PALYNOLOGICAL EVIDENCE FROM QUATERNARY SEDIMENTS IN SOUTHEAST ASIA, A REVIEW

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ABSTRACT: Pollen analyses of surface samples from Southeast Asia create an important reference for reading the fossile pollen records because information about the ecology of tropical vegetations is still limited. Changes in the altitudinal vegetation zonation in mountain areas, possibly indicating changes in the climate are the subject of palynological studies. Coastal sediments provide palynological evidence for coastline changes, possibly indicating changes in the sea level. The impact of man on the vegetation in Southeast Asia is very difficult to prove palynologically. Cultivated plants are not recognizable in the pollen records.

KEYWORDS: Quaternary, Malesia, Indonesia, palynology, climate.

1. INTRODUCTION

Pioneer studies by Polak (1933; 1949) showed that tropical peat deposits contained well preserved pollen grains. This opened new working fields for palynologists. After good results in reconstructing vegetations in temperate regions pollen analysis now expanded to tropical areas. The complicated and less-known vegetational situation made the start difficult. It lasted until the 1960s before vegetational development in peat deposits was studied in more detail (Muller, 1963; 1964; Anderson & Muller, 1975). Botanical studies helped with the interpretation of the pollen records (Anderson, 1958; 1963; 1964).

In the 1970s the number of palynological studies in Southeast Asia increased. The Canberra University (Australia) had a project in the Highlands of Papua New Guinea, including geomorphological and botanical studies as well (Hope, 1976a; Flenley, 1969; Walker & Flenley, 1979). A group of palynologists with connections to the University of Hull studied mainly deposits from Sumatra (Maloney, 1975; 1979; 1980; 1981; Morley, 1976; 1981; 1982; Flenley, 1979; 1984).

The Biologisch-Archaeologisch Instituut of the Rijksuniversiteit Groningen, the Netherlands, started in cooperation with the Geological Survey of Indonesia palynological studies in Java and Sulawesi. They were initiated by Prof. Dr. W. van Zeist who did important preparing work including coring and collecting reference material (van Zeist et al., 1979; van Zeist, 1984; Stuijts, 1984; Gremmen, in press).

French scientists are especially interested in deposits with reference to the study of early man on Java (Sémah, 1982; 1984).

The aim of the palynological investigations is to reconstruct the vegetation of the past. A special question is whether and to what extent the ice ages of the temperate zones had their influence in the tropics. The impact of man on the vegetation in younger times is of special interest. In this paper the results of palynological studies in Southeast Asia are reviewed, without trying to be exhaustive.

2. PRESENT-DAY VEGETATION

Our knowledge of the present-day vegetation of SE Asia is very incomplete. Floral descriptions are given by explorers since the last century being species lists and information about the structure of the vegetation. However, ecological information which is important for palynologists is lacking. Nevertheless very valuable information is collected in several standard works such as *Flora Malesiana* (van Steenis, 1950), *Flora of Java* (Backer & Bakhuizen van den Brink, 1963-1968), *Tree flora of Malaya* (Whitmore, 1972) and *New Guinea vegetation* (Paijmans, 1976). Besides, many other important studies have been published.

Van Steenis (1950) made clear that the Malesian region, including the political states of Malaysia, Indonesia, the Philippines and Papua New Guinea, is a separate floral region. The contacts with adjacent floral regions show an abrupt demarcation in the generic composition. It proves that the Malesian flora is a natural plant geographic unit. This does not mean that vegetations in all parts of the region are similar. Based on the distribution of genera of Phanerogams three provinces can be

