River (Pulau Apat, Muara Liso, Batu Gajah and Batu Impi), at the Merangin River (Telok Gedang), and at the Sungai Saro that is a tributary of the Tembesi River downstream of Pulau Bayur. Those localities are more fossiliferous than Mudik Bayur; their most important species are: *Darvasites* cf. *fornicatus*, *Boultonia willsi*, *Rugosofusulina parvula*, *Schubertella* ex gr. *kingi*, *Staffella moelleri*, and *Pseudoschwagerina* sp.

At Mudik Bayur, environment was shallow marine, within the photic zone.

Lubuk Cada

This locality, called Batu Mencada by Tobler (1922), belongs to the middle reaches of the Batang Tabir. A limestone, about 55 m thick, bedded at its base (IN613 and IN614) and massive at its top (IN601 and IN602) forms a cliff at the left bank of the river in front of the Telantan village. It is a packstone to grainstone, rich in algae and foraminifera:

Algae: *Tubiphytes obscurus*, *Koivaella permiensis*, *Anthracoporella*, *Epimastopora*, *Gyroporella*, *Mizzia velebitana*, *Kochanskyella tulipa*, *Salopekiella* (?), *Likanella* (?), *Permocalculus*.

Pseudoalgae: *Chuvashovia*, *Claracrusta*.

Small foraminifera: *Diplosphaerina*, *Climacammina*, *Tetrataxis*, *Globivalvulina*, *Glomospira*, *Baisalina*, *Pachyphloia*.

Fusulinids: *Nankinella*, *Schubertella*, *Parafusulina*, *Verbeekina verbeeki*, *Afghanella* cf. *schencki*.

This limestone is Murgabian in age, from base to top.

Lubuk Kelelawar

This locality, called Pondok Damar by Tobler (1922), is about 1.5 km upstream of Luluk Cada. Limestone (IN603–605) crops out in the banks of the Tabir River. It is a wackestone rich in fossils:

Algae: *Connexia* or *Likanella*, *Permocalculus*, *Clavaporella*, *Tubiphytes* (?).

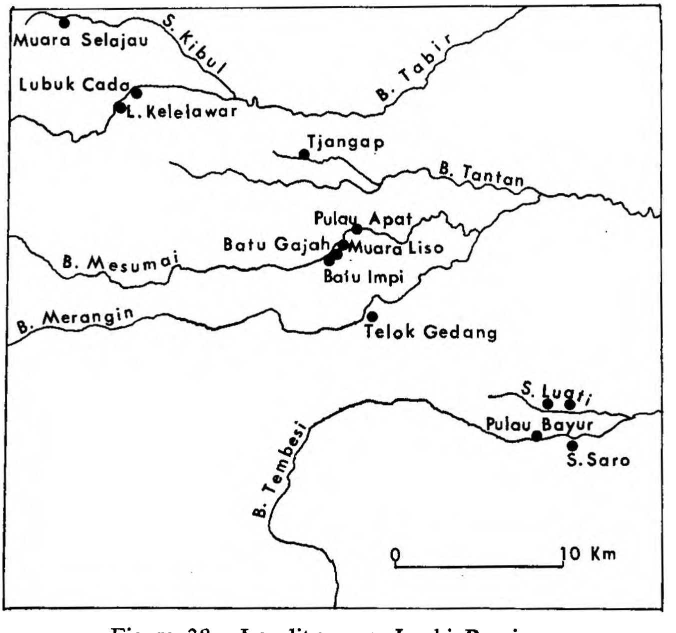

Figure 38. Locality map, Jambi Province.

Small foraminifera: *Climacammina*, *Tetrataxis*, *Globivalvulina*, *Hemigordius*, *Palaeonubecularia*, *Pseudovermiporella*, *Pachyphloia*, *Pseudolangella* (?), *Frondina permica*.

Fusulinids: *Staffella* (*Pisolina*), *Parafusulina*, *Neofusulinella*.

This limestone is also Murgabian in age.

Muara Selajau

The Sungai Selajau is a tributary of the Sungai Kibul, an important tributary of the Batang Tabir. Near its mouth, Tobler found a Permian limestone with corals. A sample stored at Delft (no. 2454) is deprived of corals; it is a wackestone rich in foraminifera. It contains:

Algae: *Mizzia*.

Small foraminifera: *Diplosphaerina*, *Tuberitina conili*, *Neoendothyra*, *Climacammina elegans*, *Globivalvulina*, *Lasiodiscus tenuis*, *Geinitzina*, *Langella* cf. *ocarina*.

Fusulinids: *Nankinella*, *Pseudo-* or *Parafusulina*, *Afghanella* or *Sumatrina*.

These fossils indicate a Murgabian age.

Muara Selajau (Mouth of Sungai Selajau) is difficult of access, but it is easy to find. Two small limestone exposures (*Fig. 39*) were visited in May 1984; they are located in the banks of the Kibul and Selajau Rivers. No coral was found. Samples collected at Sungai Selajau contain very well-preserved algae: *Anthracoporella spectabilis* (IN620). A sample (IN616) from the Sungai Kibul is a wackestone with algae and foraminifera:

Algae: *Tubiphytes obscurus*, *Mizzia*.

Small foraminifera: *Diplosphaerina*, *Climacammina*, *Globivalvulina*, *Kamurana*.

Fusulinids: *Verbeekina*, *Pseudodoliolina*.

These fossils indicate also a Murgabian age.

Another sample from Sungai Kibul is an oolithic limestone almost deprived of fossils.

Near Muara Selajau, Tobler mentioned a Lower Carboniferous locality (Sungai Landak) after identification of a few brachiopods. The presence of the Lower

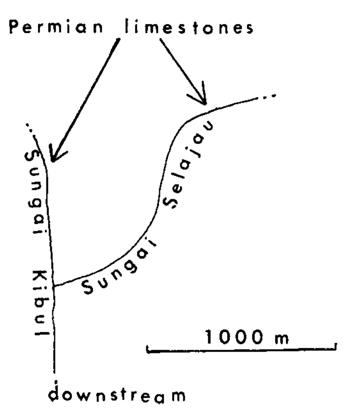

Figure 39. Limestones of Muara Selajau.

Carboniferous in a Permian area is surprising.

Sungai Landak has been impossible to find. It is a tributary of Sungai Pankal Djalan that should be a tributary of Sungai Kibul. Pankal Djalan is a common name and could not help our guide. A sample of black shale (no. 2455) is preserved at the Museum of Delft; a thin section obtained from this sample is barren of fossils.

Batu Tjangap

This locality, discovered by Tobler (1922), has not been visited by the authors because it is difficult to find without a good guide. It is a limestone exposed between the Batang Tabir and Batang Tantan, where a trail from Tanjung Putus (a village at Batang Tabir) to Merigan (a village at Batang Tantan) crosses the Sungai Menkilan, a tributary of the Batang Tantan. This limestone crops out in the vicinity of the mouth of a small tributary of the Sungai Menkilan: the Sungai Batu Tjangap. A sample of this limestone is stored at the museum of Delft with the number 2469 and the mention "reddish, pseudo-oolithic". It is a grainstone, rich in foraminifera and algae, containing cortoids and aggregate grains:

Algae: *Gyroporella, Mizzia, Succodium.*

Pseudoalgae: *Chuvashovia, Ungdarella.*

Small foraminifera: *Diplosphaerina, Tuberitina, Tetrataxis, Climacammina, Dagmarita, Glomospira, Baisalina, Pseudovermiporella, Geinitzina, Pachyphloia, Pseudolangella.*

Fusulinids: *Nankinella, Neofusulinella, Yangchienia, Pseudodoliolina, Afghanella sumatrinaeformis.*

As Lubuk Cada, Lubuk Kelelawar and Muara Selajau, Batu Tjangap is Murgabian in age and belongs to the upper half of the Murgabian. Accordingly, the Murgabian is widespread in the Tabir River basin. In the Jambi Province, the Murgabian is also present at the Sungai Luati, a tributary of the Tembesi River, where very fossiliferous grainstones crop out (Fontaine and Vachard, 1984).

Talang Glugur

The presence of limestone associated with volcanics in the Gumai Mounts led Tobler to think this limestone was Permian in age. Moreover, a sample (no. 1155) stored at the museum of Delft contains fusiform nodules that were taken for fusulinids. These nodules display no structure at all and have nothing to do with fusulinids.

The limestone of the Gumai Mounts, Late Jurassic. Early Cretaceous in age, has recently yielded a Late Jurassic coral identified *Calamophylliopsis crassa* by L. Beauvais.

Laubuluh

Limestone is widely exposed near Laubuluh (*Fig. 15*), a village located 13 km north of Tigabinanga and 60 km southwest of Medan. It is a mudstone–wackestone probably deposited in a relatively deep water. Macrofossils and microfossils are uncommon in the visited area close to Laubuluh; they consist of a few fragments of crinoids, bryozoa and productaceae associated with rare small foraminifera: *Nodosaria* (?), *Pachyphloia cukurkoyi, Multidiscus padangensis.* These latter two species, found in the sample IN716, indicate a Murgabian to Dzhulfian age. Limestone stretches over a wide area and might be not only Permian in age but also Triassic. Some Triassic conodonts have been found to the north, at Sungai Wampu (Metcalfe, 1984).

APPENDIX 2

FORAMINIFERA AND ALGAE FROM THE PERMIAN OF KAMPUCHEA

By

Nguyên Duc Tiên

Permian limestones are widespread in West (Sisophon–Battambang–Pursat areas) and South (Kampot–Kompong Trach areas) Kampuchea. They have provided many fossils, Upper Murgabian–Midian in age. Apart from the Murgabian–Midian, the Upper Permian with *Palaeofusulina* is present in the Kompong Trach area.

This study is based on the thin sections used by Gubler in his description of the fusulinids of Indochina (1935), but it is not restricted to the fusulinids; it concerns also other foraminifera and the algae. Moreover, a new species of fusuline is described.

Family SCHUBERTELLIDAE SKINNER, 1931
Subfamily BOULTONIINAE SKINNER and WILDE, 1954
Genus *Godonofusiella* DUNBAR and SKINNER, 1937
Codonofusiella gubleri n. sp. NGUYEN DUC TIEN
(Pl. 7, fig. 1–6)

HOLOTYPE: Pl. 7, fig. 5; thin section M. L. 1454(3): Maurice LYS collection, University of PARIS XI. The material was sampled by Jean GUBLER at Sisophon (Western KAMPUCHEA).
DERIVATIO NOMINIS: dedicated to Jean GUBLER, a pioneer in the research on the Geology and on the Permian fusulinids of Kampuchea.
OCCURRENCE: This species occurs in many localities of KAMPUCHEA; Sisophon, Phnom Tauch, Phnom Sampeou, Phnom Kraupeu, Pursat.
DESCRIPTION: Test minute sized, first 2 or 3 volutions (juvenarium) inflated fusiform tightly coiled; outer ones uncoiled to rectilinear. The test early uncoiled after the second or the 3rd volution. The coiled part of the test measured: L: 0.17 mm to 0.25 mm, D: 0.10 mm to 0.15 mm. The very large uncoiled part measured: 0.60 mm to 1.10 mm. Proloculus minute: 20 μ to 31 μ. Spirotheca thin, composed by a tectum and a diaphanotheca, measured 9 μ in an uncoiled part. Septa intensely fluted

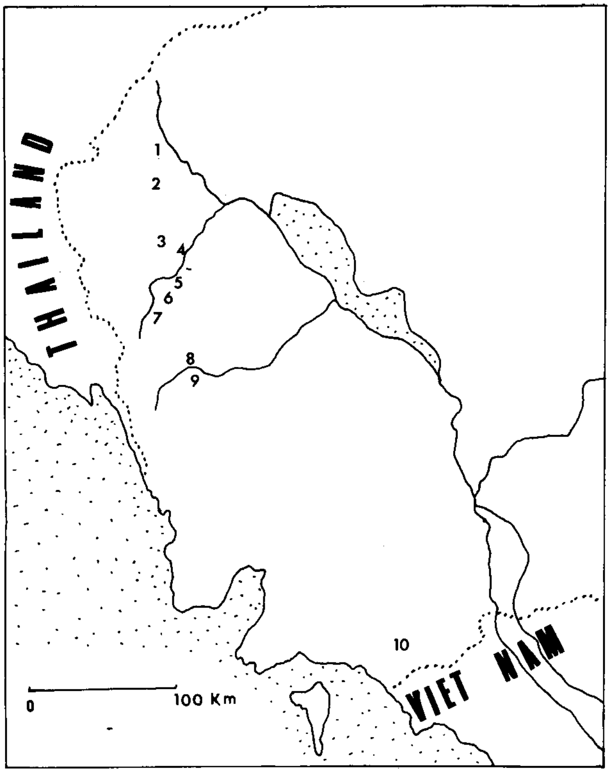

Figure 40. Main fusulinids localities of Kampuchea: 1. Hills near Sisophon; 2. Phnom Tauch; 3. Phnom Takream, Phnom Popul, Phnom Anseh, and to the northwest, Sla Pang; 4. Phnom Sampeou, Phnom Kraupeu and Phnom Banan; 5. Kompong Kol; 6. Cha Raka; 7. Cham Lang Kuy; 8. Sre Pang; 9. O Prach; 10. Kompong Trach

throughout fusiform and uncoiled part of the test. Chomata small defined a 20° to 30° tunnel.

REMARKS: This species resembles *Codonofusiella explicata* KAWANO in the large uncoiled part of the test. However, the former can be distinguished from the latter in its minute and inflated coiled part. *C. gubleri* n. sp. doesn't resemble any other species in the very small test, the large and early uncoiled part.

ASSOCIATION AND HORIZON: *C. gubleri* n. sp. is associated with: FUSULINIDS: *Lepidolina multiseptata "multiseptata"* (very abundant), *Shwagerina crassa, Pseudokahlerina discoidalis, Sichotenella* aff. *S. orientalis, Kahlerina* aff. *K. ussurica.* OTHER FORAMINIFERA: *Deckerella composita, Geinitzina postcarbonica, Geinitzina ichnousa, Pachyphloia çukurköyi, Langella çukurköyi, Frondina permica, Dagmarita chanakchiensis, Globivalvulina graeca, Globivalvulina cyprica, Globivalvulina vonderschmitti, Neoendothyra parva, Agathammina pusulla, Abadehella* cf. *A. coniformis, Lasiodiscus tenuis, Lasiodiscus minor.*

ALGAE AND PSEUDOALGAE: *Permocalculus plumosus, Girvanella* sp., *Tubiphytes obscurus, Hikorocodium* sp.

Therefore *Codonofusiella gubleri* n. sp. is Midian in age (*Lepidolina* biozone).

Plate 1

1 – 1 *Eotuberitina reitlingerae* (MIKLUKHO-MAKLAY)
(Sisophon-KAMPUCHEA)

1 – 2 *Tuberitina collosa* REITLINGER
(Sisophon-KAMPUCHEA)

1 – 3 *Tuberitina conili* NGUYEN DUC TIEN
(Sisophon-KAMPUCHEA)

1 – 4 *Bisphaera irregularis gigantea* CONIL and LYS
(Sisophon-KAMPUCHEA)

1 – 5 *Diplosphaerina inaequalis* (DERVILLE)
(Pursat-KAMPUCHEA)

1 – 6 *Palaeocancellus* cf. *P. robustus* (DERVILLE)
(Phnom Tanghen-KAMPUCHEA)

1 – 7 *Pachysphaerina pachysphaerica* (PRONINA)
(Phnom Popul-KAMPUCHEA)

1 – 8 *Umbellina*(?)sp.
(Phnom Tauch-KAMPUCHEA)

1 – 9 *Umbellina*(?)sp.
(Phnom Tauch-KAMPUCHEA)

1 – 10 *Earlandia* sp.
(Battambang-KAMPUCHEA)

1 – 11 *Calcitornella elongata* CUSHMAN and WATERS
(Cham Lang Kuy-KAMPUCHEA)

1 – 12 *Calcitornella heathi* CUSHMAN and WATERS
(Cham Lang Kuy-KAMPUCHEA)

1 – 13 *Vicinesphaera*(?)sp.
(Pursat-KAMPUCHEA)

1 – 14 *Stipulina*(?)sp. (cf. *Stipulina* LYS in LYS and MARCOUX, 1978)
(Sla Pang-KAMPUCHEA)

1 – 15 *Parathurammina* sp.
(Phnom Takream-KAMPUCHEA)

1 – 16 *Baisalina* sp.
(Sisophon-KAMPUCHEA)

1 – 17 *Pseudotristix solida* REITLINGER
(Phnom Tauch-KAMPUCHEA)

1 – 18 *Ammodiscus* sp.
(Sla Pang-KAMPUCHEA)

1 – 19 *Pachyphloia* sp.
(Phnom Tauch-KAMPUCHEA)

