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Later Mesozoic Flora from Maran, Pahang, West Malaysia Part 1: Geologic Considerations

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Abstract: Plant megafossils were collected from two localities and two stratigraphic levels in the measured section of later Mesozoic rocks that crop out near Maran, Pahang, West Malaysia. Comparisons of lithologies and of lithologic sequences suggest that the Maran section is equivalent to the medial portion of the type-section of the Tembeling Formation along the Tekai R.ver to the northwest. Similar rocks are exposed along a belt essentially parallel to the peninsular axis, and plant megafossils are known from four areas about evenly-spaced along the belt.

A biostratigraphic zone appears to be represented by the association of *Gleichenoides* (ferns) and *Frenelopsis* (conifers) in the lower Maran florule; this is the same association of plants found also in the Panti area of southern Johore. A second biostratigraphic zone appears to be represented by different species of *Gleichenoides* with several kinds of cycadophytes in the upper Maran florule; this association of plants is found also in the Ulu Endau area between Panti and Maran. The composite of both Maran florules is nearly identical to the Gagau composite flora collected from several localities in northern Pahang.

Subject to future verification, it appears that the plant-bearing beds in the Gagau and Maran areas are of equivalent age; that the Gagau plant-bearing beds (Lotong sandstone) are equivalent therefore to the medial part of the Tembeling type-section; that the Ulu Endau flora correlates floristically with the upper Maran florule; and that the Panti flora correlates floristically with the lower Maran florule. The Maran plants most closely resemble species of Neocomian age from other parts of the world. The later sediments in the West Malaysia belt are considered to be early Cretaceous in large part, with a limited palynological record suggesting a Jurassic age for the deposits lower in the series. An open forest of few plant taxa is inferred to have occupied the region, under a climatic regime having a distinct dry season.

INTRODUCTION

Plant megafossils were collected from two localities in east-central Pahang, West Malaysia, during the later part of 1968. The localities occur approximately one and four miles north of the town of Maran, in road cuts along logging tracks. The geographic coordinates are about 3°40′ North latitude, and about 102°45′ East longitude (Fig. 1).

The localities were discovered by Ayob (1968) during his field studies on lateral equivalents of the Tembeling Formation recently described by Koopmans (1968). Rocks of probably equivalent age crop out in the G. Gagau area of northern Pahang (Geological Survey of West Malaysia files), and sample fossil collections from several