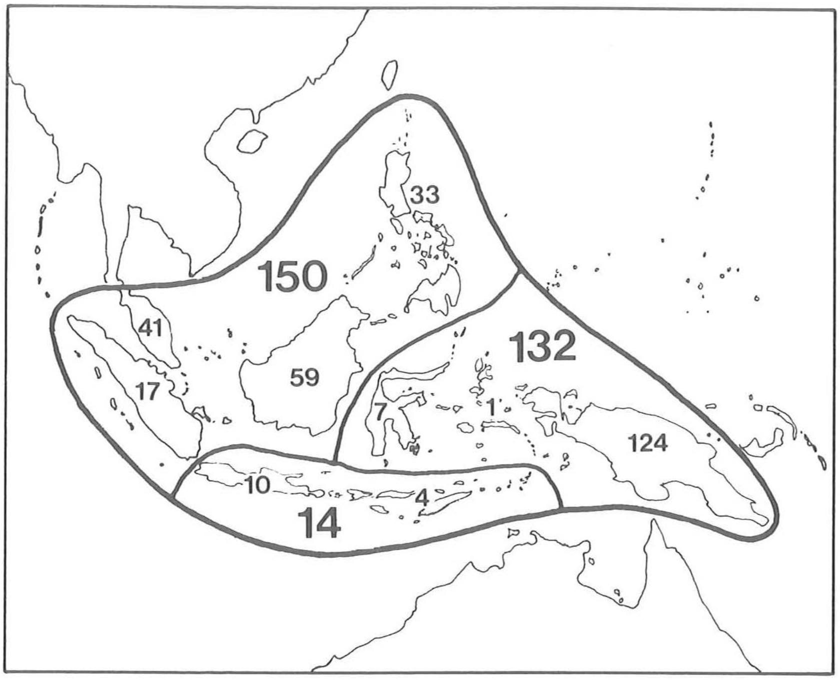

Fig. 1. Malesian flora region. Numbers indicate number of endemic genera of Phanerogams in the several islands and island groups, according to a census made in 1945 (after van Steenis, 1950).

distinguished (fig. 1). An example of the relative dissimilarities is given by van Steenis (1950, page LXX):

> the mountain flora of Java is nearly identical with that of most of Sumatra but very different from the Bornean mountain flora. The lowland floras of Sumatra and Borneo are practically identical, however, but widely different from the present Javan flora. The lowland flora of the Philippines is closely allied to that of Borneo, but the upland flora of N. Luzon shows a remarkable set of E. Asiatic genera and species. The lowland flora of New Guinea is essentially Malaysian but the summit flora has produced a unique Australian-Subantarctic element.

The disjunction in the present distribution of several monsoon plants gave rise to the idea that other climatic conditions occurred in former times. Many monsoon plants in Indonesia are of Asiatic origin, and occur in the monsoon forests of Indo-China, Birma and Siam. The humid tropical rain forest in the central part of W. Malaysia causes a disjunction in the distribution of these monsoon plants. For those which originate from Australia such a disjunction is formed by the rain forest in New Guinea. East and westward migration seems to have occurred. The exchange must have happened in geological recent times since practically all species are the same as those found in Asia and Australia. There is also a reason to assume that this migration took place during the Pleistocene glacials when a tropical climate with a pronounced dry season was more widespread than today (Verstappen, 1975).

This suggestion for climatic changes in SE Asia (van Steenis, 1935; 1939; 1950) was done before any palynological evidence was available from this area. It was supported by similar arguments from zoologists.

Although the number of ecological studies is increasing the ecological information about tropical vegetations is still poor. A very marking phenomenon is the altitudinal vegetation zonation in mountaneous areas. To tropical standards the diversity of species is rather low and a considerable change in vegetation types occurs within rather short distances. Many different factors are involved of which temperature is very important next to soil, precipitation and exposition.

The altitudinal vegetation zonation is very variable within the Malesian area. For every mountain ridge in New Guinea it is different. The vegetation of the many volcanoes in Sumatra varies widely depending on the age of the volcano, its size and shape, time of last eruption and type of effluvium (Flenley, 1979).

The actual altitudinal boundaries of the vegetation zones depend strongly on local conditions such as exposition and precipitation.

The Malesian vegetation can roughly be divided in the following categories:

- coastal beach vegetations
- mangrove vegetations
- saline and brackish swamp vegetations
- freshwater swamp vegetations
- lowland forest vegetations
- submontane forest vegetations

