# MONTANE POLLEN FROM THE TERTIARY OF NW. BORNEO

J. MULLER
Bataafsche Internationale Petroleum Mij.
The Hague, Holland

## INTRODUCTION

In NW. Borneo thick series of Tertiary sediments occur which are rich in fossil pollen and spores. The majority of these plant microfossils were derived from the various types of tropical lowland vegetation such as mangrove (Muller, 1964), mixed peat swamp forest and mixed Dipterocarp forest. Some pollen types, however, can be traced to microtherm elements in the montane vegetation. As these cannot have migrated through tropical lowlands, their past distribution is of special interest. It is the purpose of this note to review the stratigraphic occurrence of these montane pollen types and discuss briefly the phyto-geographical significance of the data. The sediments which contain the microfossils can be roughly divided in a near coastal and deltaic facies, characterized by alternating shale and sandstone with subordinate coal beds and a marine facies, consisting mainly of shale with subordinate sandstone and limestone beds.

The Tertiary sedimentation in the NW. Borneo Basin is characterized by the alternation of these two main facies, but was locally interrupted during periods of mountain building movements, particularly in late Eocene and late Miocene time. These movements shifted the axis of the depositional basin gradually northwards. The formations of interest are the Oligocene-Miocene Nyalau formation, the Miocene Setap shale, Meligan and Lambir formations, the Miocene-Pliocene Belait formation and a group of younger formations of late Miocene-Pliocene age.

The Nyalau, Meligan, Lambir, and Belait formations belong mainly to the deltaic-coastal facies, the Setap shale formation is mainly of holomarine origin.

Age indications of the formations studied are given by their foraminiferal content and for further details reference is made to Liechti (1960).

## THE POLLEN EVIDENCE

### Podocarpus imbricatus type

The pollen grains of this type are characterized by three large, well developed air sacs and are identical with those of *Podocarpus* sect. *Dacrycarpus*. *P. imbricatus* is the only species of this section known to occur in Borneo, where it is a common constituent of the montane forests above 1000 m. The present day distribution of the section *Dacrycarpus* includes Indochina, Borneo, Java, and New Guinea.

This unique pollen type is absent from most of the Tertiary of NW. Borneo and is only found occurring suddenly from the Plio-Pleistocene onwards.

### Phyllocladus type

The unmistakable pollen grains of *Phyllocladus* are characterized by the two small air sacs attached to a fairly large central body.

[1]) A former record of fossil montane pollen by F. R. van Veen (Sarawak Mus. J. 11, 1958, 351—356) I have shown to rest on an error through contamination (op. cit. 10, 1961, 325).

The genus is common in the present day Bornean montane forests and also occurs in the Philippines and New Guinea.

The *Phyllocladus* pollen type is absent from nearly the whole Tertiary and appears rather suddenly around the Plio-Pleistocene boundary, slightly later than the *Podocarpus imbricatus* type.

**Pinus type**

This pollentype matches well the pollen of *Pinus khasya* and *merkusii* and can easily be distinguished from the native *Podocarpus* pollen types with two air sacs by its large central body and finely reticulate structure in the air sacs.

At present the nearest occurrences of *Pinus* are in the montane and submontane forests of N. Sumatra, Indochina, Hainan, Formosa, and the Philippines (N. Luzon, Mindoro), but its present abundance in some of these areas may largely be a consequence of human interference. Today Borneo lies within reach of windblown Pine pollen from the Philippines and possibly also from South Indochina as shown by its occurrence in recent sediments in the South China Sea at a distance of 100—200 miles off the Bornean coast.

In the early Eocene *Pinus* type pollen is rare, it increases in abundance in the late Eocene, to reach a maximum in Oligocene and early Miocene deposits. It then decreases in the late Miocene and Pliocene.

**Picea type**

The large size, broad airsacs, finely reticulate wall and airsac structure, and the absence of a dorsal crest on the body make this pollen type easy to recognize.

The nearest present day localities of *Picea* are in the high mountains of North Indochina and Formosa and there is no evidence that its pollen is transported as far as NW. Borneo today.

*Picea* type pollen is rare in the Eocene, common in the Oligocene and early Miocene, but decreases in the late Miocene and is virtually absent in the Pliocene.