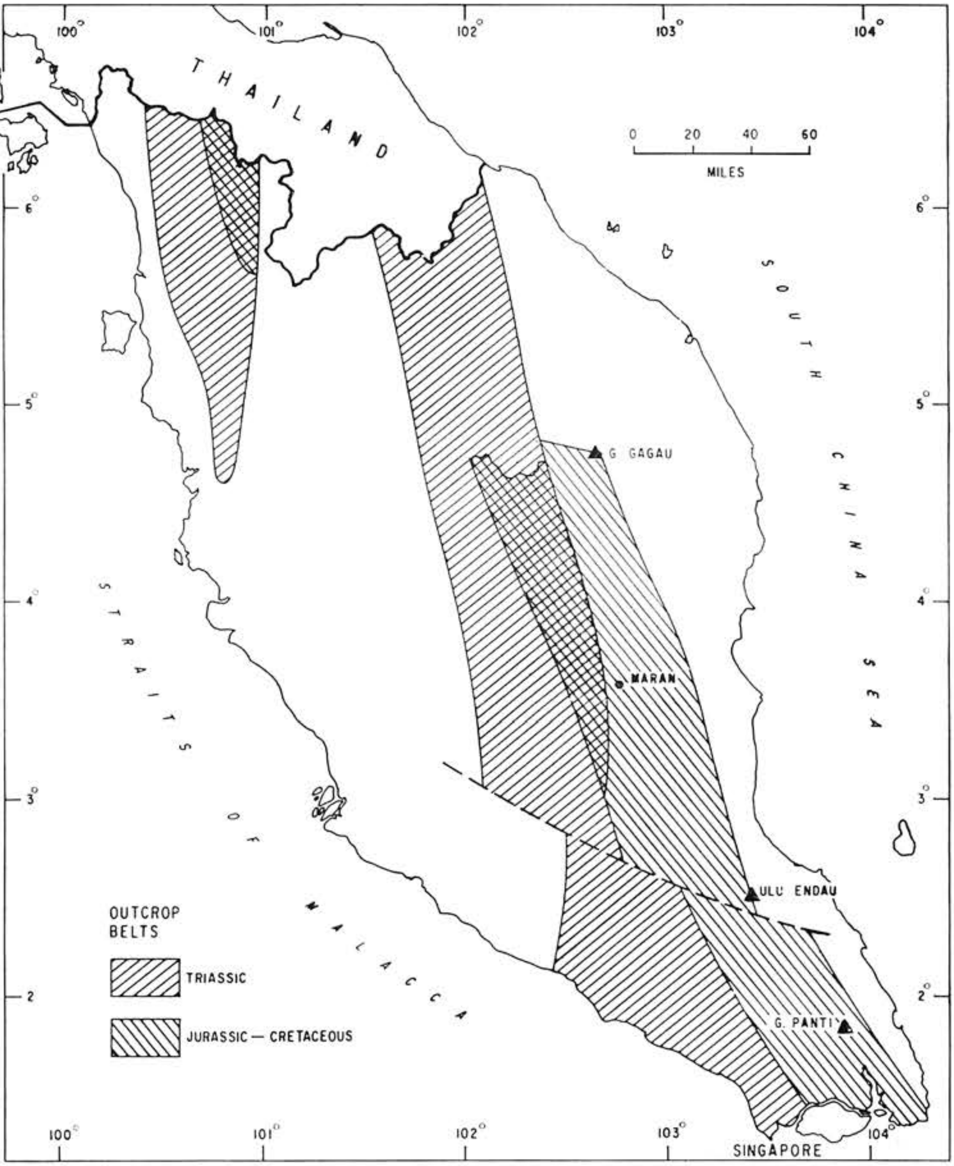

Fig. 1. Map of West Malaysia showing later Mesozoic floral localities in relation to belts of outcropping Mesozoic sediments. Gagau composite flora, and Panti flora, were sampled by members of the Geological Survey of West Malaysia, and were studied by Kon'no (1967, 1968). Ulu Endau flora was sampled by Suntharalingam (see Fig. 3). Maran florules were collected by Smiley, Ayob, and assistants from the Department of Geology, University of Malaya (this paper).

Gagau localities were described as a composite flora by Kon'no (1967, 1968). Recent field studies by S. S. Rajah and T. Suntharalingam of the Geological Survey of Malaysia have shown the lateral relations of apparently equivalent rocks in the Ulu

Endau and Panti areas of Johore (personal communications, 1969). Small sample collections of plant megafossils were obtained by them in their respective study areas, but the floras have yet to be collected and studied in detail (in his 1967 paper, Kon'no listed one species from Ulu Endau and three from Panti).

M. Ayob's field mapping and section measurements in the Maran area were a part of his Master of Science thesis (1968). He accompanied the author on a field trip to the Maran area and directed him to the fossil sites. Field assistants during this and a subsequent collecting trip were D. S. Dhillon and A. W. Boey of the Department of Geology, University of Malaya. Project funds for the floral studies were provided by the Fulbright Commission, Kuala Lumpur, and facilities for research were provided by the Department of Geology, University of Malaya. I am most grateful also to the numerous staff members of the Geological Survey of West Malaysia, and of the Department of Geology, University of Malaya, for their generous cooperation and information concerning various aspects of the study.

GEOLOGIC SETTING

Outcrop belts

An older and a younger belt of Mesozoic sediments appear to be present in the central and east-central part of West Malaysia, both trending approximately parallel to the peninsular axis (Fig. 1). The older Mesozoic belt, containing sediments of Triassic age based on marine lamellibranchs (pelecypods), is located near the center of the peninsula and generally west of the younger Mesozoic belt. The belt of later sediments appears to overlie the Triassic deposits along a part of its western edge, and to overlie upper Paleozoic deposits on the east. Regionally the strata of the older Mesozoic belt are more contorted, with high-angle dips and some overturning noted in roadcuts along the Kuala Lumpur–Kuantan highway. Strata of the younger Mesozoic belt are more gently folded, with dips not normally exceeding 15° to 20° and commonly less. On the basis of regional dips, therefore, an unconformable relation is inferred to exist between the older (marine) and the younger (nonmarine) clastic sediments of Mesozoic age.