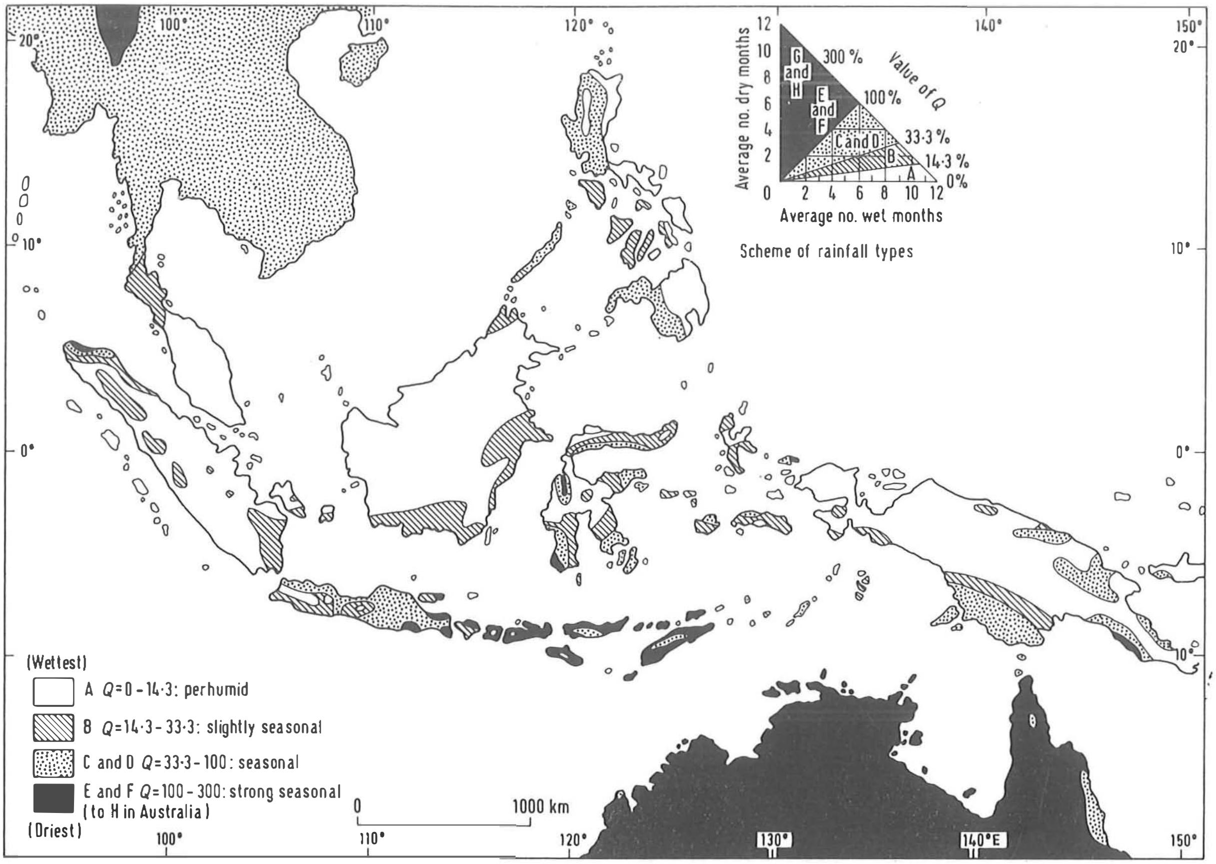

Fig. 2. Rainfall types in Malesia based on dry/wet period ratios. This climatic index, Q, developed by Schmidt and Ferguson (1951) is the only one which closely reflects present-day distributions of vegetation types. Q is defined as (dry months/wet months) x 100 where wet months are those with over 100 mm precipitation and dry those with less than 60 mm (after Whitmore (ed.), 1981).

- montane forest vegetations
- subalpine shrubland vegetations
- alpine herb vegetations.

The composition of the vegetations differs from one island to the other. Boundaries between several vegetation types are not to be seen as sudden changes in the vegetation. They are mostly gradual transitions from one vegetation type to an other.

3. CLIMATE

The present climate in the Malesian Archipelago is far from uniform. There are two large areas with an everwet, aseasonal regime, being Sumatra, Malaysia and Borneo on the one hand and New Guinea on the other. They are separated by a north to south zone of seasonally dry climates, running down the western side of the Philippines, through Sulawesi and the Moluccas. In the south the zone spreads out from the west of Java through the Lesser Sunda Islands to the Banda area reaching the southern most part of New Guinea (fig. 2). Within the seasonal areas the climate differs markedly causing a complex mosaic of rain forest and monsoon forest. Human interference made the situation even more complex. In areas of seasonal climate rain forest persists in wetter sites such as riversides and on better soils.