1 – 20 *Pachyphloia* sp.
(Sisophon-KAMPUCHEA)

fig 1-12, 14-16, 18-20 : 250 µ ; fig 13,17 : 250 µ

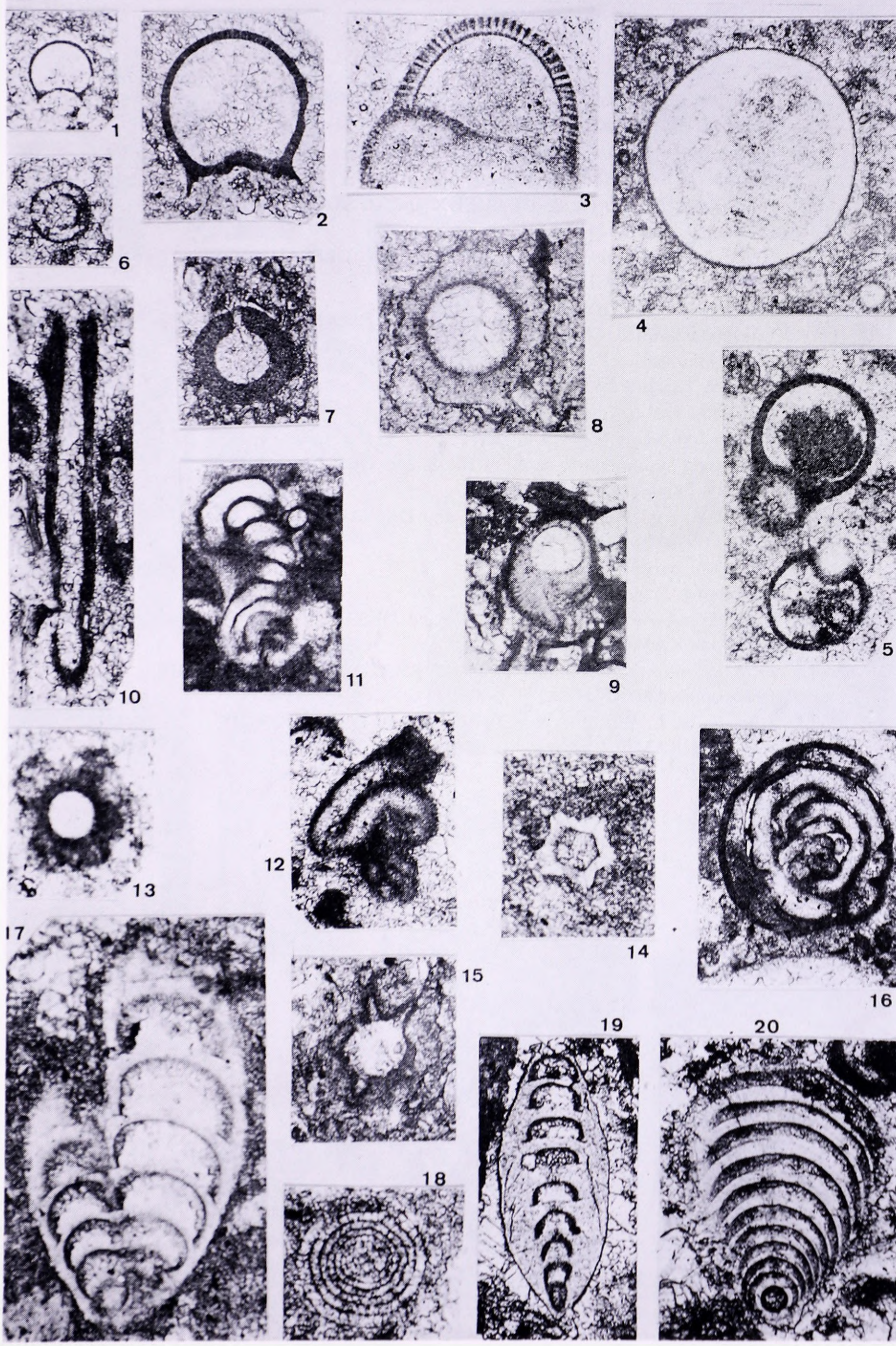

Plate 2

2 – 1 *Pachyphloia çukurköyi* S. de CIVRIEUX and DESSAUVAGIE
(Sisophon-KAMPUCHEA)

2 – 2 *Geinitzina postcarbonica* SPANDEL
(Kompong Kol-KAMPUCHEA)

2 – 3 *Geinitzina ichnousa* (S. de CIVRIEUX and DESSAUVAGIE)
(Phnom Tauch-KAMPUCHEA)

2 – 4 *Geinitzina* cf. *G. taurica* S. de CIVRIEUX and DESSAUVAGIE
(Charaka-KAMPUCHEA)

2 – 5 *Geinitzina reperta* BYKOVA
(Sisophon-KAMPUCHEA)

2 – 6 *Geinitzina*(?)sp.
(Phnom Tauch-KAMPUCHEA)

2 – 7 *Sosninella* sp.
(Cham Lang Kuy-KAMPUCHEA)

2 – 8 *Ichtyolaria latilimbata* S. de CIVRIEUX and DESSAUVAGIE
(Phnom Popul-KAMPUCHEA)

2 – 9 *Frondina permica* S. de CIVRIEUX and DESSAUVAGIE
(Phnom Tauch-KAMPUCHEA)

2 – 10 *Colaniella parva* (COLANI)
(Kompong Trach-KAMPUCHEA)

2 – 11 *Langella çukurköyi* S. de CIVRIEUX and DESSAUVAGIE
(Sisophon-KAMPUCHEA)

2 – 12 *Protonodosaria globifrondina* S. de CIVRIEUX and DESSAUVAGIE
(Sisophon-KAMPUCHEA)

2 – 13 *Langella* cf. *L. ocarina* S. de CIVRIEUX and DESSAUVAGIE
(Sisophon-KAMPUCHEA)

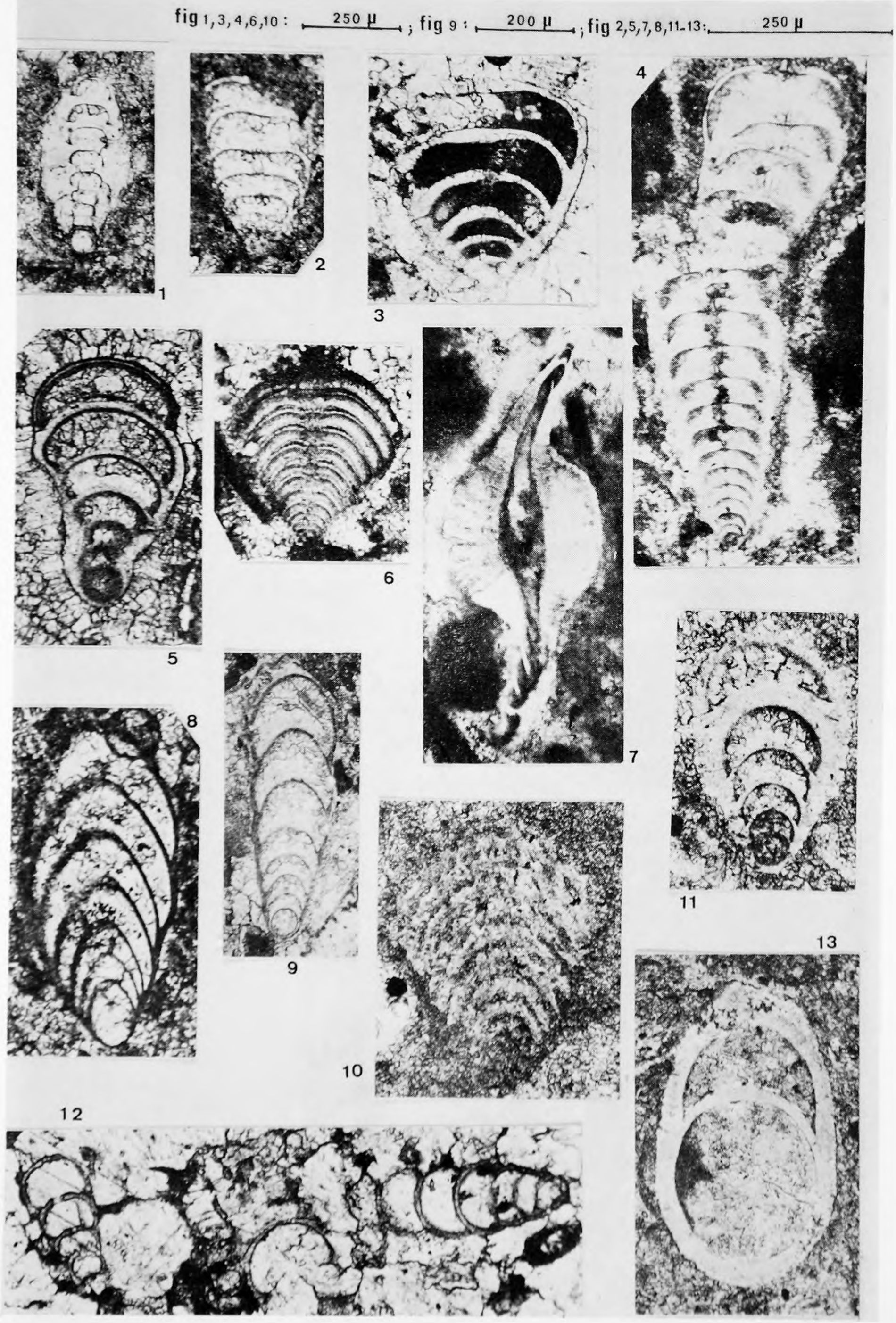
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Plate 3

3 – 1 *Nodosaria* cf. *N. postgeinitzi* EFIMOVA
(Pursat-KAMPUCHEA)

3 – 2 *Nodosaria* sp.
(Sisophon-KAMPUCHEA)

3 – 3 *Nodosaria longissima* SULEIMANOV
(Charaka-KAMPUCHEA)

3 – 4 *Protonodosaria* aff. *P. proceraformis* GERKE
(Sisophon-KAMPUCHEA)

3 – 5 *Tetrataxis conica* EHRHENBERG
(Sla Pang-KAMPUCHEA)

3 – 6 *Palaeotextularia sumatensis* (LANGE)
(Sla Pang-KAMPUCHEA)

3 – 7 *Climacammina* cf. *C. tudicla* LANGE
(Phnom Tauch-KAMPUCHEA)

3 – 8 *Climacammina valvulinoides* LANGE
(Pursat-KAMPUCHEA)

3 – 9 *Deckerella* cf. *D. composita* REITLINGER
(Sisophon-KAMPUCHEA)

3 – 10 *Cribrogenerina sumatrana* LANGE
(Sisophon-KAMPUCHEA)

3 – 11 *Climacammina elegans* MÖLLER
(Pursat-KAMPUCHEA)

3 – 12 *Climacammina*(?) *sphaerica* POTIEVSKAYA
(Sisophon-KAMPUCHEA)

3 – 13 *Dagmarita chanakchiensis* REITLINGER
(Phnom Tauch-KAMPUCHEA)

3 – 14, 15 *Abadehella* cf. *A. coniformis* OKIMURA
(Phnom Tauch-KAMPUCHEA)

3 – 16 *Abadehella* sp. OKIMURA
(Phnom Tanghen-KAMPUCHEA)

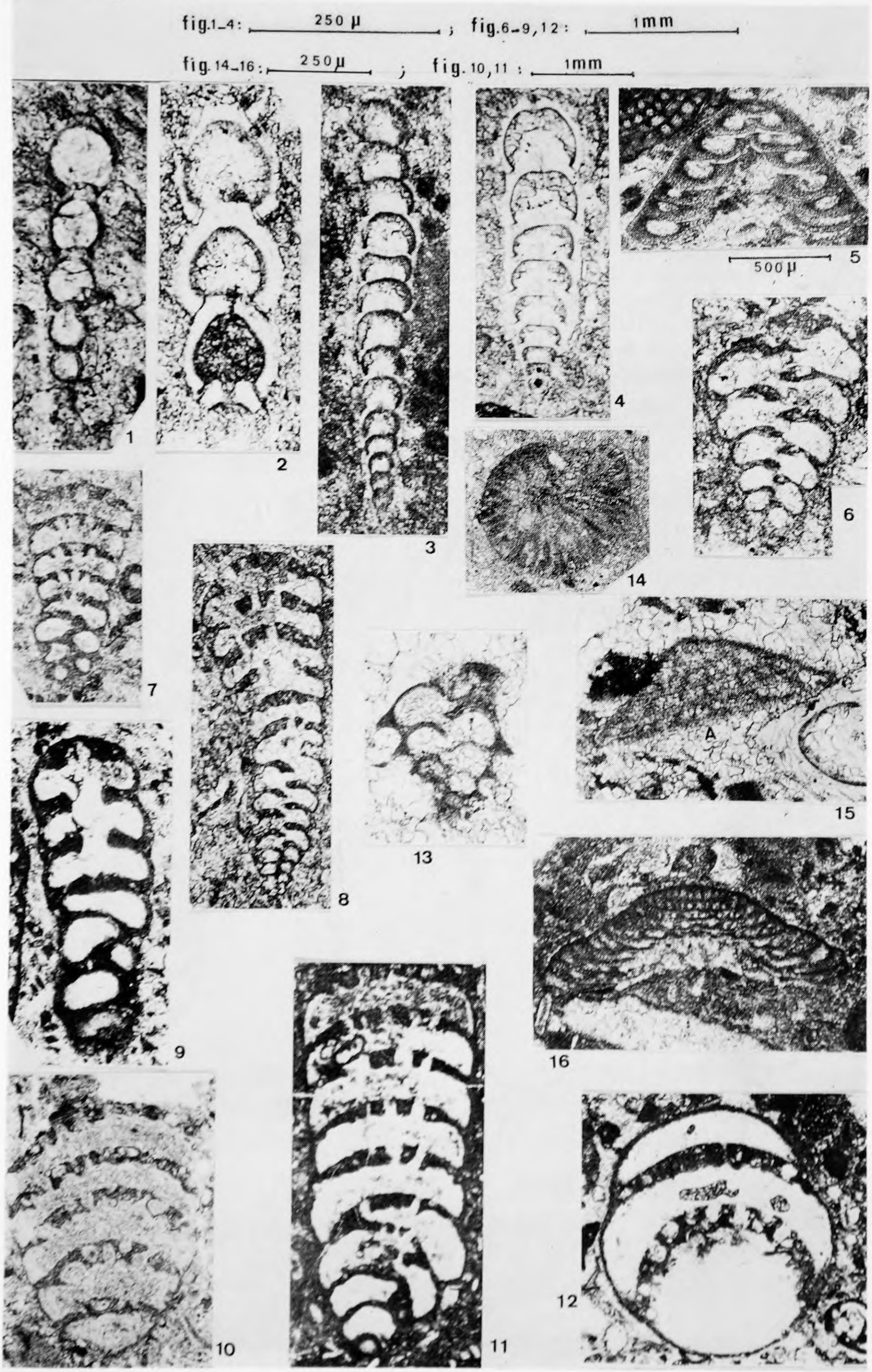
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fig.14–16: 250µ ; fig.10,11: 1mm
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Plate 4

4 – 1 *Neoendothyra parva* (LANGE)
(Phnom Tauch-KAMPUCHEA)

4 – 2 *Neoendothyra* cf. *N. bronnimanni* BOZORNIA
(Sampou-KAMPUCHEA)

4 – 3 *Neoendothyra reicheli* REITLINGER
(Cham Lang Kuy-KAMPUCHEA)

4 – 4 *Globivalvulina vonderschmitti* REICHEL
(Krapou-KAMPUCHEA)

4 – 5 *Globivalvulina graeca* REICHEL
(Cham Lang Kuy-KAMPUCHEA)

4 – 6 *Globivalvulina cyprica* REICHEL
(Phnom Popul-KAMPUCHEA)

4 – 7 *Globivalvulina* sp. B. OKIMURA, OKIMURA
(Sisophon-KAMPUCHEA)

4 – 8, 9 *Globivalvulina* sp.
(Phnom Tauch and Kampot-KAMPUCHEA)

4 – 10 *Bradyina* sp. 1
(Phnom Tauch-KAMPUCHEA)

4 – 11 *Bradyina* sp. 2
(Sisophon-KAMPUCHEA)

4 – 12 *Lasiodiscus tenuis* REICHEL
(Battambang-KAMPUCHEA)

4 – 13~15 *Lasiodiscus minor* REICHEL
(Phnom Tauch and Cham Lang Kuy-KAMPUCHEA)

4 – 16 *Lasiodiscus* sp.
(Pursat-KAMPUCHEA)

fig.1-11 : 250 µ ; fig.12-16 : 250 µ

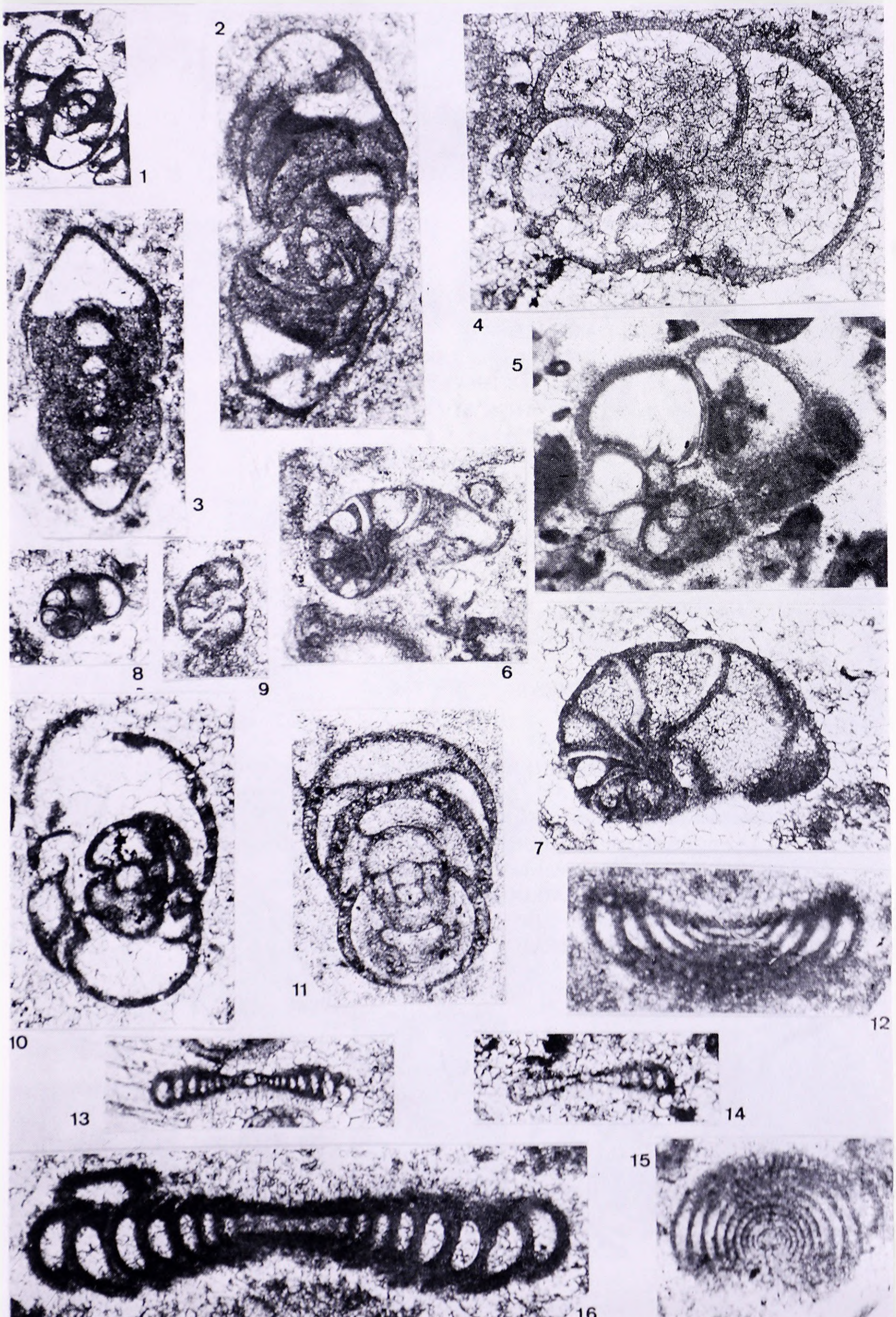

Plate 5

5 – 1 *Hemigordius* sp. 1
(Phnom Tauch-KAMPUCHEA)