The boundaries between later Paleozoic, older Mesozoic, and younger Mesozoic exposures appear to be significantly offset along a line trending eastward from about Kuala Lumpur to the Ulu Endau area (Stauffer, 1968; Burton, manuscript). This line appears to represent a complex zone of left-lateral strike-slip faulting, called the "Kuala Lumpur fault zone" by Stauffer (1968), resulting in a marked eastward displacement of the southern parts of the two Mesozoic belts. Geologists of the Geological Survey of West Malaysia have noted essentially parallel faults elsewhere in the region, suggesting an en-echelon type of faulting along the southern part of the Malay Peninsula (personal communications, 1969); but the major fault zone on Fig. 1 is the only one now known to significantly offset both older and younger Mesozoic belts.

Identifiable plant megafossils are known to be present in four areas along the younger Mesozoic belt, about equally spaced over a distance of 230 miles from G. Gagau at the north to G. Panti at the south (Fig. 1). The Gagau and Maran areas are north of the major fault zone; the fault zone cuts through the Ulu Endau area; and the Panti area is in the southern block. The same general type of Mesozoic vegetation is indicated by the plant megafossil records in the four areas.

Physical stratigraphy

The younger Mesozoic belt of sediments is in part superimposed upon rocks of Triassic age and in part upon rocks of upper Paleozoic age. Marine fossils in these underlying units are of ages ranging from Lower Carboniferous to possibly Upper Triassic (Jones and others, 1966). Underlying what appear to be typical later Mesozoic sediments in Kedah (predominantly red-colored sandstones and conglomerates) are marine clastics with species that may be of Upper Triassic age (Ong, 1968). An event of regional diastrophism between the episodes of earlier (marine) and later (nonmarine) Mesozoic sedimentation is suggested by the regional evidence of high-angle dips for Triassic strata and of gentle folding for later Mesozoic rocks.

In some places the plant-bearing sediments of later Mesozoic age rest unconformably on the denuded and weathered surfaces of granitic plutons. Snelling and other (1968), reporting on 30 whole rock Rb:Sr age determinations of various granite bodies in West Malaysia, have indicated intrusive episodes ranging from Upper Carboniferous (280 to 300 m.y.) to late Cretaceous (70 m.y.). The Paleozoic granites are located mainly on the east side of the peninsula and to the east of the Mesozoic sedimentary belts. The Triassic granites (200 to 230 m.y.) occur largely in the Main Range to the west of the sedimentary belts. Isolated late Cretaceous granite bodies are located on the west side of the peninsula. K:Ar age determinations mentioned by Hutchison (1968) on micas and hornblendes show a marked concentration between 175 and 230 m.y. (Triassic to early Jurassic).

Snelling and others note that the Rb:Sr dates indicate major episodes of granitic emplacement (and presumed uplift) in upper Paleozoic (280–300 m.y.), in earlier Triassic (230 m.y.), in later Triassic (200 m.y.), and perhaps in late Cretaceous (70 m.y.). They suggest that the K:Ar dates from micas and hornblendes indicating an upper Triassic-lower Jurassic age (about 180 m.y.), without corroborating Rb:Sr whole rock ages, probably indicate a late Triassic-early Jurassic tectonic disturbance that affected the K:Ar minerals in older granites.

In the central part of the later Mesozoic belt there appear to be some local volcanic sheets immediately underlying the younger sediments (Koopmans, 1968, p. 38; Suntharalingam, 1969). Age determinations have not yet been made on these volcanic rocks, and their relations to other Mesozoic strata are known only on a superpositional basis. They could well represent extrusive vulcanism during the late Triassic-early Jurassic tectonic activity suggested by the radiometric data mentioned above (about 180 m.y.).

From data presently available, it would appear that the sequence of physical events relative to later Mesozoic sedimentation was (1) A Permo-Triassic uplift with granitic instrusion, followed by a period of erosion; (2) development of a trough-like basin in the Triassic, essentially parallel to the axis of the present Malay Peninsula, with deposition of clastic sediments that appear to be shallow marine in origin. This Triassic belt seems to have been bounded on the west by a positive area of older granites and Paleozoic sediments, and on the east by a positive area of chiefly Paleozoic deposits; (3) in late Triassic and possibly continuing into early Jurassic, an episode of regional diastrophism resulted in cessation of deposition, folding of Triassic sediments, and subsequent erosion to depths that denuded at least some of the Triassic plutons; (4) volcanic activity resulting in lava flows and pyroclastics may have terminated this episode of diastrophism; (5) during the Jurassic a second trough-like basin developed generally parallel to the earlier one and along its eastern