The climate in tropical areas is strongly influenced by the position of the Intertropical Convergence Zone (ITC). This is the area in which the rising part of the Hadley circulations of northern and southern hemisphere meet. In this zone the air rises what affectuates the transport of heath out of the tropical zones polewards. The position of the ITC is affected by the distribution of land and sea and also changes with the season. In SE Asia the changes have a particularly large altitudinal range (fig. 3). The seasonal extremes in the position of the ITC are only indicative for the average conditions prevailing. Fluctuations can be expected over the years depending in the first place on the development of the Asiatic and secondly on the development of the Australian anticyclone.

It is certain that during the ice age the ITC had a

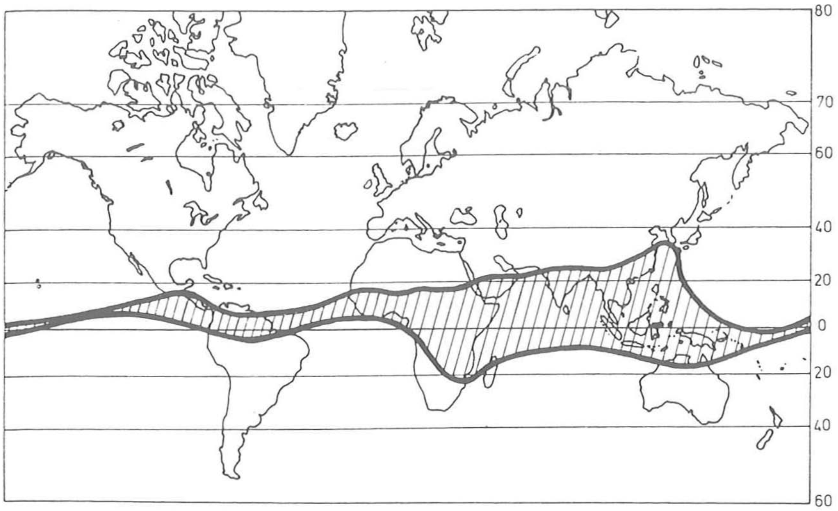

Fig. 3. Average annual latitudinal shift (hachures) of the Inter Tropical Convergence zone (ITC). The southernmost thick line indicates the average January position and the northernmost thick line the July position of same. The hachured zone is particularly broad in SE Asia; the climate of a much larger area will be affected if changes occur in the (present) average position of the ITC than as in the Pacific and some other oceanic areas where the annual shift is much less pronounced (after Verstappen, 1975).

more southern position than at present in the whole area or at least in the major part of it. The climatic changes provoked by these fluctuations are most important. Climatic variations which have been studied from meteorological observations since about one century, point to changes in humidity and precipitation caused by fluctuations of the ITC position (Verstappen, 1975). There was the general change in temperature during the last glaciation, but also very important was the change in sea level. The sea level was about 100 m lower than at present. This means that the land surface was much larger, resulting in reduced evaporation, changes in sea-currents and by the reduced sea influence a larger seasonal change in mean daily temperature. Other indications for climatic changes in the past are remains of glaciation in the high mountains. They are found in several islands such as New Guinea (Hope, 1976b), Sumatra and Borneo, and in East Malaysia (Flenley & Morley, 1978).

When studying the distribution patterns of plants and animals, biologists came to the suggestion that in former times different climatic conditions prevailed (see 2)(Whitmore, 1981).

4. MODERN POLLEN RAIN

All palynological study relies heavily on the understanding of the present relation between vegetation and climate. However, our knowledge of the ecology of tropical vegetations is rather poor. Most of the botanical studies are floristic, with poor ecological information. In order to create a basis for the interpretation of fossil pollen evidence studies of modern pollen rain are indispensable. They show the present relation between vegetation and pollen rain and accompany most of the palynological studies from the Malesian area.

Modern pollen rain has been studied in several areas among which the New Guinea Highlands (Flenley, 1969; 1973; 1979; Powell, 1970; Hope, 1976a; Walker & Flenley, 1979), the mountains of Sumatra (Morley, 1976; 1982), Borneo (Flenley, 1973) and Java (Stuijts, in prep.), the Borneo lowland swamps (Anderson & Muller, 1975), W. Malaysia lowland forest (Flenley, 1973) and coastal vegetations (Hillen, 1984; Chow, 1977).