5 – 2, 3 *Hemigordius* sp. 2
(Sisophon and Phnom Tauch-KAMPUCHEA)

5 – 4 *Agathammina* sp.
(Phnom Tauch-KAMPUCHEA)

5 – 5 *Agathammina pusulla* (GEINITZ)
(Phnom Tauch-KAMPUCHEA)

5 – 6 *Hemigordius reicheli* LYS
(Phnom Tauch-KAMPUCHEA)

5 – 7 *Kamurana*(?)sp. ALTINER and ZANINETTI
(Cham Lang Kuy-KAMPUCHEA)

5 – 8 *Dunbarula nana* (KOCHANSKY-DEVIDE and RAMOVS)
(Battambang-KAMPUCHEA)

5 – 9 *Codonofusiella paradoxica* DUNBAR and SKINNER
(Sisophon-KAMPUCHEA)

5 – 10 *Pseudoendothyra irregularis* (SAURIN)
(Siem Reap-KAMPUCHEA)

5 – 11 *Pseudoendothyra* sp.
(Pursat-KAMPUCHEA)

5 – 12 *Staffella zisongzhengensis* SHENG
(Kompong Kol-KAMPUCHEA)

5 – 13 *Rauserella* sp.
(Sisophon-KAMPUCHEA)

5 – 14 *Staffella* sp.
(Kampot-KAMPUCHEA)

5 – 15 *Reichelina tenuissima* MIKLUKHO-MAKLAY
(Pursat-KAMPUCHEA)

5 – 16 *Reichelina cribroseptata* ERK
(Kampong Trach-KAMPUCHEA)

5 – 17 *Sichotenella* aff. *S. orientalis* TOUMANSKAYA
(Cham Lang Kuy-KAMPUCHEA)

5 – 18 *Nankinella orbicularia* LEE
(Sisophon-KAMPUCHEA)

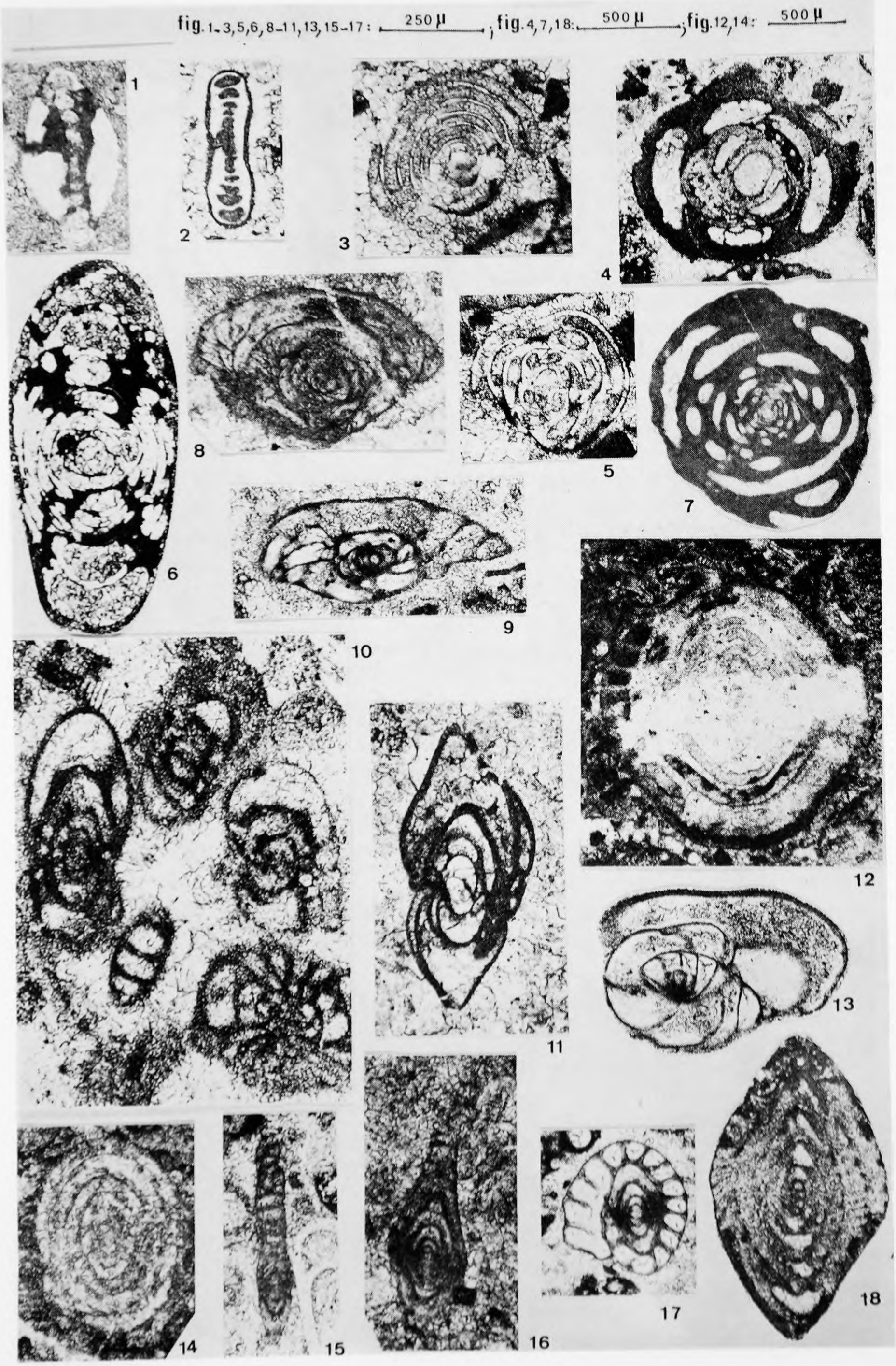
fig. 1-3,5,6,8-11,13,15-17: 250 μ ; fig. 4,7,18: 500 μ ; fig. 12,14: 500 μ
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Plate 6

6 – 1 *Reichelina* (*Parareichelina*) sp.
(Kampong Trach-KAMPUCHEA)

6 – 2, 3 *Kahlerina* aff. *K. ussurica* SOSNINA
(Cham Lang Kuy-KAMPUCHEA)

6 – 4 *Kahlerina* sp.
(Sisophon-KAMPUCHEA)

6 – 5, 6 *Pseudokahlerina discoidalis* SOSNINA
(Cham Lang Kuy and Pursat-KAMPUCHEA)

6 – 7, 8 *Palaeofusulina fusiformis* SHENG
(Kampot-KAMPUCHEA)

6 – 9 *Minojapanella*(?) sp.
(Phnom Tauch-KAMPUCHEA)

6 – 10, 11 *Schwagerina crassa* (DEPRAT)
(Sampou and Phnom Tauch-KAMPUCHEA)

6 – 12 *Schwagerina padangensis* (LANGE)
(Sisophon-KAMPUCHEA)

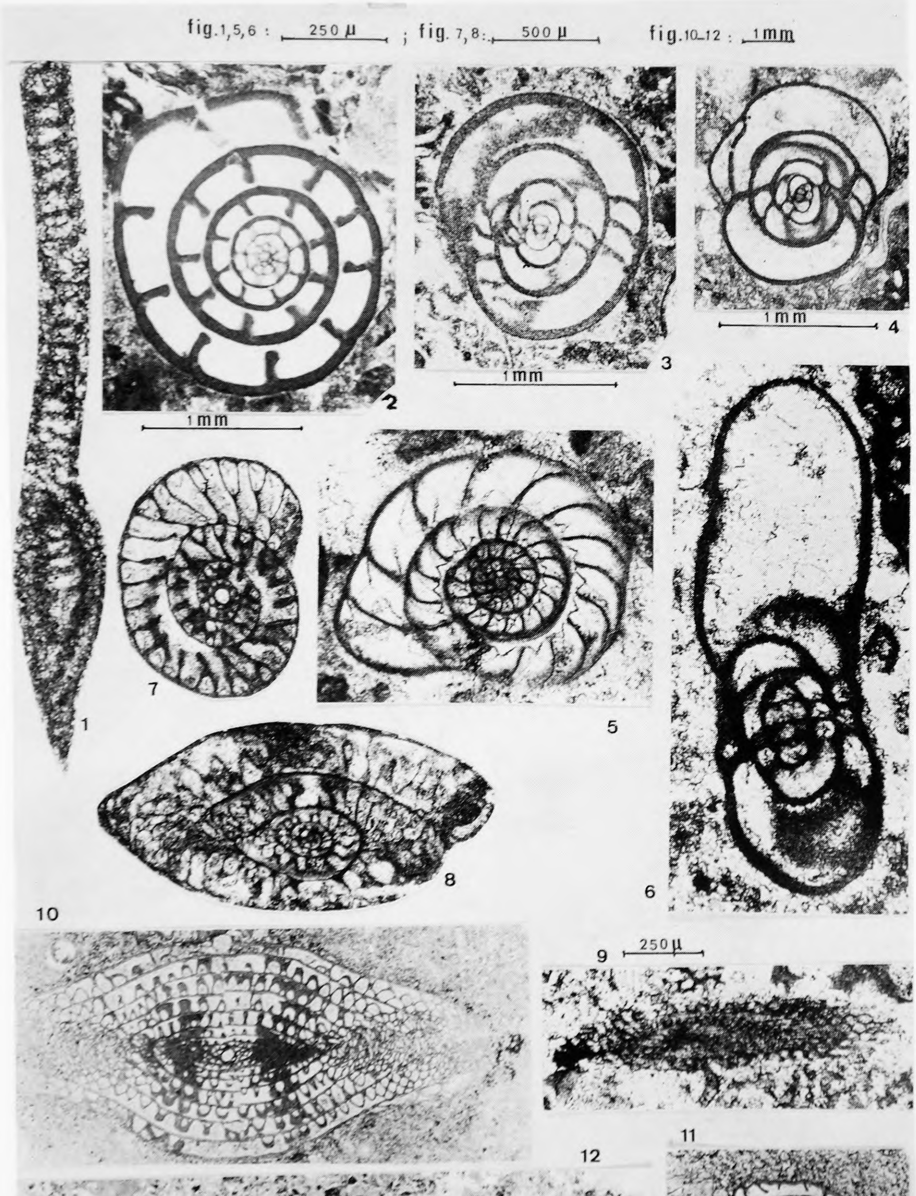
fig.1,5,6 : 250 μ ; fig. 7,8: 500 μ fig.10-12 : 1mm
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1mm
1mm
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250μ
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Plate 7

7 – 1~6 *Codonofusiella gubleri* n. sp. NGUYEN DUC TIEN
(Sisophon and Pursat-KAMPUCHEA). Holotype: 7–5.

7 – 7 *Chusenella liangshanensis* (SHENG)
(Phnom Popul-KAMPUCHEA)

7 – 8 *Chusenella cambodgensis* (GUBLER)
(Phnom Banang-KAMPUCHEA)

7 – 9, 10 *Schwagerina pursatensis* (GUBLER)
(O Prach-KAMPUCHEA)

7 – 11 *Pseudodoliolina pseudolepida* (DEPRAT)
(Sre Pang-KAMPUCHEA)

7 – 12 *Metadoliolina douvillei* (GUBLER)
(Cham Lang Kuy-KAMPUCHEA)

7 – 13 *Verbeekina verbeeki* (GEINITZ)
(Phnom Takream-KAMPUCHEA)

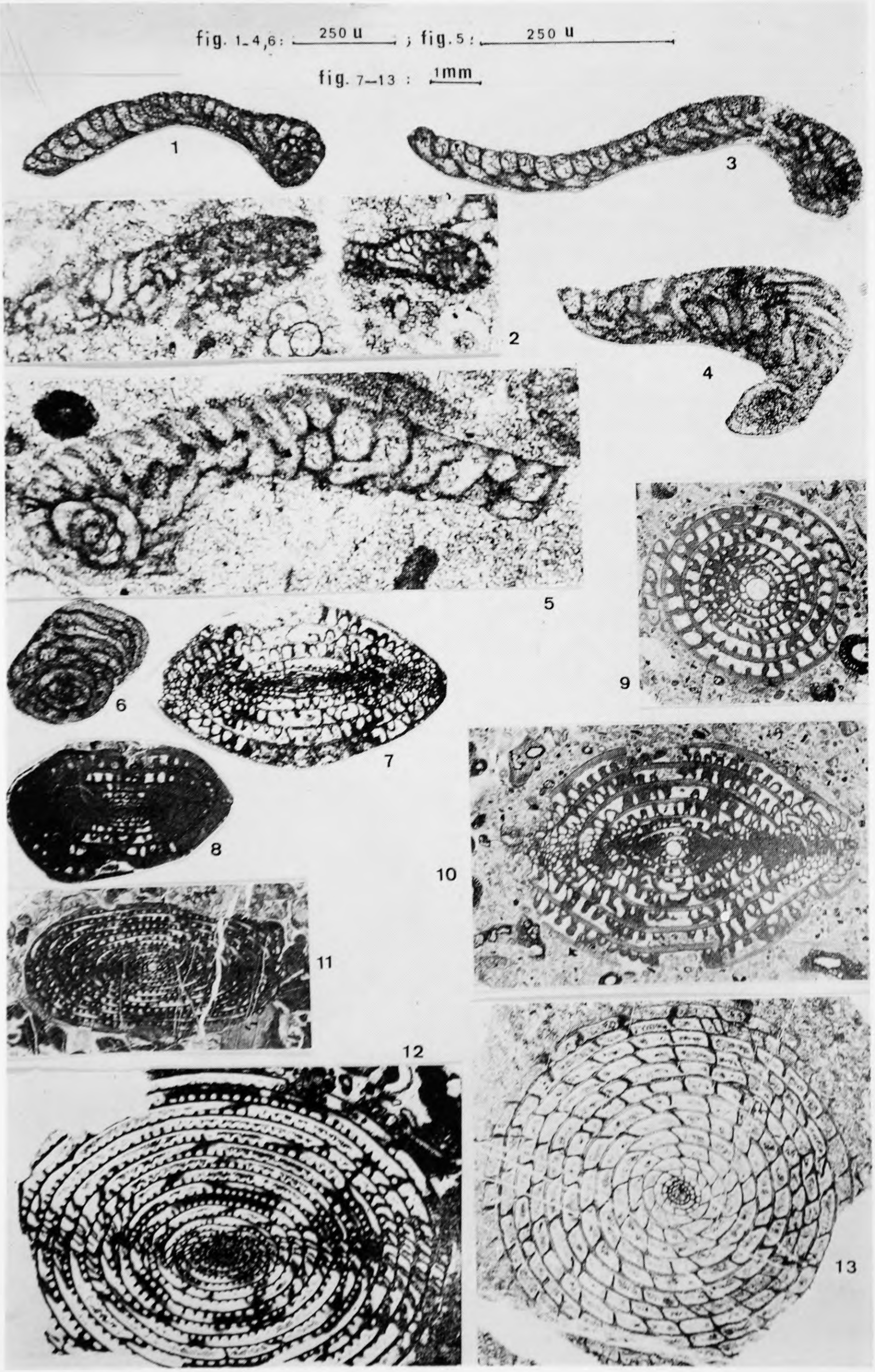
fig. 1-4,6: 250 u ; fig. 5: 250 u
fig. 7-13 : 1mm
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Plate 8

8 – 1 *Sumatrina longissima* (DEPRAT)
(Phnom Banang-KAMPUCHEA)

8 – 2 *Colania douvillei* (OZAWA)
(Kompong Kol-KAMPUCHEA)

8 – 3 *Yabeina* sp.
(Cham Lang Kuy-KAMPUCHEA)

8 – 4~7 *Lepidolina multiseptata "multiseptata"* (DEPRAT)
(Sisophon, Sla Pang, Phnom Takream-KAMPUCHEA)
4: axial section of a common specimen
5: axial section of a large proloculus specimen
6: tranverse section
7: axial section of a microspheric form

8 – 8 *Yabeina* cf. *Y. ozawai* HONJO
(Phnom Popul-KAMPUCHEA)

8 – 9 *Girvanella permica* PIA
(Cham Lang Kuy-KAMPUCHEA)

8 – 10 *Girvanella* sp.
(Pursat-KAMPUCHEA)

8 – 11 *Stromatolites*
(Pursat-KAMPUCHEA)

8 – 12 *Gymnocodium grandise* ENDO
(Phnom Tauch-KAMPUCHEA)