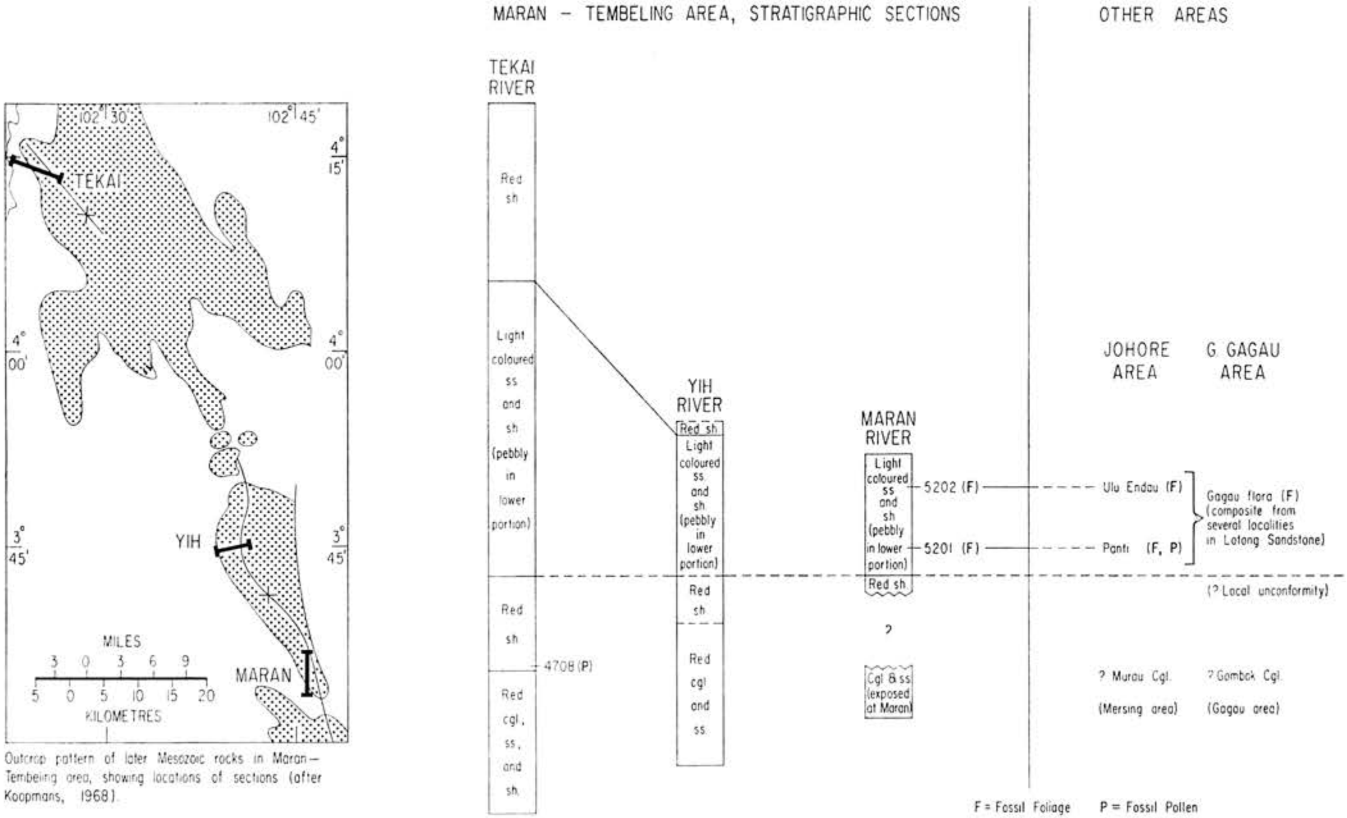

Fig. 2. Correlation of stratigraphic sections in the Maran-Tembeling area of Pahang, West Malaysia. Tekai River section (type-section of Tembeling Formation) after Koopmans (1968). Yih River section and Maran River section after Ayob (1968). Fossil horizons indicated by locality numbers (5101, etc.).

margin, with deposition of non-marine clastics that are predominantly red or white in color, and commencing with a basal conglomerate. The later Mesozoic trough was bounded on the east by a positive area of granites and Paleozoic sediments which may have been the principal source area of the basal conglomerates (Koopmans, 1968). On the west, in the general area of the present Main Range, was an upland of granites and Paleozoic sediments with folded Triassic deposits along its eastern flanks; (6) following later Mesozoic deposition, regional faulting took place on a large scale, resulting in a series of generally east-west en-echelon faults and an eastward displacement of the southern end of the Malay Peninsula. The time during which this faulting occurred is not now known with certainty, but it appears to have occurred after deposition of the later Mesozoic sediments and to have affected Neogene deposits near Kuala Lumpur.