Samples of modern pollen rain show a high diversity in pollen types although identification is at generic or family level only. In highly diverse vegetations this is not surprising. In general the spectra reflect rather accurately the local pollen deposition and its effect on the regional spectrum. High local pollen production reduces the percentages of regional elements for example.

One learns about differences in pollen production, ways of dispersal and how far pollen transport reaches; one learns which taxa are over- and which are under-represented in the pollen rain. This knowledge is indispensable for the interpretation of fossil records.

In the New Guinea Highlands the various altitudinal vegetation zones could be defined palynologically. The result of this study forms the basis for the interpretation of fossil pollen records from the same area. An effective pollen transport up-slope but not downslope is shown. It concerns mainly species from the upper canopy of the forest with a good dispersal, which are found in the pollen rain in areas above the forest limit (Hope, 1976a).

The Sumatran submontane forest (1000-1400 m), montane forest I (1400-1800 m) and montane forest II (1800-2400m) show distinctive modern pollen

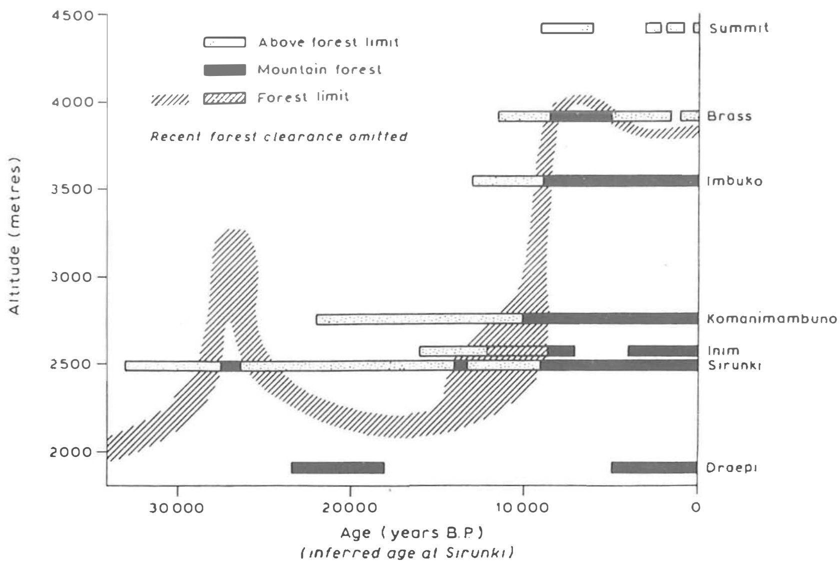

Fig. 4. Summary diagram of late Quaternary vegetational changes in the New Guinea highlands (after Flenley, 1984).

spectra. Their composition is strongly related to the arboreal composition of the forest (Morley, 1982). In lowland peat swamps lateral movement of pollen mostly is very restricted so that modern pollen samples tend to be dominated by nearby trees. They give hardly any information about the regional vegetation (Anderson & Muller, 1975).

In the coastal area several categories of depositional environment are distinguished. They differ notably in salinity. They are determined by the composition of the pollen content, but also show marked differences in variety of pollen taxa. For example, mangrove is relatively poor in taxa, whereas the freshwater swamp and peat swamps are very rich (Hillen, 1984).

In pollen samples collected in open areas such as lakes and swamps surrounded by forest mainly the upper canopy is represented. The trunk vegetation is very poorly represented, probably due to the low air movement under the upper canopy. It is not very likely that many trunk space plants are wind-pollinated (Kershaw & Hyland, 1975).

5. FOSSIL POLLEN RECORDS

From the pioneering studies of Polak (1933; 1949) we know that tropical peat deposits contain well preserved pollen and spores. Nevertheless it lasted more than 30 years before palynologists started to work in the Malesian area more frequently. Muller investigated Tertiary and Holocene peat deposits in Sarawak and Brunei in NW Borneo. The Holocene pollen record shows a wide variety of pollen types and reflects changes in vegetation which are interpreted as successive stages of development in the peat swamp vegetation. Pollen other than from the dense forest cover in the peat swamp area forms a minority. The pollen records reflect only a very local picture (Anderson & Muller, 1975).