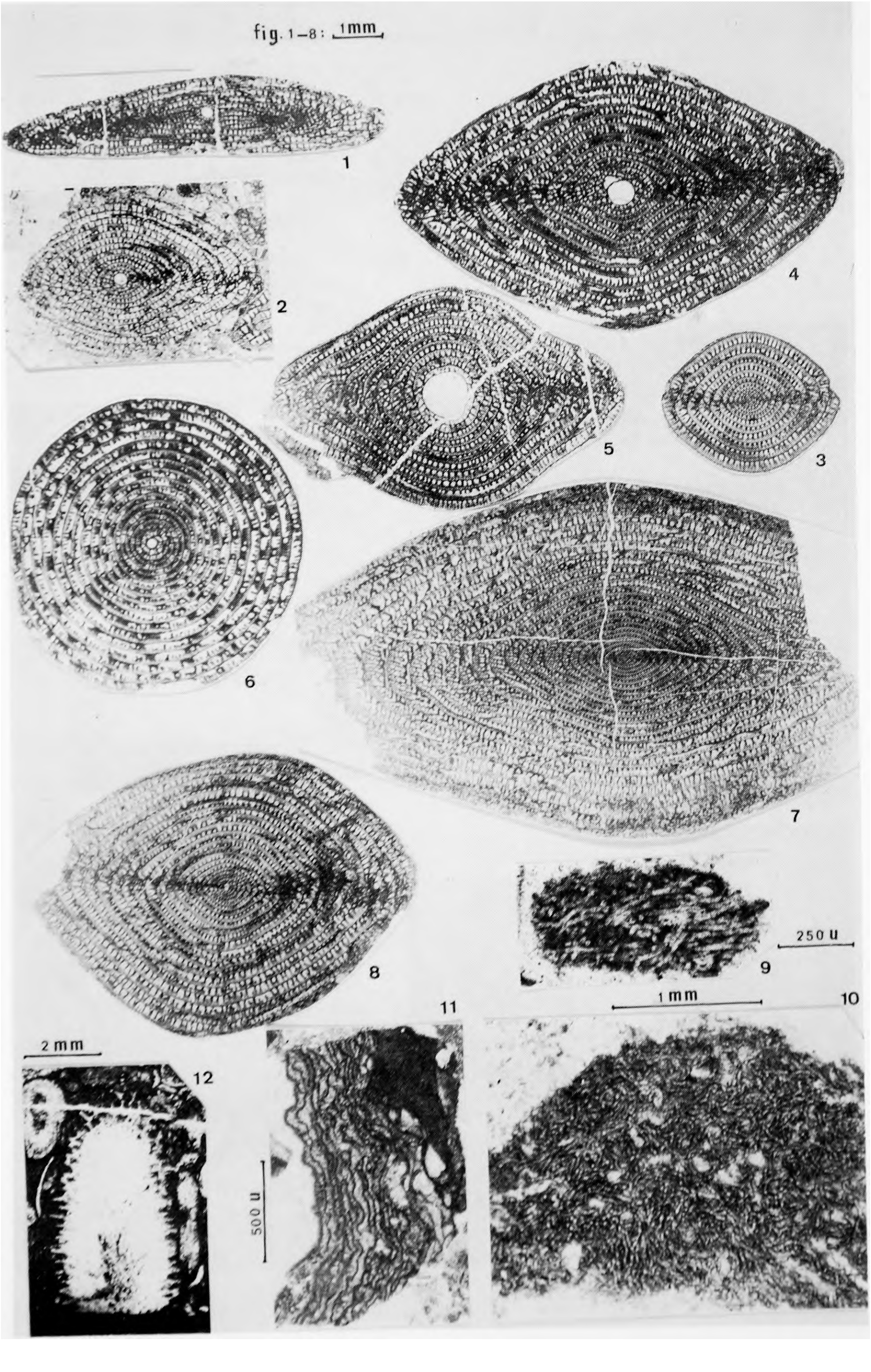
fig. 1–8 : 1mm
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2mm
12
500 u

Plate 9

9 – 1 A: *Succodium* sp.
B: *Anthracoporella spectabilis* PIA
(Pursat-KAMPUCHEA)

9 – 2 *Succodium* sp.
(Phnom Tauch-KAMPUCHEA)

9 – 3, 4 *Mizzia velebitana* SCHUBERT
(Sisophon-KAMPUCHEA)

9 – 5 *Gyroporella*(?) sp.
(Cham Lang Kuy-KAMPUCHEA)

9 – 6, 7 *Vermiporella nipponica* ENDO
(O Prach-KAMPUCHEA)

9 – 8, 9 *Permocalculus plumosus* ELLIOTT
(Phnom Sua-KAMPUCHEA)

Plate 9

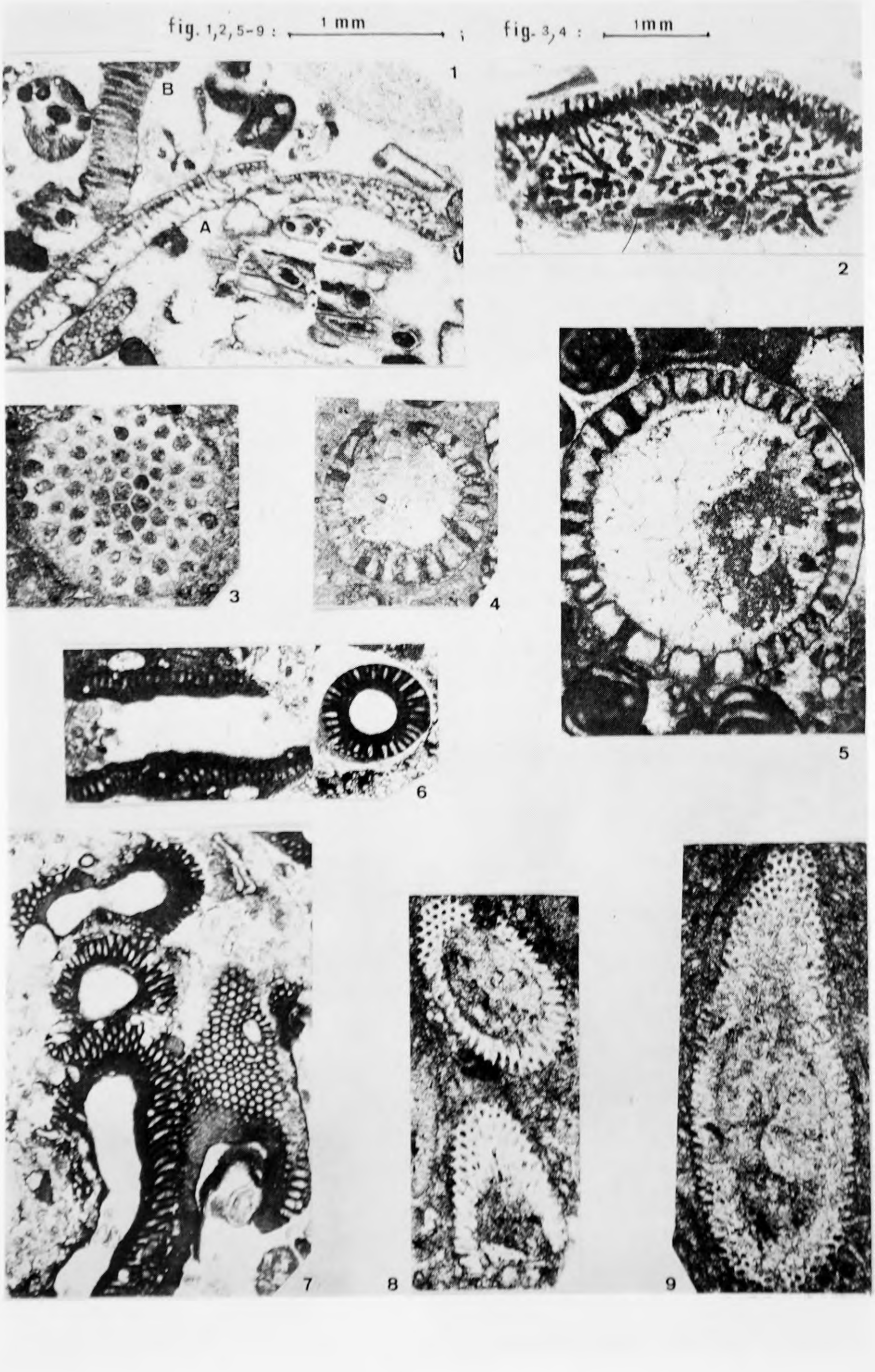

Plate 10

10 – 1 *Ungdarella uralica* MASLOV
(Sisophon-KAMPUCHEA)

10 – 2 *Anthracoporella spectabilis* PIA
(Pursat-KAMPUCHEA)

10 – 3 *Hikorocodium* sp.
(Phnom Tauch-KAMPUCHEA)

10 – 4 A: *Atractyliopsis* sp.
B: *Gyroporella*(?) sp.
(Pursat-KAMPUCHEA)

10 – 5 *Gyroporella* sp.
(Pursat-KAMPUCHEA)

10 – 6 *Macroporella*(?) sp.
(Pursat-KAMPUCHEA)

10 – 7 *Anchicodium* cf. *A. fukuiense* ENDO
(Phnom Tauch-KAMPUCHEA)

10 – 8~10 *Tubiphytes obscurus* MASLOV
(Sisophon, Charaka, Pursat-KAMPUCHEA)

10 – 11 *Tubiphytes corynthiacus* (FLUGEL)
(Charaka-KAMPUCHEA)

10 – 12 *Epimastopora* sp.
(Damrey-KAMPUCHEA)

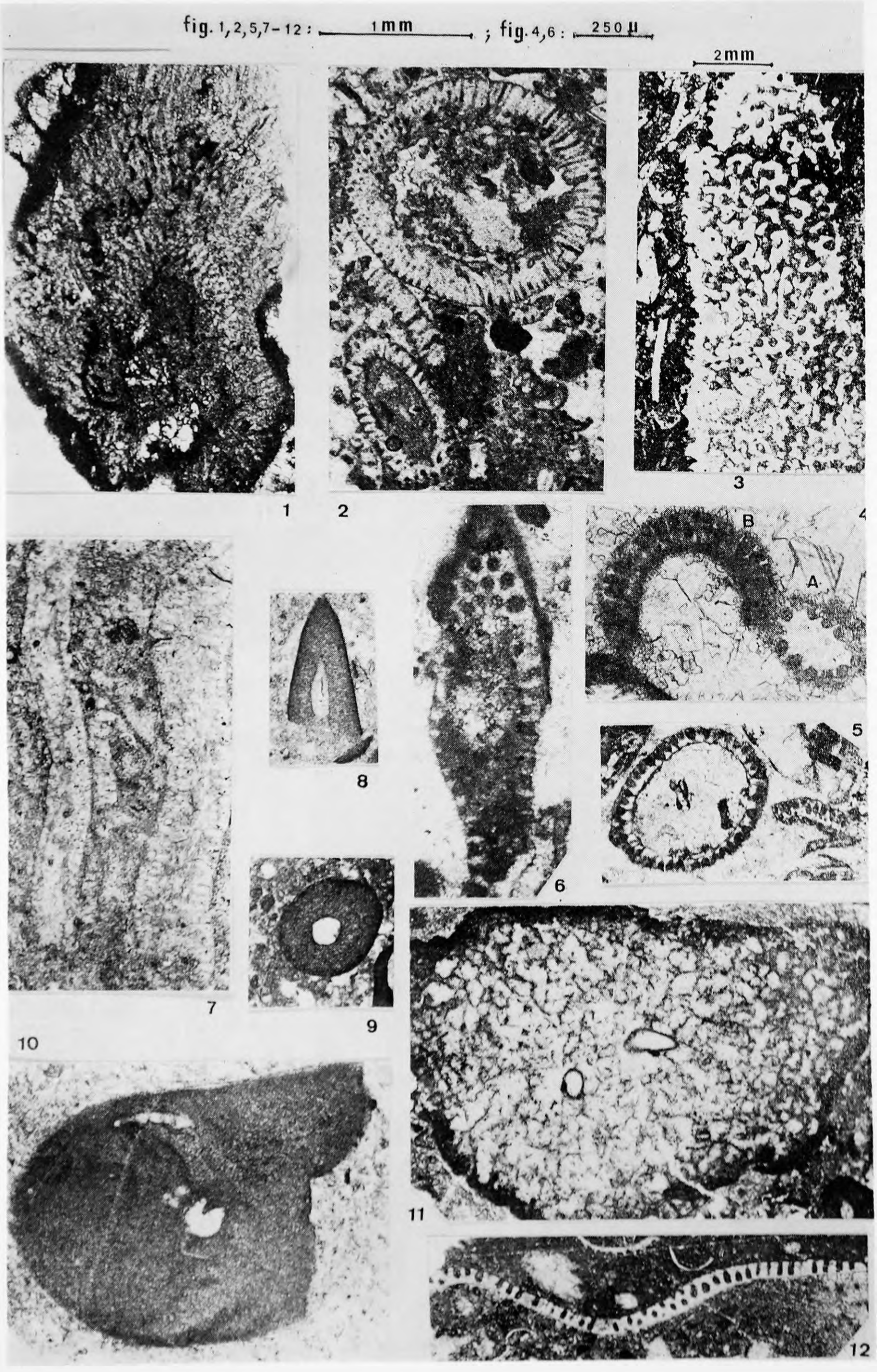
fig. 1,2,5,7-12 : 1mm ; fig. 4,6 : 250 µ
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APPENDIX 3

FORAMINIFERA AND ALGAE FROM THE PERMIAN OF GUGUK BULAT AND SILUNGKANG, SUMATRA

By

Nguyên Duc TIÊN

In the Highland of Padang in Central Sumatra, two Permian localities are well-known: Guguk Bulat and Silungkang (*Fig. 15*). They are easy of access. Guguk Bulat is very fossiliferous and contains abundant algae, foraminifera, sponges and corals; it is a reefal limestone. On the contrary, fossils are few and scattered at Silungkang. Massive corals are so far unknown at Silungkang; algae are locally prolific, but are represented by *Tubiphytes*, a puzzling organism (*Pl. 20, Fig. 3*).

Guguk Bulat has been already the subject of a few papers (Volz, 1904; Lange, 1925; Fontaine, 1982 and 1983).

Silungkang has been recently mentioned in two papers (Hahn and Weber, 1981; Fontaine, 1983).

Plate 11

11 – 1~6 *Colania douvillei* (OZAWA)
2, details of 11–1
6, details of 11–5
(Guguk Bulat-INDONESIA)

11 – 7, 8 *Colania douvillei* (?) (OZAWA) microspheric forms (?)
(Guguk Bulat-INDONESIA)

11 – 9 A: *Colania douvillei* (OZAWA)
B: *Cribrogenerina sumatrana* LANGE
C: *Deckerella* sp.
(Guguk Bulat-INDONESIA)

11 – 10 *Colania douvillei* (OZAWA)
(A: *Pseudodoliolina pseudolepida* (DEPRAT))
(Guguk Bulat-INDONESIA)

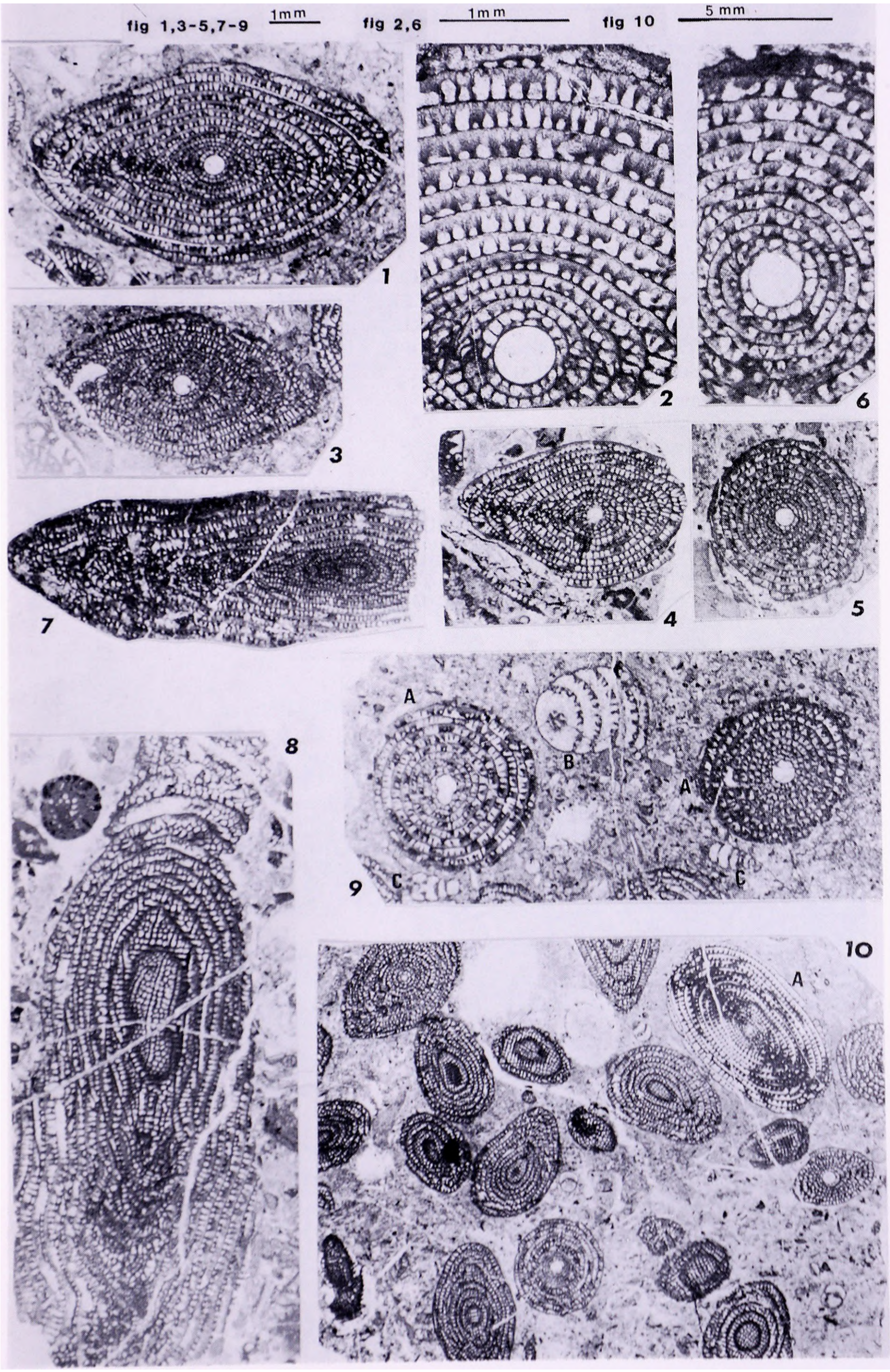
fig 1,3-5,7-9
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Plate 12

12 – 1～3 *Pseudodoliolina pseudolepida* (DEPRAT)
2, details of 12–1
(Guguk Bulat-INDONESIA)

12 – 4, 4a *Sumatrina longissima* (DEPRAT)
(Guguk Bulat-INDONESIA)

12 – 5 A: *Sumatrina longissima* (DEPRAT)
B: *Schwagerina pursatensis* (GUBLER)
C: *Cribrogenerina sumatrana* LANGE
D: *Pseudodoliolina pseudolepida* (DEPRAT)
(Guguk Bulat-INDONESIA)

12 – 6, 7 *Schwagerina crassa* (DEPRAT)
7, details of 12–6
(Guguk Bulat-INDONESIA)

12 – 8 *Schwagerina pursatensis* (GUBLER)
(Guguk Bulat-INDONESIA)

12 – 9, 10 *Schwagerina padangensis* (GUBLER)
(Guguk Bulat-INDONESIA)

12 – 11 A: *Verbeekina verbeeki* (GEINITZ)
B: *Pseudodoliolina pseudolepida* (DEPRAT)
(Guguk Bulat-INDONESIA)