Rock units have been studied in varying degrees of detail in three parts of the later Mesozoic belt: (1) the G. Gagau area on the north, by the Geological Survey of Malaysia (files of unpublished field reports); (2) the Maran–S. Tembeling area in the middle portion of the belt, by Koopmans (1968) and M. Ayob (1968); (3) the Johore area on the south, presently under study by S. S. Rajah and T. Suntharalingam of the Geological Survey of Malaysia.

Reconnaissance study of the northernmost (G. Gagau) area indicated the presence of two unconformable units that have been referred to the Gagau Group: a lower conglomeratic unit called the Gombok conglomerates, and an upper unit of predominantly sandstone with interbedded lavas called the Lotong sandstone. The field study did not include detailed section measurements or lithological descriptions of sequential beds, and the stratigraphic positions of the fossil plant localities were not determined at that time. Because of the present lack of detailed knowledge of the rocks in this northern area, and because of the undetermined stratigraphic positions of the various plant localities within the local section, the Gagau stratigraphy and floral records are difficult to use as standards of reference for regional correlations.

The centrally-located Maran-Tembeling area has received the most detailed study of any area in the later Mesozoic belt. The field studies of Koopmans and Ayob have resulted in the lateral tracing and the geographic delimitations of later Mesozoic deposits in the area, and have resulted in several detailed sections that have been measured, described, correlated, and recorded in the literature (Fig. 2). Two taxonomically distinct florules have been found at different levels in Ayob's measured section from S. Maran, providing a basis for regional biostratigraphic correlations. This reasonably well-known, accessible, and centrally-located area would appear to be the best standard for reference of lithostratigraphic and of biostratigraphic units that are found along the later Mesozoic belt to the north and to the south.

The current studies of Rajah (1969) and Suntharalingam (1969) in Johore have established the lateral continuity of later Mesozoic sediments from the Panti area northward to the Ulu Endau area. These predominantly sandstone units, called the Panti formation, appear to be lateral equivalents of a portion of Koopman's Tembeling Formation and of Ayob's Maran section. They also appear to be equivalent to the upper unit (Lotong sandstone) of the Gagau group in the G. Gagau area.

The Murau Conglomerate, named by Koopmans (1968) for rocks exposed in the east coastal Mersing area of Johore, is here considered as a formally established rock unit. Whether the basal conglomerates in the Maran-Tembeling area are equivalents of the Murau Conglomerate as proposed originally by Koopmans has not been demonstrated by lateral tracing. Thus the position of the Murau Conglomerate at the base of the Tembeling Formation as shown on Koopmans' correlation chart (1968, fig. 3, p. 28) is not yet proven. Until the proposed lateral extension of the Murau Conglomerate into other areas can be demonstrated by additional studies, the formal name should be limited to the exposures in the type area near Mersing.

The two plant megafossil localities in the Maran section occur at distinctly different stratigraphic levels (Fig. 2). According to the section measurements of M. Ayob, locality 5201 is about 130 metres (425± feet) above the base of the section; locality 5202 is about 260 metres (850± feet) stratigraphically higher, and about 140 metres (450± feet) below the top of the section. In addition to occurring at different stratigraphic levels, the two plant megafossil collections are taxonomically distinct (Table 1).

Correlations of sections within the Maran-Tembeling area can be postulated on the basis of general lithology and sedimentary sequences. The Tekai River section (type-section of Koopmans' Tembeling Formation), comprising about 3,000 metres (9,750± feet) of section, has a basal unit 600 metres (1,950± feet) thick of red-colored conglomerate, sandstone, and shale, overlain by a red shale unit about 400 metres (1,300± feet) thick. The middle portion of the section is composed of about 1,250 metres (4,050± feet) of light-colored sandstone and shale that is conglomeratic in the lower part. The upper portion of the section contains about 750 metres (2,450± feet) of red shale. Similar sequences of similar sediments are found in Ayob's Yih River and Maran River sections, as shown in Fig. 2.

Such physical correlations within the Maran-Tembeling area suggest that the light-colored sandstones and shales comprising the middle portion of the Tembeling type-section are equivalent to the upper part of the Yih River section and to the major portion of the Maran section that contains the plant megafossil localities. Although the possible factor of time-transgression of facies cannot be eliminated, it is here presumed that such time-transgression within the limits of the Maran-Tembeling area should not significantly affect these local correlations. The Maran floral records are considered to be representative of the middle part of the Tembeling Formation as described by Koopmans.