Studies in the New Guinea Highlands delivered evidence about more general climatic changes, concluded from shifts in the altitudinal forest limit. By chosing sites at different elevations in the mountains, also changes in the altitudinal vegetation boundaries could be proved. The results of these studies by Hope (1976a), Powell (1970), Walker & Flenley (1979) are summarized by Flenley (1984) as shown in figure 4.

The longest sequence in time is that of Sirunki-swamp and dates back to about 33,000 BP (Walker & Flenley, 1979). The earlier half of this record shows, except for a peak of forest pollen between 28,000 and 25,000 BP, a great abundance of *Astelia* and Gramineae. Vegetations with a similar pollen spectrum nowadays occur more than 1000 m above the level of the Sirunki-swamp which is situated at 2500 m. This means that from 33,000-14,000 BP, except for the period between 28,000 and 25,000 BP, the forest limit was situated below 2500 m. A forest phase occurs between about 14,000 and 12,500 BP after which herb vegetations become dominant again. The chief forest development started at about 9000 BP and a closed forest resulted. This coincides with a rise of the forest limit to the present level. From 5000 BP arboreal pollen values started to decrease what is interpreted as the result of forest clearance by man.

Pollen records from other sites at different altitudes in the New Guinea Highlands complete the picture of the last 15,000 to 10,000 years with analogous evidence.

From the Bornean mountains traces of glaciation are known but so far only palynological evidence is available from lowland swamp forests in Sawarak and NW Borneo (Anderson & Muller, 1975). The records give no information about regional vegetation changes but represent mainly the development of the local swamp vegetation.

The Sumatran mountains form a chain, mainly volcanic, with many sites suitable for pollen sampling. The principle areas studied are those near Mt. Kerinci and those near Lake Toba. The sites are situated at lower elevations than those in New Guinea and therefore give information about altitudinal changes in montane forest vegetation mainly. As indicator the value of Gymnosperms in the pollen record is used. Nowadays the lower limit of coniferous dominated vegetations is situated at about 1800 m, forming the boundary between montane forest I and montane forest II as defined by Morley (1982).

Flenley (1984) summarized the evidence of the Sumatran pollen records and compared it with that of New Guinea. The Sumatran evidence is mainly based on the record of Danau Di-Atas which covers about 31,000 years. The early part of the record is dominated by Gymnosperms. A gradual change to forest of the modern type is indicated from about 12,000 BP. The Gymnosperms disappear completely by about 7000 BP. Other Sumatran pollen records date less far back but for the period they represent they support substantially the evidence from Danau Di-Atas. Evidence for the period older than about 10,000 BP is too poor to be conclusive. A more reliable picture can only be build up with more pollen records from this period.

In great outlines the records of Sumatra and New Guinea are similar, and comparable to evidence from Java, gained from the pollen record of Situ Bayongbong (Stuijts, 1984). This record dates back to about 17,000 BP. From 17,000 to c. 12,000 BP cooler conditions than today are reflected by the presence of an upper montane forest vegetation. Starting from about 11,000 BP the species of lower montane forest rise markedly. From about 8000 BP modern conditions are established. This indicates an altitudinal shift of the vegetation zones of at least 500 m upward. There are no indications for drastic changes in the rainfall regime. This and other evidence from western Java support the generally accepted change in climate at about 10,000 BP in New Guinea and Sumatra. The climate then turned warmer to reach present conditions.

The overall conformity in vegetation development shown in pollen records from New Guinea, Sumatra and Java does not mean that these pollen records are similar in detail, too. As mentioned before vegetations in the areas differ considerably what is reflected in the pollen rain by distinctive behaviour of single pollen types.

Typical coastal and alluvial areas are poorly investigated by palynologists. The reason could be that these areas hardly give any information about the regional vegetation but only about a very local vegetation development. These local conditions can be influenced by so many different factors that one can only guess the reason of changes reflected in the pollen record.

Hillen (1984) characterized various tropical lowland depositional environments through their pollen content. He distinguished the following habitats: shallow offshore, deltaic/estuarine, mangrove, transition (brackish), freshwater swamp and (shallow) peat swamp. Except for the variety in pollen types, he used the total pollen influx. He roughly estimated the amount of pollen in each sample without absolute pollen counting. The figures are indicative only. Several records show the transition from salt-water mangrove vegetations to freshwater peat swamps.