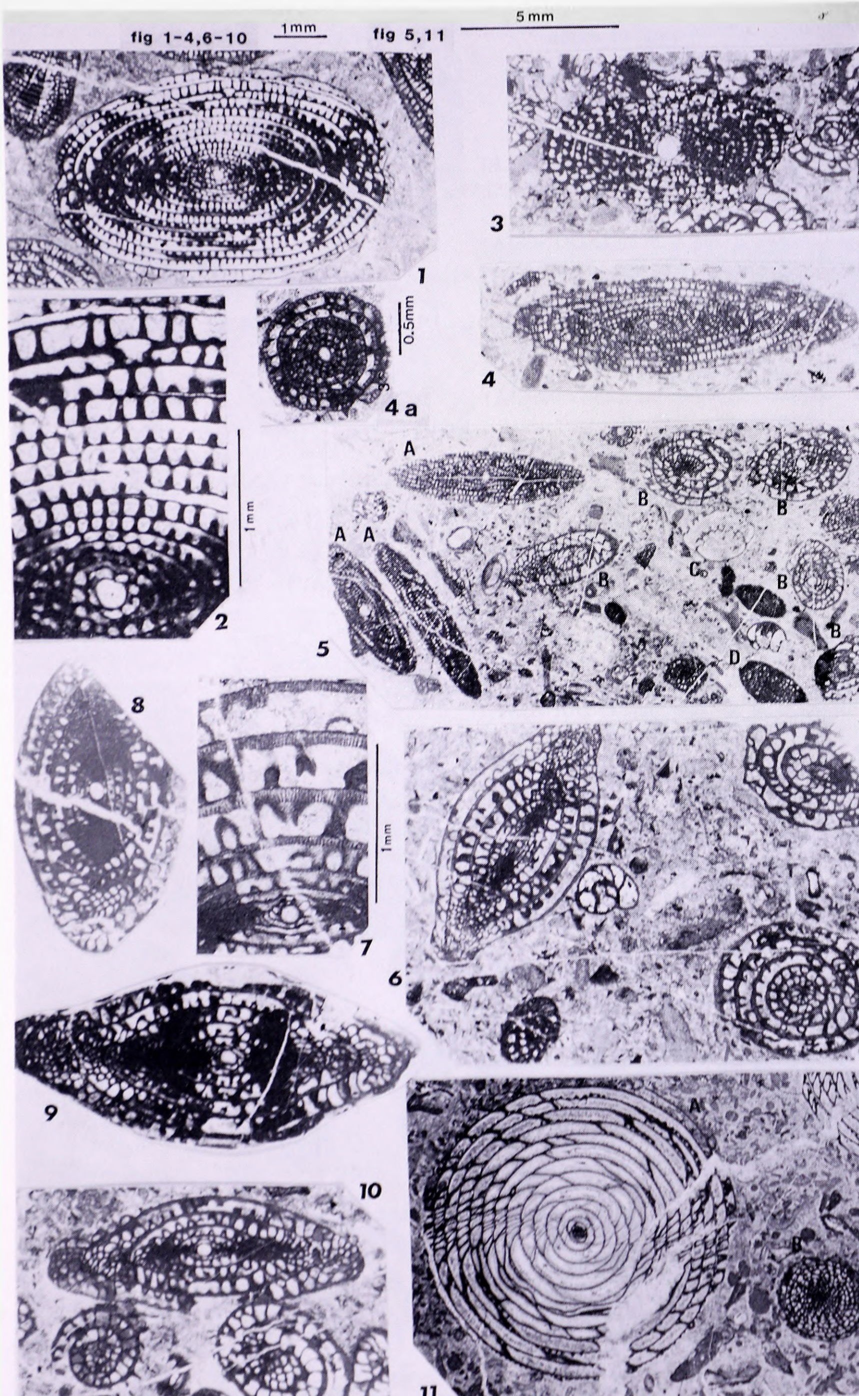
fig 1-4,6-10
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Plate 13

13 – 1, 2 *Nankinella orbicularia* LEE
(Guguk Bulat-INDONESIA)

13 – 3 *Codonofusiella*(?) sp.
(Guguk Bulat-INDONESIA)

13 – 4 *Rauserella* sp.
(Guguk Bulat-INDONESIA)

13 – 5 *Codonofusiella* cf. *C. paradoxica* DUNBAR and SKINNER
(Guguk Bulat-INDONESIA)

13 – 6 *Boultonia* sp.
(Guguk Bulat-INDONESIA)

13 – 7 *Codonofusiella* cf. *C. gubleri* NGUYEN DUC TIEN
(Guguk Bulat-INDONESIA)

13 – 8, 9 *Dunbarula nana* (KOCHANSKY-DEVIDE and VANDA)
(Guguk Bulat-INDONESIA)

13 – 10 *Minojapanella*(?) sp.
(Guguk Bulat-INDONESIA)

13 – 11 *Eotuberitina reitlingerae* (MIKLUKHO-MAKLAY)
(Silung Kang-INDONESIA)

13 – 12 *Tuberitina collosa* REITLINGER
(Silung Kang-INDONESIA)

13 – 13 *Tuberitina conili* NGUYEN DUC TIEN
(Guguk Bulat-INDONESIA)

13 – 14~18 *Globivalvulina cyprica* REICHEL
(Guguk Bulat-INDONESIA)

13 – 19 *Agathammina* sp.
(Guguk Bulat-INDONESIA)

13 – 20 *Neoendothyra parva* LANGE
(Guguk Bulat-INDONESIA)

13 – 21 *Hemigordius* sp.
(Guguk Bulat-INDONESIA)

13 – 22 *Hemigordius* sp.
(Guguk Bulat-INDONESIA)

13 – 23 *Agathammina* sp.
(Guguk Bulat-INDONESIA)

13 – 24, 25 *Agathammina pusulla* (GEINITZ)
(Guguk Bulat-INDONESIA)

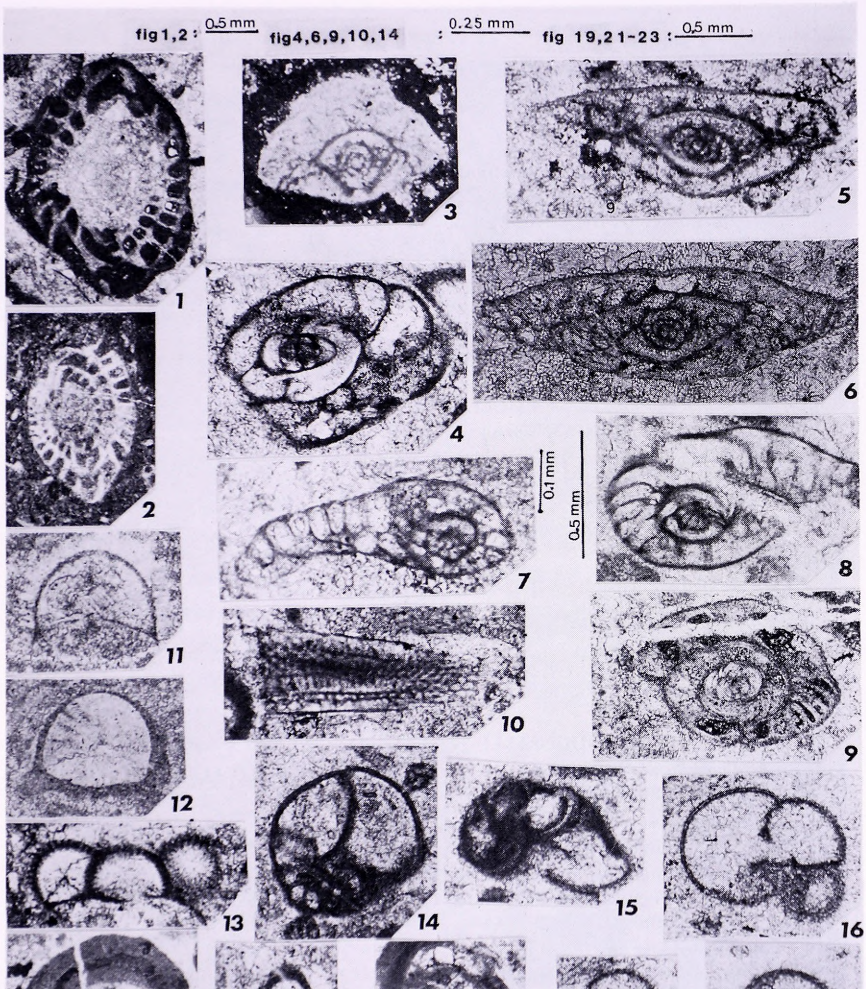
fig 1,2 : 0.5 mm
fig 4,6,9,10,14 : 0.25 mm
fig 19,21-23 : 0.5 mm
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fig 3,5,11,12,15-18 : 0.1 mm
fig 13 0.1 mm
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Plate 14

14 – 1 A: *Palaeotextularia sumatrensis* (LANGE)
B: *Ungdarella uralica* MASLOV
(Guguk Bulat-INDONESIA)

14 – 2, 6 *Cribrogenerina sumatrana* LANGE
(Guguk Bulat-INDONESIA)

14 – 3 *Deckerella* sp.
(Guguk Bulat-INDONESIA)

14 – 4, 5 *Climacammina* cf. *C. tudicla* LANGE
(Guguk Bulat-INDONESIA)

14 – 7 *Climacammina elegans* MÖLLER
(Guguk Bulat-INDONESIA)

14 – 8 *Frondina permica* S. de CIVRIEUX and DESSAUVAGIE
(Guguk Bulat-INDONESIA)

14 – 9 *Frondina* (?) sp.
(Guguk Bulat-INDONESIA)

14 – 10 *Geinitzina* sp.
(Guguk Bulat-INDONESIA)

14 – 11 *Protonodosaria* (?) sp.
(Guguk Bulat-INDONESIA)

14 – 12 *Abadehella* cf. *A. coniformis* OKIMURA
(Guguk Bulat-INDONESIA)

14 – 13 *Pachyphloia* sp.
(Guguk Bulat-INDONESIA)

14 – 14 *Langella* af. *L. ocarina* S. de CIVRIEUX and DESSAUVAGIE
(Guguk Bulat-INDONESIA)

14 – 15 *Lasiodiscus tenuis* REICHEL
(Guguk Bulat-INDONESIA)

14 – 16 A: *Tetrataxis conica* EHRENBERG
B: *Pachyphloia çukurköyi* S. de CIVRIEUX and DESSAUVAGIE
(Guguk Bulat-INDONESIA)

14 – 17 *Pachyphloia* sp.
(Guguk Bulat-INDONESIA)

14 – 18 *Langella ocarina* S. de CIVRIEUX and DESSAUVAGIE
(Guguk Bulat-INDONESIA)

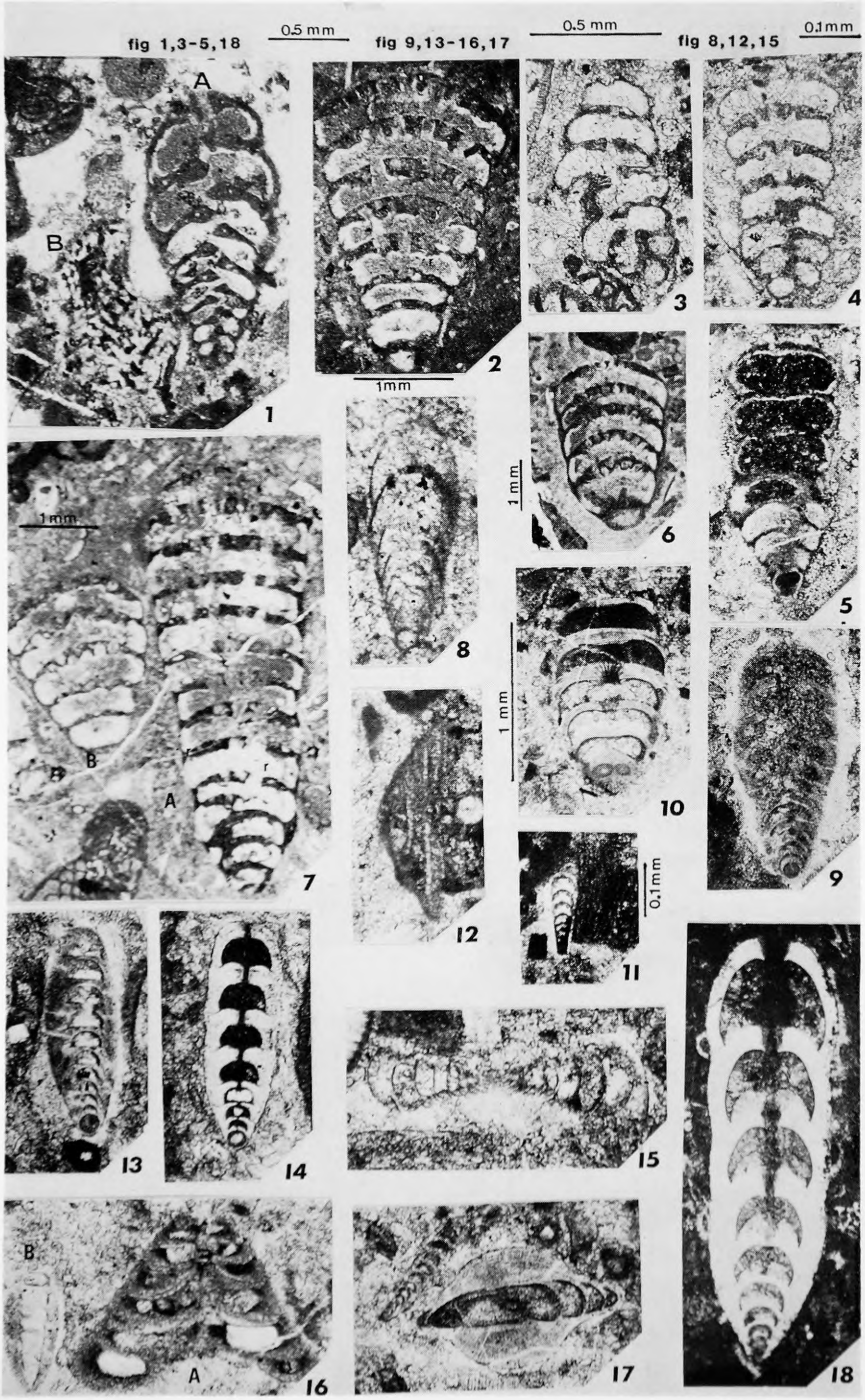
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fig 9,13-16,17
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fig 8,12,15
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Plate 15

15 – 1 *Vermiporella nipponica* ENDO
(Silung Kang-INDONESIA)

15 – 2 *Mizzia velebitana* SCHUBERT
(Guguk Bulat-INDONESIA)

15 – 3 *Succodium* sp.
(Silung Kang-INDONESIA)

15 – 4 *Tubiphytes obscurus* MASLOV
(Silung Kang-INDONESIA)

15 – 5 *Permocalculus* sp.
(Guguk Bulat-INDONESIA)

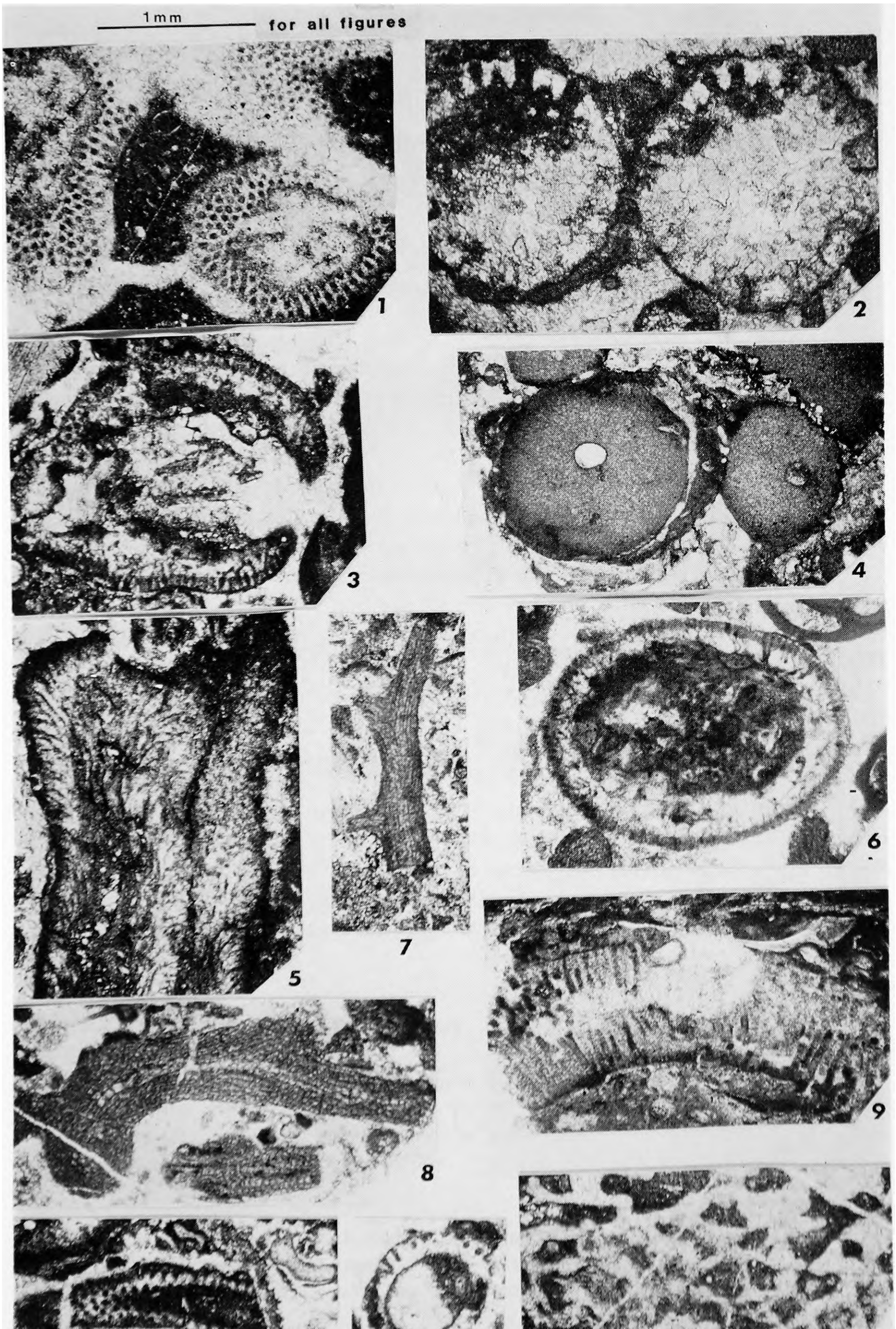
15 – 6 *Succodium* sp.
(Guguk Bulat-INDONESIA)

15 – 7, 8 *Ungdarella uralica* MASLOV
(Guguk Bulat-INDONESIA)

15 – 9 *Anthracoporella spectabilis* PIA
(Guguk Bulat-INDONESIA)

15 – 10, 11 *Gyroporella* sp.
(Silung Kang-INDONESIA)

15 – 12 *Hikorokodium* sp.
(Silung Kang-INDONESIA)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APPENDIX 4

MICROFACIES OF A FEW PERMIAN LIMESTONES OF SUMATRA, PENINSULAR MALAYSIA AND THAILAND

By

Henri FONTAINE

Microfacies of the Permian limestones of Southeast Asia have not been so far extensively studied, even though they are commonly well-preserved. In this paper, a few thin sections will be briefly described; photographs will help the reader to get more information.