BIOSTRATIGRAPHY

Local biostratigraphy

The section measurements of Ayob (Fig. 2) show the local stratigraphic positions and the superpositional relations of the two Maran florules, indicating that they are locally distinct stratigraphic entities. The lists of plant species given on Table 1 shows that they are taxonomically distinct also. The florules appear to represent restricted and easily recognised biostratigraphic zones in the local section.

Plants at the lower level (loc. 5201) include fronds of three fern species of the genus *Gleichenoides*, in association with cones and shoots of the conifer genus *Frenelopsis*. Other leaf forms provisionally referred to *?Pelourdea* and *?Nageiopsis* are of uncertain affinities, but are stratigraphically limited to the lower Maran florule. The three species of *Gleichenoides* at this level (5201) are replaced by two different species of the genus in the upper Maran florule (5202). The lower Maran florule is characterized by the association and common occurrence of *Gleichenoides* and *Frenelopsis*.

Plants at the upper level (loc. 5202) include fronds of two species of *Gleichenoides*, in association with fronds of five species of cycadophytes in three genera (*Otozamites*, *Ptilophyllum*, and *Zamites*). Jointed stems of horsetails are present but rare. In contrast to the association of ferns and conifers in the lower Maran florule, the upper florule is characterized by the association of ferns and varieties of cycadophytes.

Regional biostratigraphy

Table 1 shows a comparison between the centrally-located Maran floral records and the Gagau composite flora from an area about 85 miles to the north, the Ulu Endau floral area about 85 miles to the southeast, and the Panti floral area about 60 miles southeast of Ulu Endau. The four floral areas thus are about evenly distributed along 230 miles of the younger Mesozoic belt, from Gagau at the northern limit to Panti near the southern end.

Comparisons with the Ulu Endau and Panti floras to the south seem to corroborate the presence of two biostratigraphic zones in the Maran section. A sample collection obtained by Suntharalingam in the Ulu Endau area contains five genera of plants: *Equisetites*, *Gleichenoides*, *Otozamites*, *Ptilophyllum*, and *Zamites*. This fern-cycadophyte association is the same as that found at the upper Maran locality (5202), and there is no evidence in the Ulu Endau flora of lower Maran taxa. Similarly the Panti flora contains an association of taxa that is stratigraphically restricted in the Maran section, but the *Gleichenoides-Frenelopsis-Conites* association is that of the lower Maran florule (5201). Here as at Ulu Endau there is no evidence of a mixture of taxa that are stratigraphically restricted in the Maran section.

Table 1. Correlation chart of Maran Taxa, showing suggested Biostratigraphic Zones and ages. Maran florules represent local stratigraphy based on superposition. Maran, Gagau, Ulu Endau, and Panti floras show regional correlations along the belt of later Mesozoic exposures. World correlations are shown on right-hand column, with ages indicated.

Plant Taxa	Maran	Gagau	Ulu Endau	Panti	Ages Indicated
Loc. 5202					
Equisetites sp.	X	O	O	–	Resembles Cretaceous forms.
Gleichenoides gagauensis	X	X	?X	–	Jurassic to Recent for family.
Gleichenoides maranensis	X	–	–	–	-do-
Otozamites gagauensis	X	X	X	–	Resembles Lower Cretaceous species.
Otozamites malaiana	X	–	–	–	Triassic to Cretaceous genus.
Ptilophyllum ayobanum	X	–	O	–	Resembles Lower Cretaceous species.
Zamites cf. buchianus	X	X	X	–	-do-
Zamites microphylla	X	–	–	–	Jurassic to Cretaceous genus.
Loc. 5201					
Gleichenoides pantiensis	X	–	–	X	Jurassic to Recent family.
Gleichenoides serratus	X	X	–	–	-do-
Gleichenoides steno-pinnula	X	X	–	–	-do-
Frenelopsis malaiana	X	X	–	X	Lower Cretaceous genus.
(Conites spinulosus)	X	X	–	X	-do-
?Pelourdea cf. megaphyllus	X	X	–	–	Triassic to Cretaceous genus
?Nageiopsis cf. longifolia	X	X	–	–	Resembles Lower Cretaceous species.

X = same genus and species; ?X = same genus, probably same species;
O = same genus, similar species.