**Tsuga type**

This pollen type is unique because of its frill-like annular air sac, on the margin of which minute spines are inserted. Both the '*diversifolia*' and the '*canadensis*' subtype are found.

*Tsuga* grows at present in closest proximity in the high mountains of Formosa, South China, and the Himalayas (Bhutan). *Tsuga yunnanensis*, *T. diversifolia*, *T. dumosa*, and *T. chinensis* from these areas appear to be characterized by the '*diversifolia*' pollen subtype, *Tsuga sieboldii* by the '*canadensis*' subtype, judging from the data presented by van Campo-Duplan (1950). The pollen of *Tsuga formosana* has not been described.

*Tsuga* type pollen is rare in the Eocene, abundant in the Oligocene and early Miocene, gradually decreases in abundance in the course of the Miocene, and is virtually absent from Pliocene deposits.

It is clearly associated in its occurrence with *Picea* type pollen.

**Ephedra type**

The *Ephedra* type pollen grains occurring in the Tertiary of NW. Borneo conform closely to type 'A' as described by Steeves and Barghoorn (1959). This type characterizes most of the East Asian species of *Ephedra*. The spindle shape, the few high and narrow ridges, and the very characteristic branchings of the colpi are diagnostic.

The nearest localities of the genus at present are Hainan, S. China, and the alpine zone of the Himalayas.

The Tertiary occurrences of the *Ephedra* pollen type are concentrated in the Oligocene deposits, it is rare in the Miocene and very rare in the Pliocene.

**Alnus type**

This is a very characteristic pollen type which cannot be confused with the pollen of any plant living in Borneo at present.

*Alnus* grows today in the mountains of North Indochina and Formosa as nearest localities.

The pollen type is abundant in the Oligocene and early Miocene; it gradually decreases in frequency in the course of the Miocene to become very rare in the Pliocene and absent in the recent sediments.

## DISCUSSION

The palynological evidence suggests that considerable change has taken place in the montane flora, surrounding the Neogene basin of deposition in NW. Borneo. The present day abundance of *Podocarpus imbricatus* and *Phyllocladus* is shown to date only from the late Pliocene, while in the Oligocene and lower Miocene genera such as *Pinus*, *Picea*, *Tsuga*, *Alnus*, and *Ephedra* must have been present, which do not occur in the Bornean mountains at present. The pollen types indicative of the latter group of genera will be referred to as the 'Asiatic montane' association, because at present they are forming a dominant element in the higher montane vegetation of the SE. Asian mainland and their pollen occurs associated in its stratigraphic distribution in Borneo.

*Podocarpus imbricatus* and *Phyllocladus* can still be envisaged as immigrating into mountain areas similar in size and distribution to the recent ones. The same, however, cannot be assumed for the montane vegetation in the older Neogene, where the palaeogeography may have been different.

In order to show the problems raised by the unexpected occurrence of the Asiatic montane pollen association in proper perspective, a further discussion of geologic history and pollen dispersal is necessary. In the first place the fact has to be taken into account that the genera involved are notoriously large pollen producers, compared to tropical lowland plants. In the second place it will be clear that these temperate montane genera, if growing at the latitude of Borneo, must have been restricted to high montane areas. Both circumstances will have favoured long distance transport. However, only for *Pinus* has it been shown that at the present time its pollen is transported to the sea offshore Borneo, either from the Philippines or from South Indochina. Also, in case of such long distance transport, the amount of pollen reaching the area of deposition is relatively small. In near-shore sediments it is outnumbered by the locally produced coastal pollen associations derived from mangroves, river banks, and peat swamps. The fact that in the Oligocene and early Miocene near shore to deltaic Nyalau and Meligan formations, the amount of Asiatic montane pollen easily equals or even dominates the local pollen association suggests a montane area, directly bordering the basin of deposition. Quantitative estimates of the distance between this montane source and the area of deposition are of course difficult to give, but may be thought of as in the order of 50—500 km.