Grainstones (IN356 and IN601), oolitic limestone (IN618) show that the Permian sediments were deposited in shallow water (less than 15 m deep) with high energy in some localities of the Jambi Province (Sumatra).

In the Shan-Thai Block, Permian limestone is commonly micritic. It contains tabulata, solitary tetracorallia and bryozoa at Ban Phu Plu in the Kanchanaburi area. South of Mae Sot, it is very rich in bryozoa associated with uncommon trilobites. Near Thong Pha Phum, Hagen and Kemper (1976) found the same type of limestone. "The rocks are mostly micrite and the by far dominant clastic components are bryozoan and crinoid fragments". This facies may correspond to a water depth of a few tens of meters.

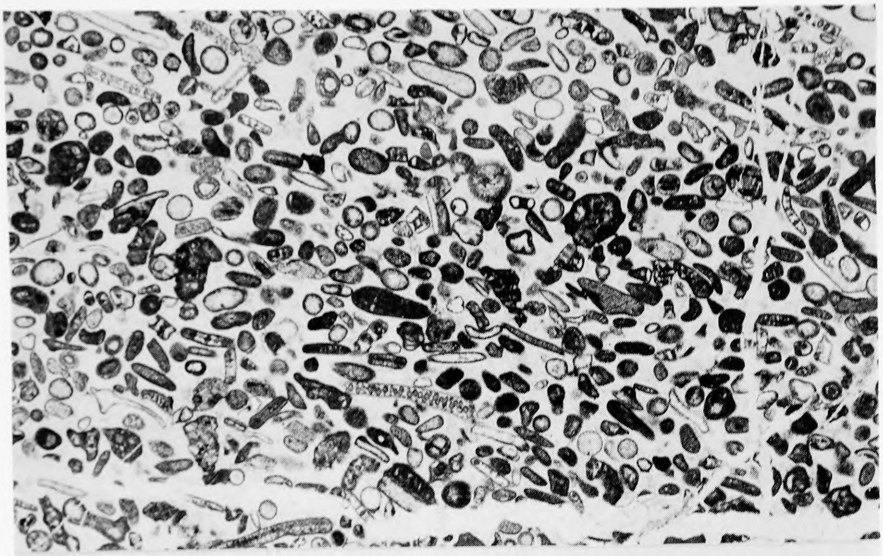
Many limestones of Southeast Asia are rich in fusulinids. A few thin sections are presented in the following plates. A foraminifera assemblage with abundant *Hemigordius renzi* has been found at Khao Pha Daeng about 20 km south of Phetchabun in Northeast Thailand (Sample T518).

All the samples photographed in this appendix are sediments deposited in sea with a normal salinity. Warm water environment is probable for all of them.

Plate 16

16 – 1, 2 Massive limestone (IN356) at Sungai Luati, a tributary of Batang Tembesi, Jambi Province, Sumatra. Murgabian in age. Bioclastic grainstone rich in algae (mainly *Epimastopora*) and foraminifera; particles are oriented (16–1) and indicate current energy. Cortoids are abundant. Aggregate grains are frequent. Water depth: less than 15 m.

16 – 3 Massive limestone (IN601) of Lubuk Cada at Tabir River, Jambi Province, Sumatra. Bioclastic grainstone, similar to that of Sungai Luati. Cortoids are less frequent; algae are more varied. Murgabian in age. Water depth: less than 15 m.



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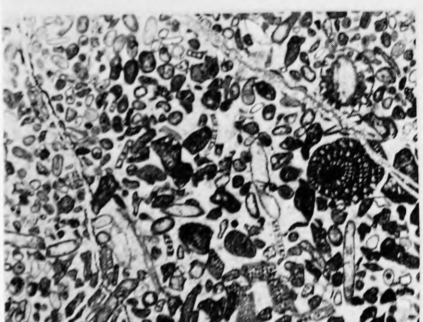

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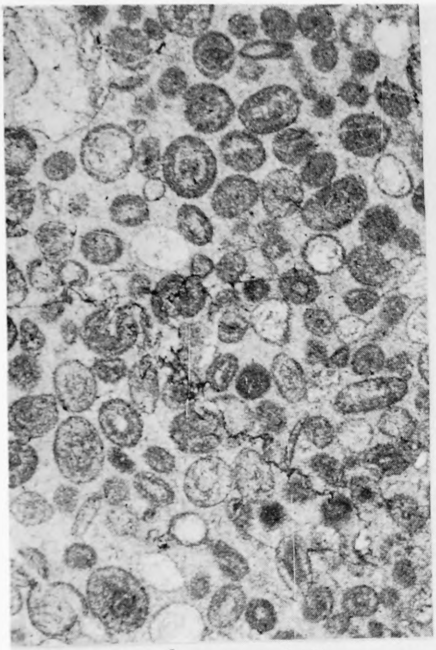
3 — 1 mm

Plate 17

17 – 1 Limestone (IN618) at Sungai Kibul, a tributary of the Tabir River, Jambi Province, Sumatra. Murgabian in age. Oolithic grainstone, poor in fossils. Shallow water and high energy.

17 – 2~4 Limestone (T833=17–2; T853=17–3; T856=17–4) of Ban Phu Plu, Kanchanaburi area, West Thailand. Wackestone containing a few fusulinids, abundant bryozoa, a few corals: *Sinopora* (17–2) and *Lophophyllidium* (17–4); displaying bioturbation characteristics (17–3). Murgabian in age (See chapter on Stratigraphy (Sai Yok Group). Water depth: probably twenty to a few tens of meters.

17 – 5 Limestone (T435) of Khao Pang Sawong near Muak Lek, a village located between Saraburi and Pak Chong, Central Thailand. Wackestone containing a few tetracorallia and scarce fusulinids. Lower Permian in age.



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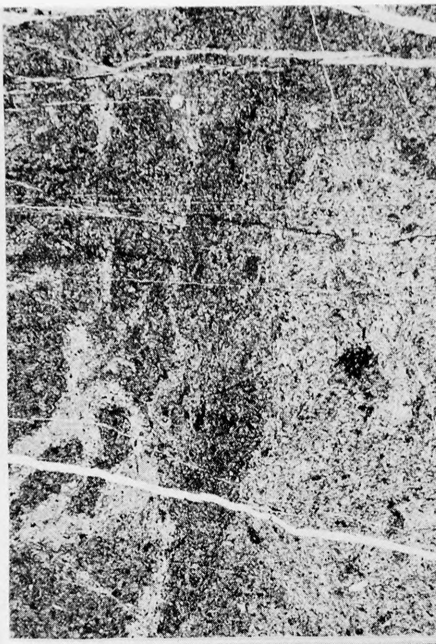

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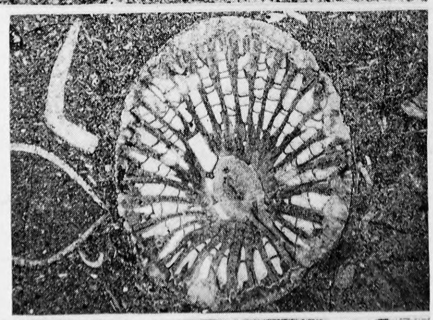

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5 1 mm

Plate 18

18 – 1, 2 Limestone (T1054) croping out near the road from Mae Sot to Umphang, at 49 km from Mae Sot. Wackestone very rich in bryozoa (See pictures of sample T1058 on plate 19; T1058 is from the same locality). Fusulinids are absent; one trilobite has been found. Probably Permian in age.

18 – 3 Limestone (M34) from the Jengka Pass on the road from Kuala Lumpur to Kuantan (Peninsular Malaysia). Packstone rich in fusulinids; the fusulinids are micritized at their periphery and some of them are wrapped in oncolithic structures. Late Murgabian–Early Midian in age.

18 – 4 Limestone (IN603) from Lubuk Kelelawar at the Tabir River, Jambi Province, Sumatra. Packstone rich in algae and foraminifera. Murgabian in age.

Plate 18

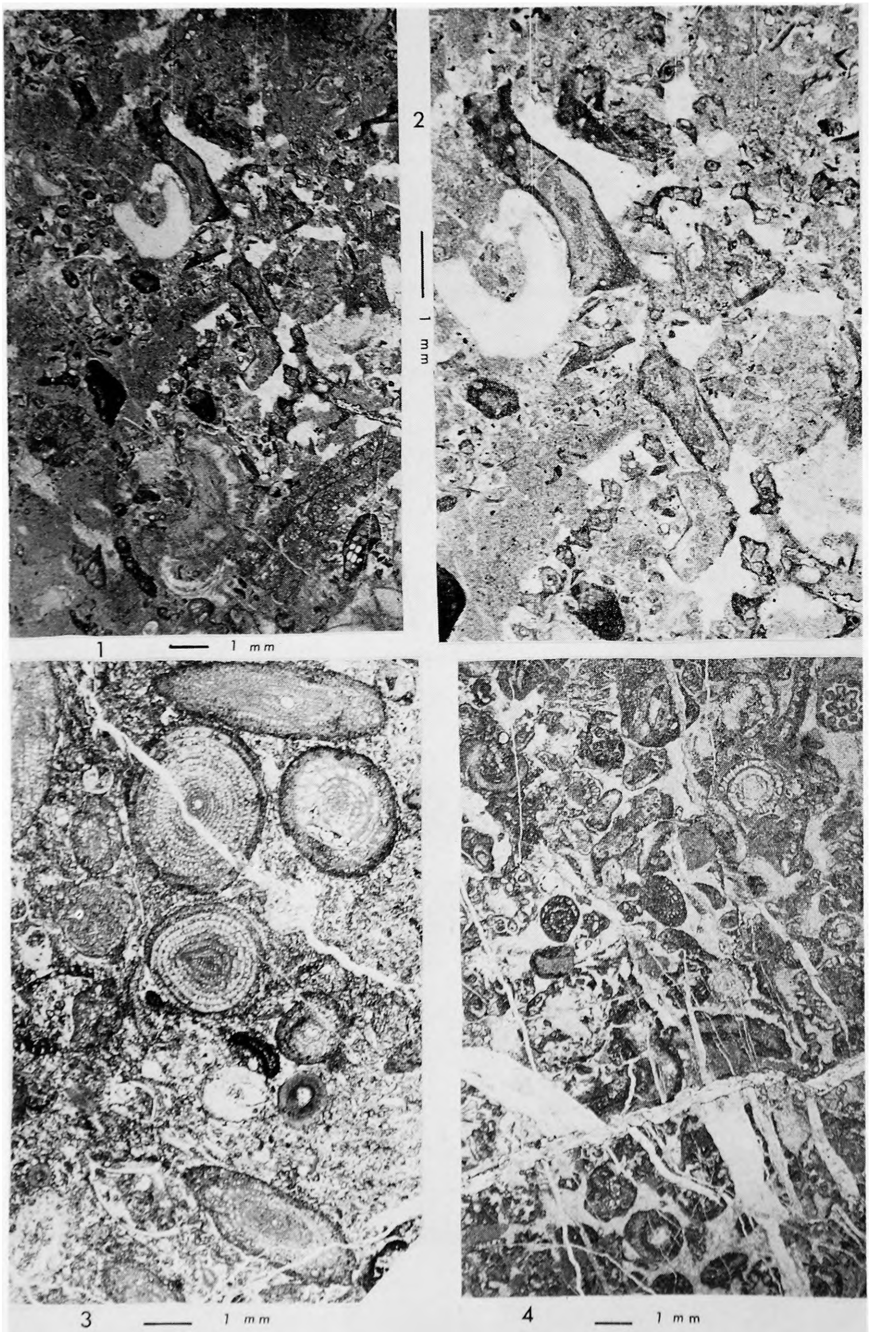


Plate 19

19 – 1 Bedded limestone (IN614) of Lubuk Cada at Tabir River, Jambi Province, Sumatra. Phylloid algae are well-developed; they are almost entirely recrystallized and are encrusted by some *Tubiphytes*. They were sediments binding organisms, contributing to the formation of quiet water "mud-mounds". Murgabian.

19 – 2 Limestone (T609) from Phra That Muang Kham in Lampang area, North Thailand. Wackestone containing corals (*Liangshanophyllum*) and foraminifera (*Neoendothyra*, *Dagmarita*, *Pseudovermiporella*, *Frondina permica*, *Pseudocolaniella*, *Colaniella*, *Reichelina*; identifications of D. Vachard); it is Late Permian in age, probably Wuchiapingian, not Early Triassic as it was previously believed.

19 – 3～5 Rock (T1058) almost entirely composed of Bryozoa. One trilobite pygidium has been found (19–4). Rock exposed along the road from Mae Sot to Umphang at 49 km from Mae Sot.

Plate 19

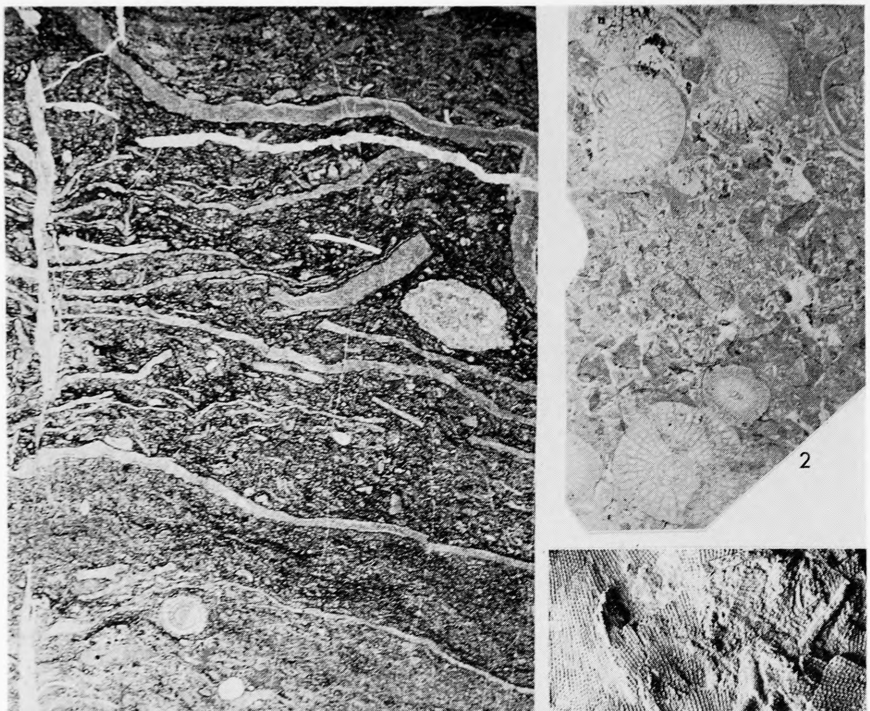


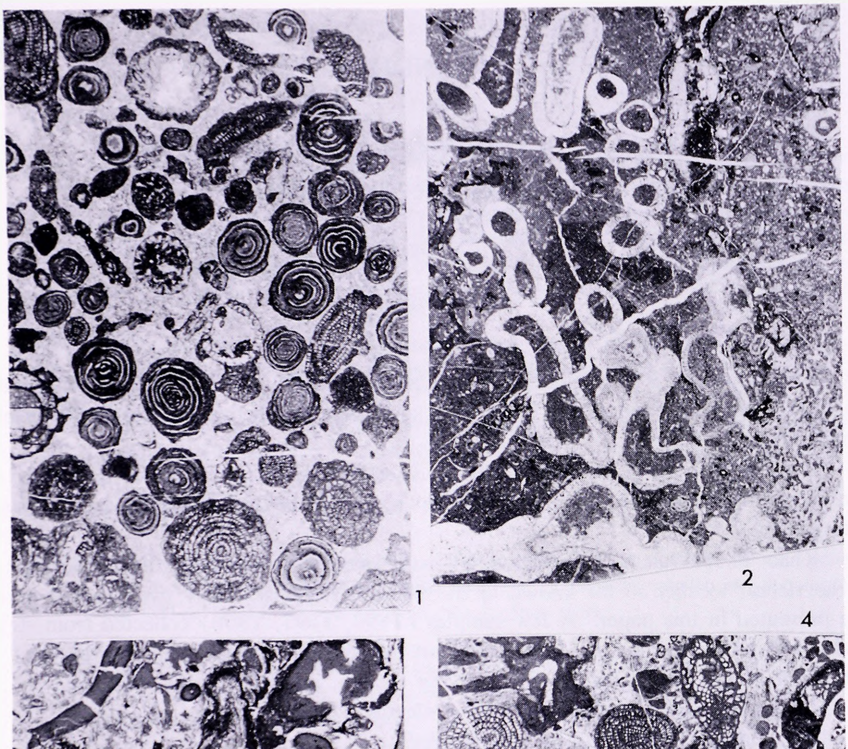
Plate 20

20 – 1 Packstone (T518) with algae and foraminifera. *Hemigordius renzi* is abundant. Khao Pha Daeng, south of Phetchabun. Late Murgabian.

20 – 2 Packstone (IN214) with *Vermiporella* and *Hikorocodium*. Bukit Macanti, Silungkang, Highland of Padang, Sumatra.

20 – 3 Packstone (IN214) rich in *Tubiphytes*. Silungkang, Sumatra. *Tubiphytes* is very common in the Permian limestones of Southeast Asia; it is not a good stratigraphical marker.

20 – 4 Packstone (IN260) with foraminifera and algae (*Ungdarella*). Tanah Sirah, a hill next to Guguk Bulat, Sumatra.


1
2
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APPENDIX 5

A FEW CORALS FROM MALAYSIA AND PENINSULAR THAILAND

By

Henri FONTAINE

This appendix is restricted to two localities, namely the Jengka Pass in Central Peninsular Malaysia and Khao Tham Sua southwest of Phetburi in North Peninsular Thailand.