The Gagau flora described by Kon'no (1967, 1968) was a composite of small collections from several localities, and probably from different stratigraphic levels, in the Lotong sandstone unit of the G. Gagau area. There is at present the need for detailed section measurements to clarify the stratigraphic position of floral localities in the Gagau section. The Gagau composite flora is very similar to a Maran composite flora combining taxa from localities 5201 and 5202. The presence of a distinct floral assemblage at Ulu Endau that has a stratigraphically restricted equivalent in the Maran section (5202), and the presence of another distinct floral assemblage at Panti that has a stratigraphically restricted equivalent at a different level in the Maran section (5201), suggest the probability that the Gagau composite flora is a stratigraphic mixture.

On the basis of present knowledge, it is suggested that two biostratigraphic zones are delimited in the Maran section, and that elements of these zones can be distinguished along the belt of later Mesozoic sedimentation. The Panti correlates with the lower Maran (5201), the Ulu Endau correlates with the upper Maran (5202), and the Gagau correlates as a composite of 5201 and 5202. The Maran, Gagau, Ulu Endau, and Panti are all correlated with the middle portion of the Tembeling type-section described by Koopmans (Fig. 2).

A limited amount of pollen data is present in addition to the plant megafossil records. A sample from the lower part of the Tembeling Formation, shown as 4708 (P) on Fig. 2, was examined by Esso Production Research Company with the comment (Koopmans, 1968, p. 39): "Sample 4708 yielded a small assemblage of carbonized palynomorphs associated with organized organic debris. The main constituents of the assemblage are *Classopollis classoides* Pflug and *Circulina* sp. Because this species association is known in the Jurassic from other areas, the sample is interpreted as Jurassic." Koopmans (p. 28, Fig. 3) shows the level of indeterminable plant remains providing the palynomorphs to be the red shale unit in the lower portion of the Tembeling Formation, underlying the light-colored sand-shale section from which the Maran megafossils were derived (Fig. 2).

Kee reports (1966, p. 12–13) a pollen sample from the Panti megafossil beds that was examined at the Paleontology Laboratory, Brunei Petroleum Limited, Brunei, with the following evaluations: "(1) *Classopollis* spec. (cf. *Classopollis classoides* Pflug emend. Pocock and Jansonius) is very common. The maximum known stratigraphic range is Upper Triassic (Rhaetian) to Upper Cretaceous (?Cenomanian). (2) *Aequitriradites* spec. (cf. *Aequitriradites verrucosis* Cookson and Dettman) is rare in the sample. According to literature and our world wide experience, this type is restricted to Lower Cretaceous." The Panti megafossils equate floristically with the lower Maran florule, and appear to represent a stratigraphic level higher in the Tembeling section than the Tekai River beds containing the "Jurassic" assemblage (Fig. 2).

World correlations and age

The right-hand column on Table 1 shows the age indicated for each plant taxon based on floral records from other parts of the world. More specific discussions can be found in Part 2: Taxonomic Considerations.

According to Arnold (1964, p. 61), the fern family Gleicheniaceae is not conspicuously represented by fossils in world floras until the Cretaceous. M. Bose, however, noted the common occurrence of the family in Jurassic collections of the Birbal

Sahni Institute at Lucknow (personal communication, March, 1969); but the Jurassic *Gleichenites* from India has pinnules that are much larger than those on fronds of the Malayan species.

D. D. Pant and associates at Allahabad University are currently studying a flora from central India, from beds considered to be near the Jurassic-Cretaceous boundary (personal communications, March, 1969). The similarity between their megafossil assemblage and the ones from West Malaysia is remarkable from the standpoint of taxonomic diversity and of general taxonomic composition, although some of the species appear to be different. The species of Gleichniaceae in this Indian flora has pinnules that are much smaller than the Indian Jurassic form, and that are near the size of pinnules in the species from West Malaysia; shape of the pinnules is considerably different, however.

The Malayan species of *Otozamites*, *Ptilophyllum*, *Zamites*, *Frenelopsis*, and *?Nageiopsis* most closely resemble leaf-form complexes that are commonly found in lower Cretaceous (Neocomian) floras of Eurasia and North America. Other leaf forms are of types that elsewhere range through longer intervals of the Mesozoic.

Some Maran taxa are indicative of ages no younger than Cretaceous, and others closely resemble forms that are elsewhere recorded in floras of Neocomian age or less commonly in floras of late Jurassic age. Such floral correlations suggest that the later Mesozoic plants from West Malaysia can be dated near the Jurassic-Cretaceous boundary; they appear most like floral assemblages from other regions that are considered to be of early Cretaceous (Neocomian) age.