Similar studies are carried out by Haseldonckx (1974), Chow (1977) and Bin Hassan (in press). Absolute dates are not available. All studies are carried out in the coastal area of West Malaysia. Haseldonckx (1977) examined a core from a marginal peat swamp near Pekan Nanas, Johore, Malaysia. The pollen record reflects a development in peat swamp vegetations, and is accompanied by a radiocarbon date of c. 4900 BP.

The present author palynologically examined Holocene sediments from the Tempe depression in Southwest Sulawesi (in press). Three pollen records are presented, two with radiocarbon determination. They show that mangrove vegetations were present east of Singkang in what is now the Cenrana alluvial plain between c. 7100 and 2600 BP. It is an indication for changes in the sea level like they are found in other places in SE Asia.

Fossil bones of early man are found in late Pliocene and early Pleistocene sediments on Java. In order to learn more about the natural environment in which early man lived these sediments have been studied palynologically (Sémah, 1982; 1984). The pollen records inform us mainly about local environment which has changed markedly. Changes in the upland vegetation composition could not be proved, because of the relatively low presence of pollen from the regional vegetation. An adequate interpretation of the pollen records is obstructed by the fact that the pollen grains as well as the human bones in the mostly fluviatile sediments most probably are washed in from the hinterland.

Evidence for climatic changes in the past is not the only important object in Southeast Asian pollen studies. Another question is: 'When did early man start to influence the forest vegetation in such a way that it is reflected in the pollen record?' Related to this is the problem which pollen types can be used as indicators for the human influence in the forest. Changes in the pollen records of Papua New Guinea are attributed to forest disturbances by man since about 5000 BP almost certainly (Walker & Flenley, 1979; Flenley 1979). Archaeological finds show traces of human occupation from this period and support that interpretation.

Pollen records from northern Sumatra suggest disturbance of the forest vegetation by man from about 7500 BP. Far less convincing evidence dates back to about 17,800 BP. However, also climate has changed since then and it is not possible to isolate the causal factors (Maloney, 1980).

Anthropogenic indications in the pollen diagrams have been hardly defined so far. Little is known about recognizing indications of the impact of prehistoric man on the vegetation in the pollen records. As long as no agricultural activities took place the influence will have been limited and therefore not tracable in the pollen rain. To some extent there is always disturbance in a rain forest. During storm dead trees or branches of trees can fall causing small open spots in the vegetation. Light-demanding plants are the first to establish in these places. This so-called 'spotwise' regeneration is part of the natural regeneration process in tropical forests and will be reflected in pollen records as a background effect.

Agricultural activities imply forest clearance on a larger scale. These more radical changes cause regular changes in the vegetation composition of the forest. At the edges of the open areas light-demanding plants will establish themselves and on abandoned fields a secondary forest vegetation will develop. This becomes a slowly increasing permanent factor in the forest and will at a certain point become tracable in the pollen record. In such a gradually occurring process it will be difficult to determine the point at which the impact of man on the vegetation started.

Unfortunately, plants that are cultivated nowadays and could have been cultivated by early man too are not recognized in the pollen records. Mostly it concerns plants which are cultivated for their roots and therefore do not reach the flowering stage. Even when flowering, it will be difficult to prove their presence. Plants traditionally cultivated in southeastern Asia cannot be distinguished palynologically from their non-cultivated relatives also present in the area. One of the examples is rice. With light-microscope techniques it is not possible to distinguish between rice pollen and pollen of some wild grass species (Flenley, 1979; Maloney, 1980).

Archaeological finds from Papua New Guinea show that agriculture existed in that area from about 9000 BP. A series of drainage ditches are dated to this age. Which crop was grown can only be guessed (Flenley, 1979).

In the discussion of the pollen diagrams of Situ Gunung and Telaga Patengan in Java, van Zeist et al. (1979) prefer to look for natural factors to explain vegetational changes at about 5000 BP. They judge it very unlikely that in this period a change in the upland vegetation of West Java was the direct or indirect result of the activity of prehistoric farmers. However, van Zeist (1984) is confident that pollen analysis will prove its usefulness for the study of agricultural practices of prehistoric farmers, like it did for the temperate regions.

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