For the first time, the Genus *Parawentzelella* (*Parawentzelella*) is mentioned at the Jengka Pass. Its stratigraphical position is similar to that of the types in western Kampuchea.

Khao Tham Sua is a limestone hill with massive Waagenophyllidae (corals); it is the richest locality so far known in the Shan-Thai Block. Only two massive corals are presented in this paper. A few samples (T893, T897, T906) collected from strata underlying and overlying the coral beds are Midian (or maybe Late Murgabian) to Dzhulfian in age; they contain the following species, identified by D. Vachard:

Algae: *Tubiphytes obscurus*, *Permocalculus*, *Mizzia*

Pseudoalgae: *Chuvashovia*, *Stacheoides*?

Small foraminifera: *Tetrataxis*, *Glomospira*, *Hemigordius* cf. *harltoni*, *Pachyphloia schwageri*, *Robuloides* aff. *lens*, *Diplosphaerina*, *Neoendothyra* cf. *reicheli*, *Climacammina*, *Tuberitina*, *Globivalvulina*.

Fusulinids: *Nankinella*, *Parafusulina*, *Pseudokahlerina*

Incertae sedis: *Permumbella*

At Khao Tha Mo, a hill near Khao Tham Sua, limestone contains very well-preserved *Shanita*, also indicating a Murgabian to Dzhulfian age. This foraminifera, known in the Middle-East, has been found only in the Shan-Thai Block in Southeast Asia.

Corals of Khao Tham Sua indicate a warm environment in North Peninsular Thailand by the beginning of the Late Permian and maybe the end of the Middle Permian.

Plate 21

21 – 1 *Paraipciphyllum*. Sample T903, Khao Tham Sua, southwest of Phetburi, North Peninsular Thailand. Transverse section. Corallites are 5 to 6 mm in diameter. Septa of two orders, 28 to 32 in number; minor septa are almost as long as the major septa. They are associated with elongate dissepiments and take a vesicular aspect at the corallite periphery. Walls are normally thick, with the exception of very short distances where they are thin or even absent.

21 – 2 *Paraipciphyllum*. T903, see 21–1. Longitudinal section. Columella, tabulae and clinotabulae are well-developed. Dissepiments, slightly irregular in size, in 3 to 5 rows.

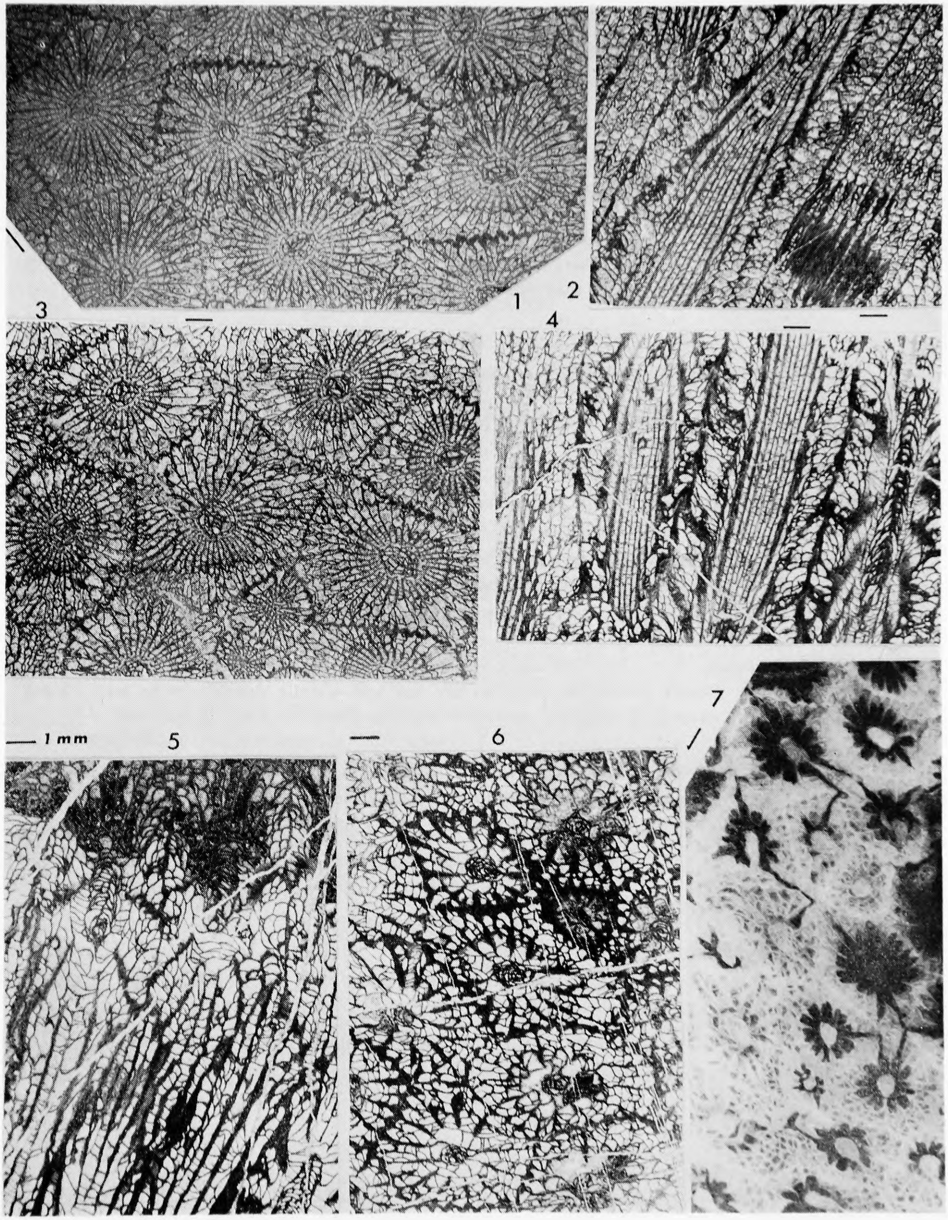
21 – 3 *Paraipciphyllum*. T904, Khao Tham Sua, southwest of Phetburi, North Peninsular Thailand. This sample is very similar to T903 of pl. 21–1, 21–2.

21 – 4 *Paraipciphyllum*. T904, see 21–3. Longitudinal section.

21 – 5 *Parawentzelella* (*Parawentzelella*) *canalifera* Mansuy. Longitudinal section; sample M31 from the Jengka Pass, Peninsular Malaysia. Columella, tabulae and clinotabulae are well-developed. Dissepiments in two to four rows.

21 – 6 *Parawentzelella* (*Parawentzelella*) *canalifera* Mansuy. Transverse section; M31, see 21–5. Canals connecting corallites are few and slightly difficult to be seen. Septa of two orders, 22 to 26 in number. Corallites are 4 to 6 mm in diameter.

21 – 7 *Parawentzelella* (*Parawentzelella*) *canalifera* Mansuy. Polished surface; M31, see 21–5. Canals connecting corallites are conspicuous. Age corresponding maybe to the extreme top of the Murgabian and mainly to the Lower Midian.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7
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APPENDIX 6

DISCOVERY OF PERMIAN LIMESTONE SOUTH OF TARA ISLAND IN THE CALAMIAN ISLANDS, PHILIPPINES

By

Henri FONTAINE, Nguyên Duc TIÊN and Daniel VACHARD

In the northeastern part of the Calamian Islands, limestone is exposed in three small islands; Malemeglemeg (= Malubutglubut on the map of scale 1 : 50,000; sample P107), Botulan (P106) and Getche (P105). Those islands are from 7 to 12 km south of the Tara Island and about 10 km offshore northeast of the Busuanga Island; they are rocks without inhabitants. In their surroundings, rocks exposed at low tide and islands are chert.

Limestone is massive. Slopes are steep and continue abruptly into the sea. Macrofossils are absent. Microfauna is locally rich.

The Permian was recognized as early as 1981, but only very poor in microfauna (Fontaine, 1982) were observed in thin sections; new thin sections were cut and new data have been obtained.

The sample P107 from Malemeglemeg is a wackestone poor in fossils, probably

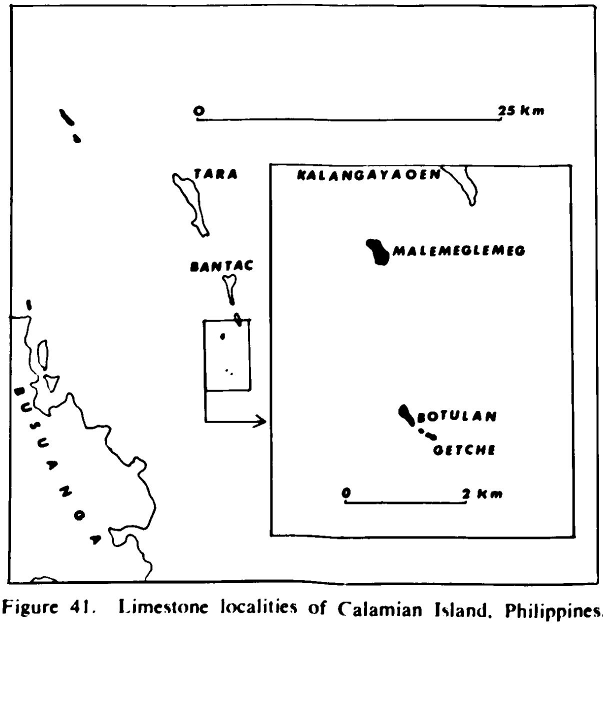


Figure 41. Limestone localities of Calamian Island, Philippines.

deposited in a relatively deep water (a few tens of meters).

It contains a few small foraminifera: *Baisalina, Pachyphloia, Geinitzina.* Its age is probably Murgabian-Midian in age as the Botulan limestone.

At Botulan Island, a wackestone (P106) with pellets and bioclasts, contains algae and foraminifera (Pl. 22–24):

Algae: *Tubiphytes obscurus, Mizzia velebitana, Permocalculus gracilis, P. plumosus.*

Small foraminifera: *Diplosphaerina, Climacammina, Globivalvulina, Dagmarita chanakchiensis, Glomospira, Baisalina pulchra, Geinitzina postcarbonica, Pachyphloia, Frondina permica, Partisania typica, Nodosaria, Ichtyolaria.*

Fusulinids: *Staffella, Reichelina tenuissima, Pseudokahlerina* (?), *Codonofusiella* (?).

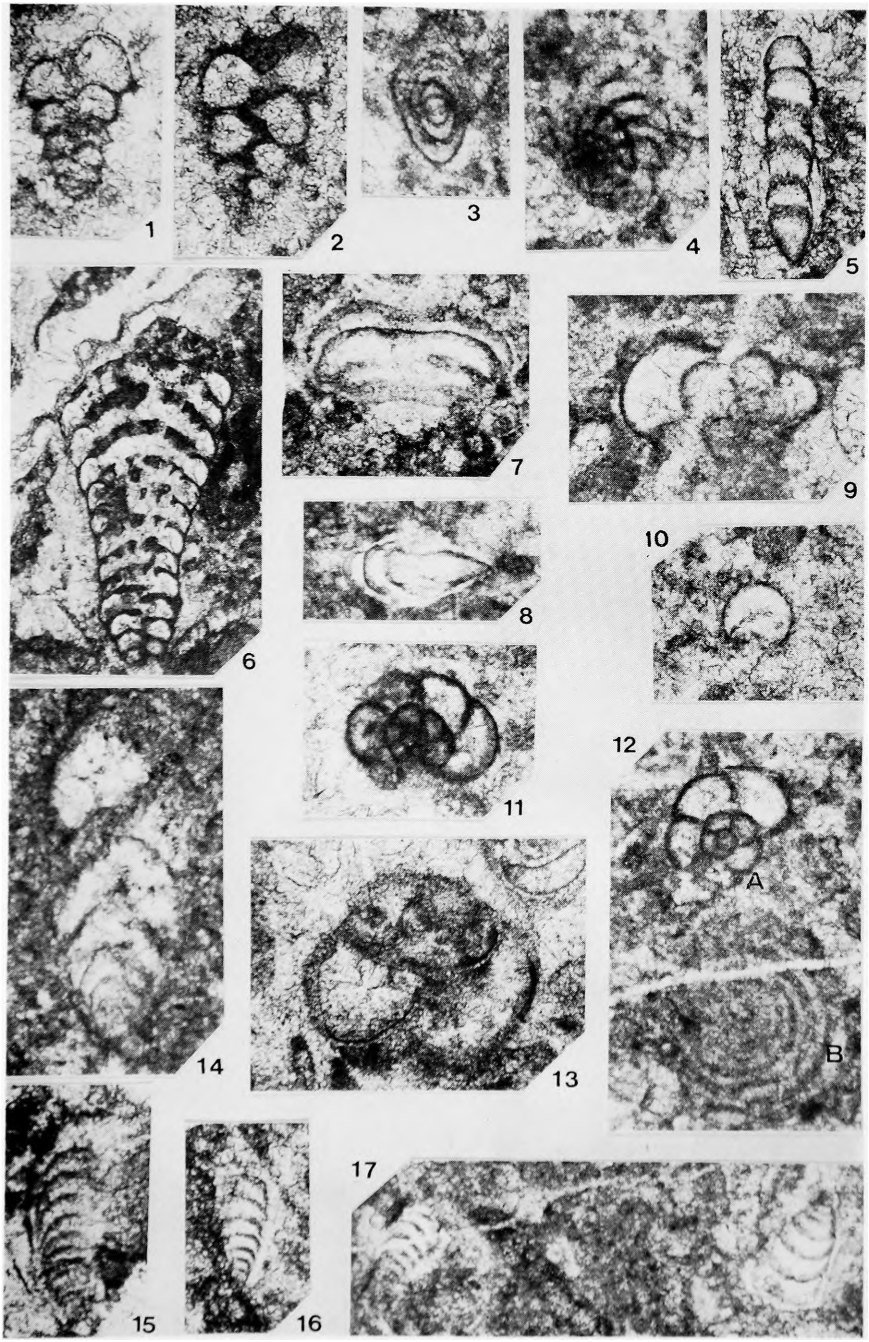
The Botulan limestone is Late Murgabian-Midian in age.

The limestone of Getche Island (P105) is a grainstone with oolithes; it is almost barren of fossils. It might be Permian or more probably Lower Triassic (maybe Scythian) in age.

Plate 22

Enlargement: ×80

22 – 1, 2 *Dagmarita chanakchiensis* REITLINGER
22 – 3, 4 *Reichelina tenuissima* MIKLUKHO-MAKLAY
22 – 5 *Nodosaria* sp.
22 – 6 *Climacammina valvulinoides* LANGE
22 – 7, 8 *Pachyphloia* sp.
22 – 9 *Tuberitina collosa* REITLINGER
22 – 10 *Eotuberitina reitlingerae* MIKLUKHO-MAKLAY
22 – 11 *Globivalvulina* cf. *graeca* REICHEL
22 – 12 A: *Globivalvulina* cf. *graeca* REICHEL
B: *Lasiodiscus* (?)
12 – 13 *Globivalvulina vonderschmitti* REICHEL
12 – 14 *Ichtyolaria latilimba* de CIVRIEUX & DESSAUVAGIE
12 –15~17 *Geinitzina postcarbonica* SPANDEL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A
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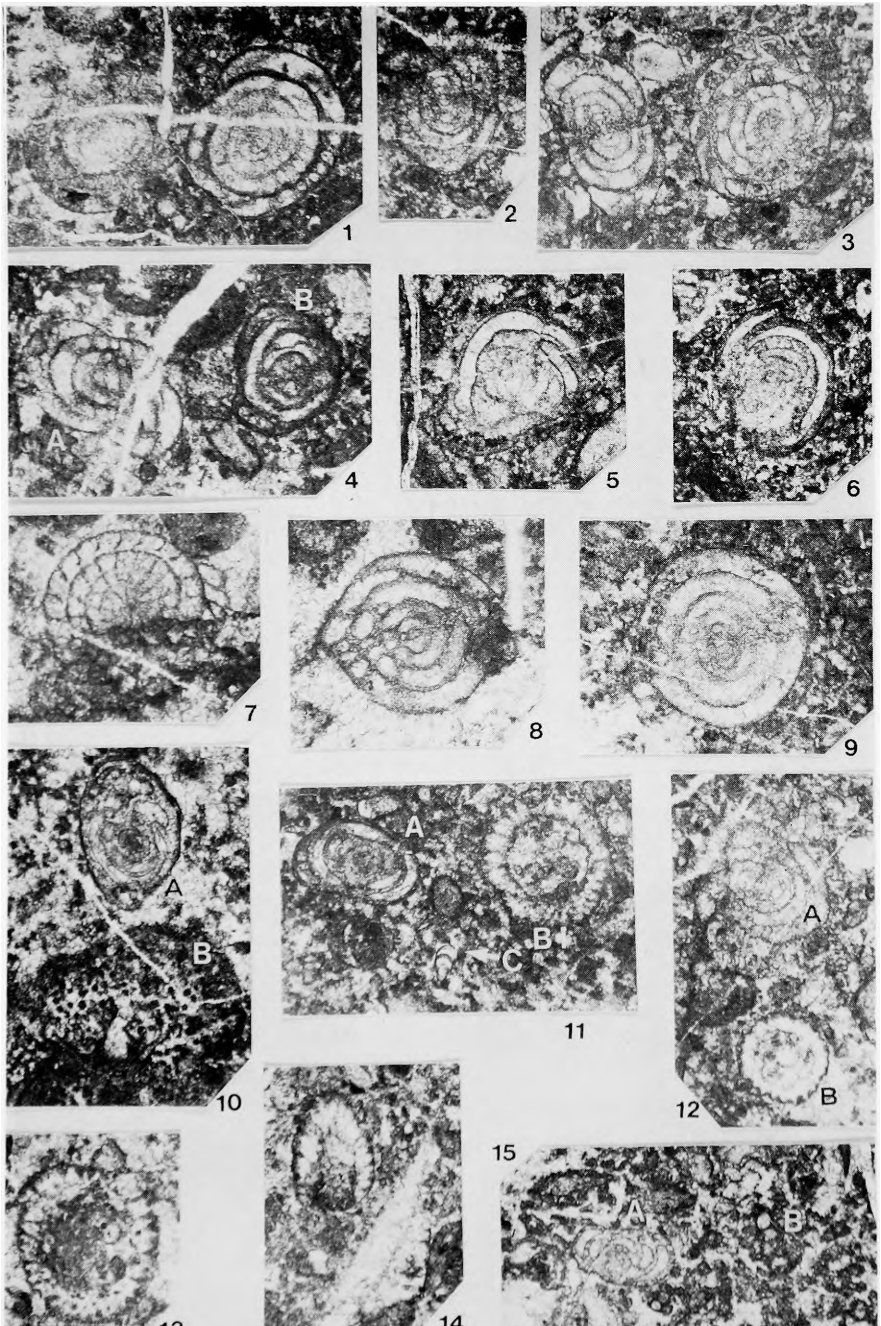
17

Plate 23

Enlargement: ×30

23 – 1~3 *Staffella* sp. 1
23 – 4 A: *Staffella* sp. 1
B: *Baisalina pulchra* REITLINGER
23 – 5, 6 *Baisalina pulchra* REITLINGER
23 – 7~9 *Staffella*(?) sp. 2
23 – 10 A: *Glomospira* sp.
B: *Succodium* (?)
23 – 11 A: *Glomospira* sp.
B: *Permocalculus plumosus* ELLIOTT
C: *Geinitzina postcarbonica* de CIVRIEUX & DESSAUVAGIE
23 – 12 A: *Staffella* sp. 1
B: *Permocalculus plumosus* ELLIOTT
23 – 13, 14 *Permocalculus plumosus* ELLIOTT
23 – 15 A: *Glomospira* sp.
B: *Dagmarita chanakchiensis* REITLINGER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10
A
B
C
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A
B
12
13
14
15
A
B

Plate 24

Enlargement: ×30

24 – 1, 2 *Mizzia velebitana* SCHUBERT

24 – 3 *Mizzia velebitana* SCHUBERT
(A: *Glovivalvulina* sp.)