Such a Neocomian age determination based on plant megafossils is supported by the pollen records from two levels in the later Mesozoic sections from West Malaysia. The presence of a pollen assemblage in the lower part of the section has been recorded, and indicates a probable Jurassic age. A second pollen assemblage from the medial portion of the section containing the plant megafossil records has been interpreted as indicating a Lower Cretaceous age.

Thus the later Mesozoic sediments appear to have begun accumulating during upper Jurassic time, and the deposition of clastics continued into the Cretaceous. The age of the upper red shale unit in the Maran-Tembeling area is unknown at present, but it appears to represent a conformable continuation of later Mesozoic deposition.

PALEOECOLOGY

The basin of later Mesozoic sedimentation appears to have been a linear trough trending approximately parallel to the present peninsular axis. Topographic highs paralleling the subsiding trough were probably present some distance to the west in the general area of the present Main Range, and along the eastern edge of the trough on the east side of the peninsula. Lateral facies changes and sedimentary structures suggest that the eastern upland was the major source area of clastic sediments deposited in the trough (Koopmans, 1968, p. 41). T. Suntharalingam and R. Cook (personal communications) have noted some sedimentary structures suggesting that clastics washed into the trough from marginal sources were subsequently "sluiced" southward by streams flowing to the sea in that direction.

Depositional environments appear to have been largely if not entirely nonmarine, representing varied terrestrial conditions such as fluvial, flood plain, deltaic, lacustrine, and paludal. Because the sediments are known to be many hundreds of metres thick, the rate of sedimentary accumulation would seem to have equalled the rate of subsidence, and the surface of accumulation remained above the level of the sea. Such an inference is supported also by the paleontological evidence: the good preservation of delicate organs of land plants at several sites along the trough, indicating that such plants grew near the depositional site where they were buried and preserved; and the apparent lack of marine fossils in the later Mesozoic deposits.

Koopmans (p. 41) suggests that at least some of the sedimentary data seem to indicate deposition in a relatively warm and dry climate. This physical evidence conforms with inferences derived from the fossil floras. The fern family Gleicheniaceae includes a group of "sun ferns", several species of which are still living in the Malay region. They are found typically in open sunny sites or along the borders of forests. Modern cycadophytes may grow in a variety of habitats, but they are most commonly found in exposed and well-drained sites. The genus *Cycas* is still living in West Malaysia, and in lowland habitats it typically inhabits open cliff sites or well-drained sandy soils. In areas such as northwestern Thailand and south-central India where drought seasons are of several months duration, *Cycas* is a common plant on the open floor of teak forests where drought-deciduous trees are widely spaced and of few kinds. The conifer *Frenelopsis* has small scale-like leaves reminiscent of some modern conifers (e.g. *Juniperus*) growing in summer-dry regions such as the western interior of the United States.

The small number and regional distribution of plant taxa that are preserved in the later Mesozoic sediments of West Malaysia suggest that the regional vegetation was composed of relatively few kinds of plants capable of being preserved in the fossil record. The few taxa, in conjunction with their modern analogues, suggest further that the later Mesozoic forests of the region were open savannah-type with wide-spaced trees and a ground cover of small cycadophytes and sun-ferns. This general type of vegetation is now found in mainland areas of southern and southeast Asia (e.g. Thailand and India) where climates are warm and there is a prolonged season of drought. Such a vegetation type is totally unlike the modern dense tropical rainforest of the Malay Peninsula that is presently surrounded by warm shallow seas.

The later Mesozoic vegetation and climates postulated for the present peninsular area may have been the result of regional uplift exposing the shelf areas of southeast Asia that are now covered by seas. The present Malay Peninsula thus would be situated on an extensive land area and apparently bounded by uplands to both the east and the west. Such an interior valley on an extensive landmass, with topographic highs acting as barriers to moisture-laden winds from east and west, could well produce a climate with seasonal drought similar to that which now prevails under similar conditions in northwestern Thailand and in the interior of southern India. Vakhrameev (1964, p. 134–135) and Minato and others (1965, p. 166) also show the Malay Peninsula on their paleogeographic maps as part of an extensive land area during early Cretaceous time.

The fossil plants from Maran are considered systematically in "Later Mesozoic flora from Maran, Pahang, West Malaysia, Part 2: Taxonomic Considerations."

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