Geological evidence is compatible with the hypothesis that the source area was present in the elevated area bordering the mid-Tertiary NW. Borneo geosyncline. Wilson (1964) has recently summarized the geologic history of that part of the geosynclinal area lying in NE. Sarawak and SW. Sabah. He cites evidence for a sedimentary source in the South and East during Oligocene to late Miocene time. This source is envisaged as a rising cordillera, subjected to rapid erosion, with no great distance between elevated area and the place of deposition of the sediments. Towards late Miocene times the land areas were ceasing to supply significant amounts of sediment, probably a result of gradual peneplanation. There is evidence that a late Miocene tectonic phase may have caused new uplift, but this did probably not result in mountains of the size and extent present in the late Eocene.

Wilson's evidence fits in well with the hypothesis of a source relatively close to the sedimentary basin and the picture of a gradually eroding cordillera may explain the disappearance from the pollen record of the Asiatic montane association during the Miocene. If, at a given time, the summits of all mountain chains had been levelled down to the 1500 m countour, it is unlikely that any of the Asiatic montane elements could have survived. Their disappearance from Borneo must have been completed by the time the mountain massive of Kinabalu had reached its present elevation which on geologic evidence, has been not earlier than Pliocene. The rare occurrences in the Pliocene may then be due to long distance transport.

The phytogeographic interest of the data presented here lies of course mainly in the evidence which they provide for mid Tertiary mountainous links with the SE. Asian mainland and for late Tertiary links with the East.

The existence of such connections has been postulated by van Steenis (1934, 1935, 1962) in his classic studies on the origin of the Malesian mountain flora. He distinguishes on the basis of the present day distribution of key montane genera, three different migratory tracks along which these plants have reached the Malesian area. His Formosa-Luzon track would form a more likely pathway for the Asiatic montane pollen association than the Sumatra track. The New Guinea track evidently has formed the pathway of migration for *Podocarpus imbricatus* and *Phyllocladus*. Couper (1960) has already drawn attention to the immigration of these plants from the SE. into New Guinea and the Malesian area, but the late appearance of these pollen types is difficult to reconcile with present day distribution, especially of *Podocarpus imbricatus* which has reached Hainan, Kwangsi, Kwantung, Indochina, and Burma. Summing up, it would appear that during the course of the Tertiary the palaeogeography of Borneo and the surrounding areas has undergone significant changes, resulting in a dynamic interchange of invading floristic elements from various directions. It will be clear that the data presented in this paper can be interpreted in various ways and a further study of the Tertiary succession in the Philippines, on Java and Sumatra will be necessary before the undoubtedly complex pattern of migration in time and space can be further clarified.

## ACKNOWLEDGMENTS

Thanks are due to the Management of Brunei Shell Petroleum Company Ltd., Seria, for permission to publish the data on which this study is based and to Prof. Dr. C. G. G. J. van Steenis for discussions and criticism.

REFERENCES

COUPER, R. A. 1960. Southern Hemisphere Mesozoic and Tertiary Podocarpaceae and Fagaceae and their Phytogeographical significance. Proc. R. Soc. B. 152: 491—500.

LIECHTI, P. et al. 1960. The geology of Sarawak, Brunei and the Western part of North Borneo. Bulletin 3, Geol. Surv. Dept. Brit. Terr. Borneo, Kuching: 1—360.

MULLER, J. 1964. A Palynological contribution to the history of the Mangrove vegetation in Borneo, in Ancient Pacific Floras: The pollen Story, Hawaii.

STEENIS, C. G. G. J. VAN. 1934. On the Origin of the Malaysian Mountain Flora, part 1. Bull. Jard. Bot. Btzg., ser. III, 13: 135—262.

—— 1935. On the Origin of the Malaysian Mountain Flora, part. 2. Bull. Jard. Bot. Btzg., ser. III, 13: 289—290.

—— 1962. The Land Bridge Theory in Botany. Blumea 11: 235—372.

STEEVES, M. W. and E. S. BARGHOORN. 1959. The pollen of Ephedra. Journ. Arnold Arboretum. 40: 221—255.

VAN CAMPO-DUPLAN, M. 1950. Recherches sur la Phylogenie des Abiétinées d'après leurs grains de pollen. Trav. lab. Forest. Toulouse, T. II, Vol. IV. art. 1: 10—183.

WILSON, R. A. M. 1964. The geology and mineral resources of the Labuan and Padas valley area, Sabah, Malaysia. Memoir 17, Geol. Surv. Borneo reg., Malaysia, Kuching: 1—150.