24 – 4 *Mizzia velebitana* SCHUBERT
A: *Staffella* sp.
B: *Geinitzina* sp.

24 – 5 *Tubiphytes obscurus* MASLOV

24 – 6 *Permocalculus plumosus* ELLIOTT

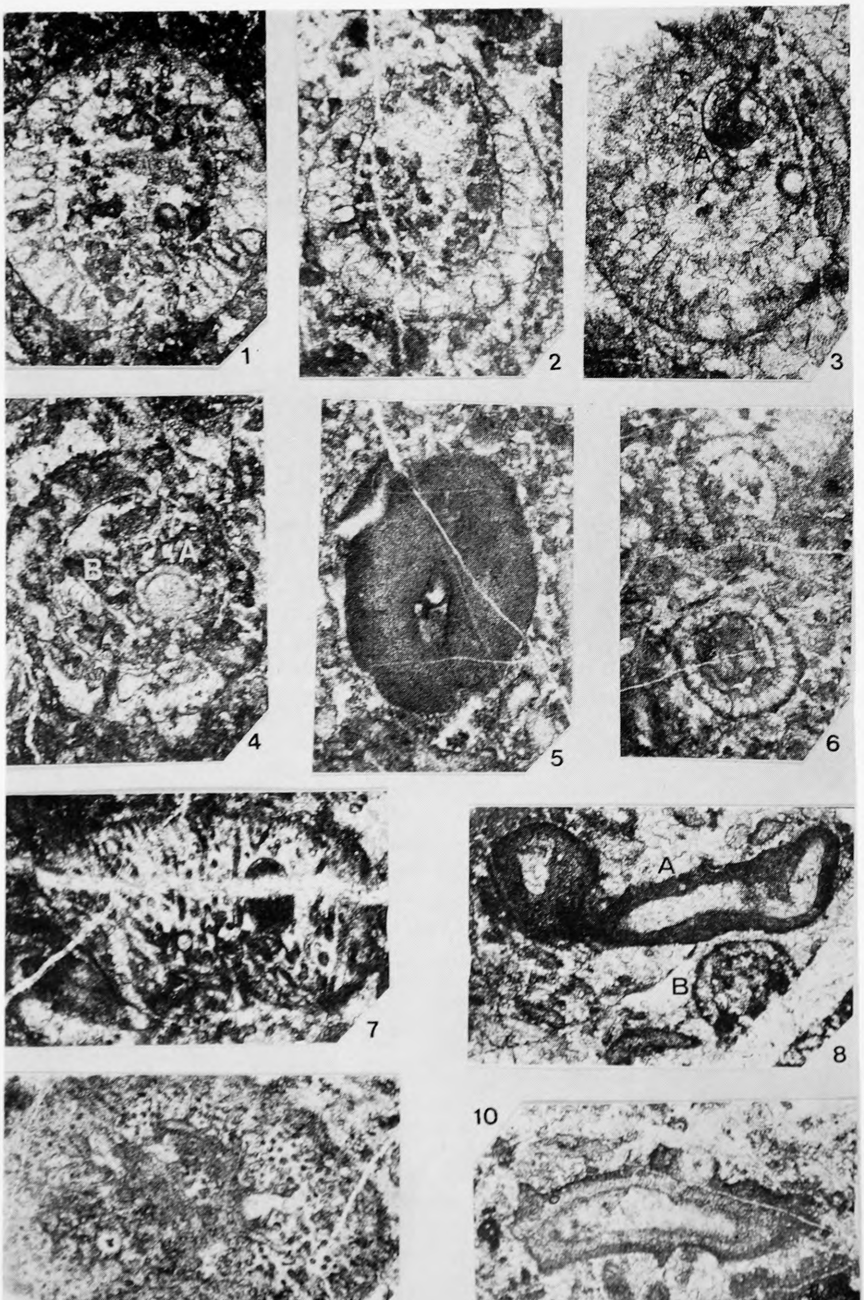
24 – 7 *Succodium* (?) sp.

24 – 8 A: *Tubiphytes obscurus* MASLOV
B: *Permocalculus plumosus* ELLIOTT

24 – 9 *Succodium* (?) sp.

24 – 10 An unidentified algae-

Plate 24



APPENDIX 7

TWO GYMNOSPERMOUS WOODS FROM THE LOWER PERMIAN OF JAMBI, SUMATRA

By

Colette VOZENIN – SERRA

At Telok Gedang in the rice fields of the left bank of the Merangin River, fossil woods are abundant and scattered on the ground; they are commonly parts of huge tree trunks. Two samples: IN442 and IN445 were collected in 1983 by Henri Fontaine; they are described in the following plates. They belong to the Cordaitaceae (IN442) and to the Coniferaceae (IN445); they are in agreement with a Lower Permian age, the age of the rocks upon which they lie.

Growth rings are not discernible; accordingly, these woods are indicative of a tropical climate.

The cordaitean structure described in this paper is akin to woods found in North America, Europe, China, Kampuchea and Southwest Egypt. It is different from structures known in the Upper Palaeozoic of Angara and Gondwana.

The characteristics of *Dadoxylon* cf. *saxonicum* are primitive, looking more primitive than the Lebachiacean woods collected from Europe. This fact may be explained by more stable conditions in tropical areas, allowing relict forms to survive. Such a fact is usual in the Cathaysian flora which is rich in plants known from the Carboniferous onwards.

References:

Frentzen, K., 1931, Beitrage zum Oberrheinischen Fossilkatalog. Nr 1 & 6. *Abh. Heideb. Akad. Wiss. Math. Nat. Kl.*, vol. 16, p.1–93, pl. 1–3; vol. 19, p. 1–51, pl. 1–5.

Vozenin-Serra, C., 1971, Notes sur des bois mésozoïques et cénozoïques du Viet Nam et du Cambodge. *Arch. Géol. Viet Nam*, vol. 14, p. 1–14, 8 fig., 2 pl.

Plate 25

Dadoxylon (*Cordaioxylon*) *roviengensis* Vozenin-Serra

Anatomic features: Pycnoxylic wood. Resin ducts and growth rings absent. Tracheids sections widely quadrangular; average diameter of lumen: 60–88 μM. "Cordaixyloid" radial pits (Frentzen, 1931), 3 to 5–seriate, hexagonal, occupying the whole tracheid wall, with oblique slit-like apertures and crossed apertures; average radial diameter of pit border: 14–16 μM. Very high rays (up to 52 cells deep), 1–seriate or locally 2–seriate for several cells and at several levels in the same ray, with a rather heterogeneous aspect. Density: 7 to 9 per horizontal mm, 18 to 26 per square mm. Ray cells elongate in radial section (Height: 32 μM; width: 20–40 μM; length: 210 to 240 μM). There are normally 2 to 9 pits arranged in 1 or 2 rows in each field; they are broadly elliptical in outline, separated from each other. The aperture is broad, slightly bordered and horizontally orientated, locally coalescing.

25 – 1 Sample IN442. Transverse section showing the quadrangular shape of the tracheids lumina.

25 – 2 IN442. Tangential section displaying biseriate rays, rather heterogeneous.

25 – 3 IN442. Radial section showing "cordaixyloid" pits in radial tracheid walls.

25 – 4 IN442. Radial section; cross fields aspect–observe the laterally compound pits in the the cross fields (arrow).

25 – 5 IN442. Cross fields; slightly bordered pits, with large elliptical apertures.

IN442 = Fragment of black wood, 6 × 4 × 6 cm

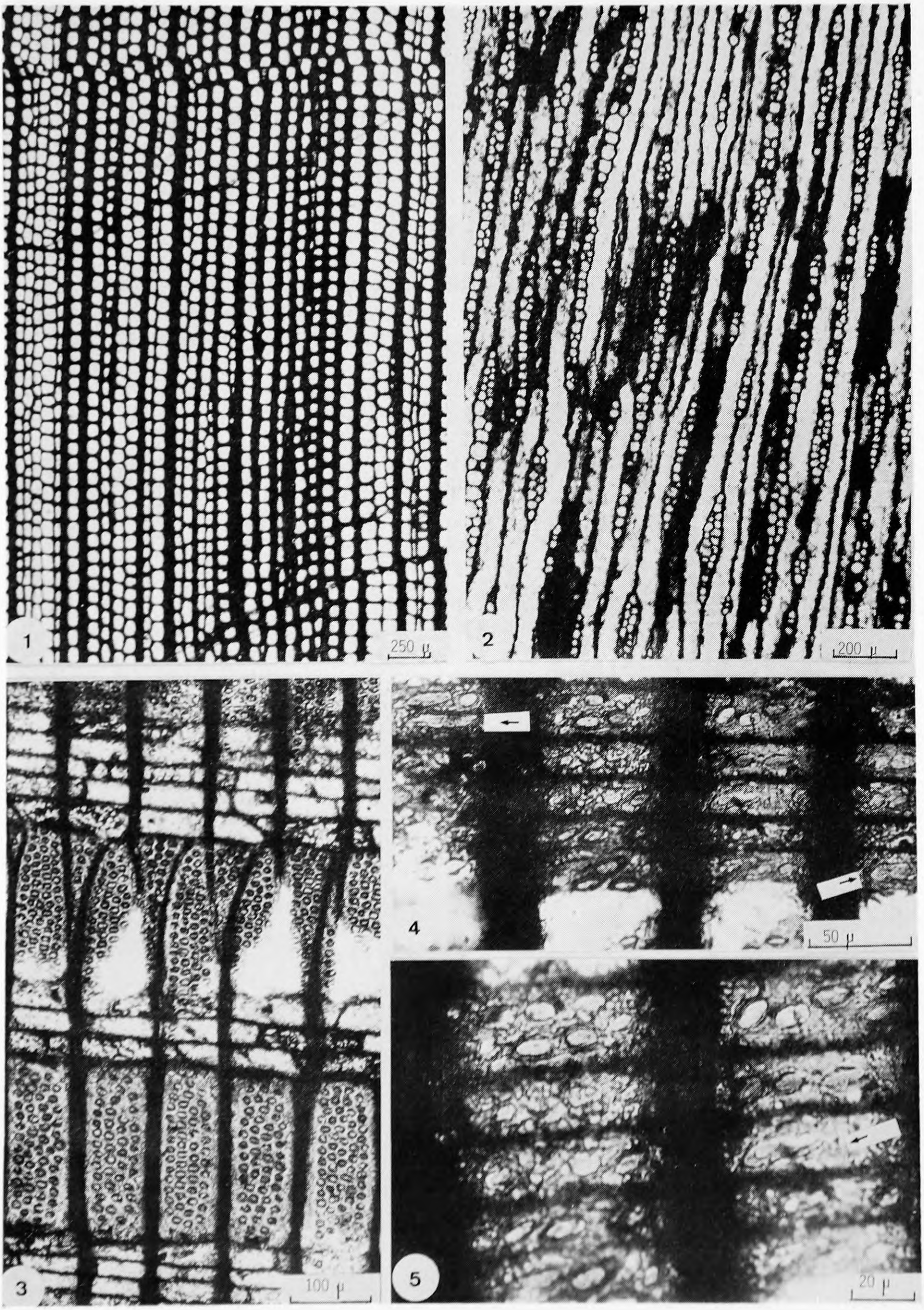

1
250 μ
2
200 μ
3
100 μ
4
50 μ
5
20 μ

Plate 26

Dadoxylon cf. *saxonicum* (Goeppert) Frentzen

Anatomic features: Pycnoxylic wood, without resin ducts and growth rings.

Tracheids with quadrangular lumina (Diameter=25 to 70 μM)

Typical araucarioid pitting, 1–2–3 seriate, hexagonal (Diameter=17–20 μM) with circular to elliptical aperture, occuring on the whole surface of the tracheids.

Homogeneous Rays, 1–seriate (scarcely 2–seriate for one cell), normal height (up to 25 cells).

Density: 9 to 11 per horizontal mm, 32 to 38 per square mm.

Ray cells with smooth and thin horizontal walls; length=about 240 μM, width=28 to 36 μM.

Cross fields, rectangular, araucarioid; they exhibit many cupressoid bordered pits (2 to 9 in one field, but more frequently 4 to 6), alternate and contiguous (about 12 μM in diameter).

26 – 1 Sample IN445. Transverse section. Growth rings indiscernible.

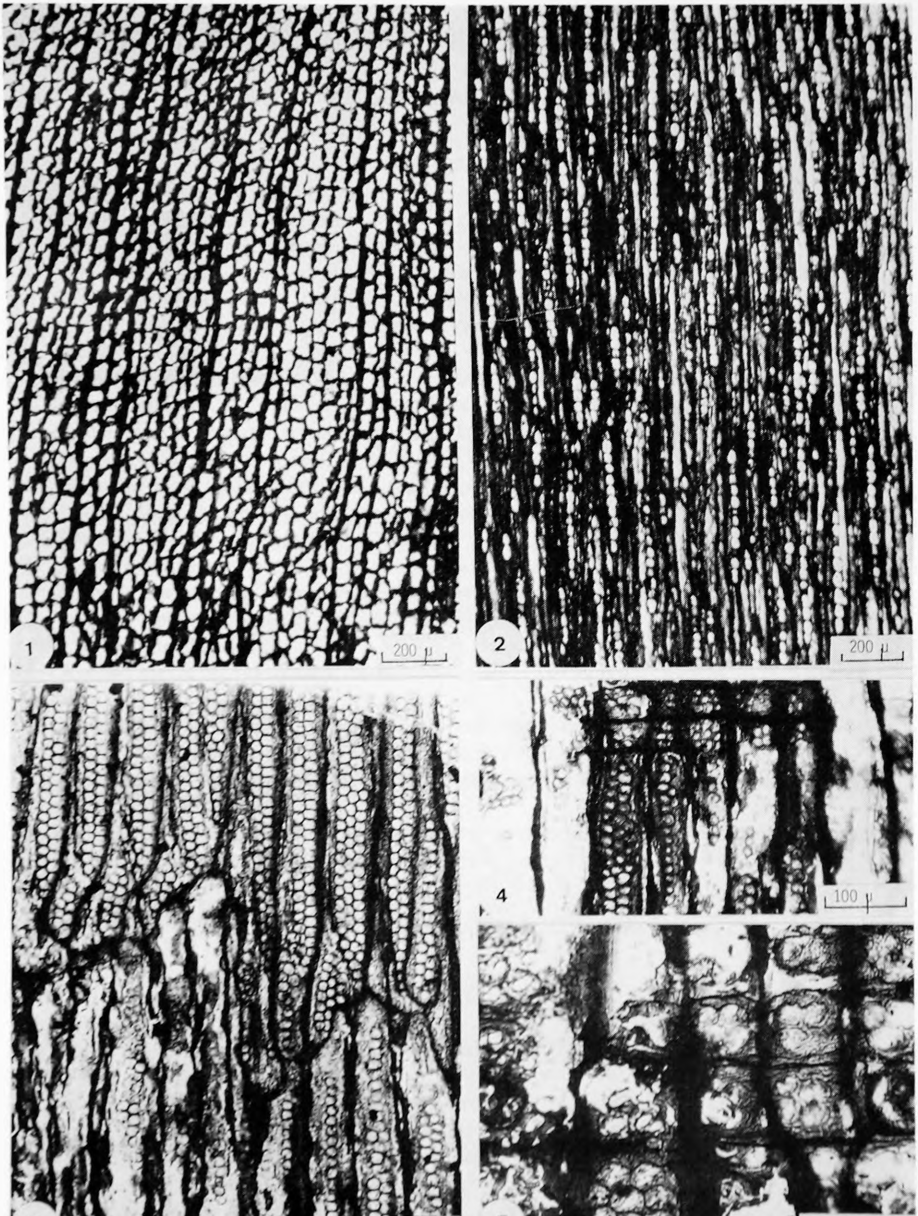
26 – 2 IN445. Tangential section; low and narrow rays.

26 – 3 IN445. Radial section showing araucarioid pattern in the tracheid walls.

26 – 4 IN445. Radial section showing araucarioid cross fields.

26 – 5 IN445. Cross fields displaying several crowded cupressoid pits in araucarioid arrangement.

IN445=Wood fragment, beige at surface, black at fractures, 5×7×6.5 cm in size.


1
200 µ
2
200 µ
3
100 µ
4
100 µ
5
50 µ

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By
W. Bosum[1], J. C. Fernandez[2], E. G. Kind[1] and C. F. Teodoro[2]

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1 Bundesanstalt für Bodenforschung, 3 Hannover-Buchholz, Federal Republic of Germany
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Geological Survey of Japan, 1964, Geological Map of Japan: Scale 1:2,000,000, one sheet.

Menard, H. W., 1964, *Marine geology of Pacific:* McGraw-Hill, New York, U.S.A., 271 pp.

Murauchi, S., and H. Hotta, 1968, Studies of the continental slope off the Sanriku Coast by seismic profiler survey (in Japanese): *Natl. Sci. Museum. Mem.*, no. 1, p. 37–40.

———*et al.*, 1968, Crustal structure of the Philippine Sea: *Jour. Geophys. Research*, vol. 73, p. 3143–3171.

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