THE UNIVERSITY OF HULL

LATE QUATERNARY VEGETATIONAL HISTORY OF THE WEST SUMATRAN HIGHLANDS

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GEOGRAPHY

SUMMARY Summary of Thesis submitted for PhD degree

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on

Late Quaternary vegetational history of the West Sumatran Highlands

A palynological investigation of sediments from montane West Sumatra (c. 1500 m a.s.l.) was carried out. Two fossil cores were examined. One, Danau di Atas, is at least 31000 uncorrected radiocarbon years old, and is relatively well dated; pollen influx values were calculated for this core. The second, Telago, is of Holocene age. To aid interpretation of these, the present vegetation of the area was studied, using plots, and pollen rain produced by this vegetation was also examined, using moss polsters and surface samples taken from within the plots. Pollen rain on a high mountain, Gunung Kerinci, south of the main field area was also studied. The modern pollen studies demonstrate the importance of canopy taxa in the regional pollen rain and aid in elucidating the relative pollen production of many taxa.

The pollen assemblages recovered from both cores suggest a number of changes, both in the independent hydroseral development at the two sites, and dry land vegetation. The dry land vegetation changes have been interpreted in terms of environmental change and indicate that climates were formerly cooler, particularly from c. 17900 to c. 12900 years B.P., when the vegetation of the area included an important gymnosperm element. During this cool period mean annual temperatures were between 1.6 and 5.2°C cooler

than at present. There is however no evidence to suggest that the climate was drier, or more seasonally dry, than at present during the period represented by the sequence. Changes in the vegetation due to human interference may have occurred on a minor scale up to 8200 years ago, but widespread forest clearance appears to have been a relatively recent phenomenon.

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ABBREVIATIONS AND INDONESIAN TERMS COMMONLY USED IN THE TEXT AND FIGURES

Abbreviations

APF	absolute pollen frequency
B.P.	before 1950
DDA	Danau di Atas (core)
DLP	Dry Land Pollen
R.A.	reciprocal averaging
TDLP	Total Dry Land Pollen
TEL	Telago (core)

Abbreviation	Indonesian	English
D.	Danau	lake
B.	Batang	river
S.	Sungei	river
G.	Gunung	mount
Bt.	Bukit	hill/mountain

CHAPTER 1

PALYNOLOGICAL EVIDENCE FOR ENVIRONMENTAL CHANGE IN THE TROPICS

1.1 Introduction

The technique of pollen analysis has been developed in recent decades as an important palaeoecological tool. Because of the evidence, in the North Temperate Zone, of major climatic changes associated with glaciations during the Pleistocene, palynological studies have both developed and been concentrated in this region. As a consequence, vegetation changes related to climatic change and other factors in the North Temperate Zone are on the whole well documented. The idea that climatic change might have occurred in the tropics, coeval with the major glaciations of the Northern Hemisphere, developed more recently. Only within the last c.25 years have palynological studies been carried out in the tropics, much of the work done to date having been produced within the last 15 years.

It was initially thought by Faegri (1966) that pollen analysis would not be a suitable tool for the elucidation of past vegetation in the lowland tropics, for a number of reasons. These included the diversity of species present and associated difficulties of identification of important taxa, the high incidence of entomophily and relative rarity of anemophily among the taxa, and the relative windlessness of the environment, which would affect pollen dispersal. Indeed, much of the early work done in the tropics was at high altitude sites, usually above c.2000m a.s.l. where vegetation is of a less diverse nature and anemophilous taxa may be more important, so these potential problems are less serious. However, subsequent research has shown that if suitable polliniferous deposits are available there is no reason why pollen analysis cannot be applied as a successful palaeoecological tool even in the lowland tropics (eg. Bartlett and Barghoorn, 1973; Morley, 1981a, 1982; Salgado-Labouriau, 1980). Although there are some difficulties, many of these can be overcome, particularly by the use of modern vegetation - pollen rain studies in the interpretation of fossil pollen assemblages. Further evidence (eg. Flenley, 1973) also suggests that pollen rain in the tropics is of the same nature as that in temperate regions, except that different components may have different relative importance.

The present study set out to elucidate the past vegetation of an area of moderate altitude in the mountains of West Sumatra, over a period spanning at least the last 30000 years. The area was selected for the study because it was thought that changes in the environment, eg. those caused by climate or man, would affect the vegetation of the area in a way which would be recognizable in the pollen assemblages. As in other tropical regions, the nature and composition of the forest vegetation of West Sumatra varies with altitude, although transitions from one vegetation type to another are gradual rather than sharp. The cause of the vegetation - altitude relationship is presumably climatic, and the predominant control over the vegetation appears to be temperature through its effect on plant growth. However, with increasing elevation the air and soil environments become not only cooler but also moister and the increased moistness may also influence the vegetation to some extent (eg. prevalence of cloud cover may give rise to 'mossy' forest). Both temperature and moisture may affect the vegetation through their influence on soil development (Whitmore and Burnham, 1969). It is possible that other climatic factors such as input of UV light may also affect the vegetation but their significance to vegetation zonation on these mountains, if any, has yet to be elucidated. Because of this relationship between altitudinal vegetation zones and climate, any past climatic change might be reflected in the vegetation growing in the area. The nature of the vegetation changes which occur with altitude are considered in Section 2.4 and details of the vegetation of this area are considered in Chapter 4.

Pollen analyses were carried out on two cores from former lake/swamp deposits. One of these extends in age over at least the last 30000 years; the second is of Holocene age. Both are from sites in a lower montane environment at altitudes of 1535m and 1550m a.s.l., respectively. To facilitate the interpretation of the fossil pollen spectra obtained from these cores the present vegetation of the area, and pollen deposition patterns within it, were also investigated using plots, and surface samples taken from these. Additional information about pollen deposition patterns at higher altitudes was obtained from a series of surface samples collected from Gunung (G.) Kerinci, a 3800m volcanic peak which lies to the south of the main field region, and its surrounding area.

Those factors which might have influenced the vegetation of the area in the past are considered in detail in the following sections. The evidence for vegetation and environmental change in the tropics is then reviewed.

1.2 Environmental factors which might have influenced the vegetation of the region

1.2a A note on scale

The vegetation present in an area is dependent on a large number of environmental factors which vary in the extent of their influence. Some of these may have an extremely local effect on the composition of the vegetation eg. variations in drainage or soils, while others may be of regional importance eg. temperature and rainfall regime. Changes in the nature of some environmental factors may affect the vegetation in the short term while others may have a long term effect. It is clear that the pollen assemblages recorded in a pollen diagram or individual samples may simultaneously reflect both local and regional environmental factors, since they normally include pollen derived from both local and regional vegetation sources. However, only small scale variations occurring in proximity to the deposition site are likely to be recognized in pollen assemblages; those occurring further afield will tend to be masked by the regional pollen assemblage. Where the samples are from lake or swamp deposits most of these small scale, local variations are concerned with development and changes in the hydroseral[1] vegetation and its

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[1] Swamp and aquatic vegetation

environment. Changes in the pollen assemblages having a regional source are more likely to be due to variation in larger scale environmental factors.

Temporal changes in factors affecting the vegetation of an area are more likely to be recognized in fossil pollen assemblages if they have quite a long term effect on the vegetation of the area. The temporal spacing of the fossil samples analysed in this study is quite wide and therefore short term changes in the vegetation may not be recorded in the samples analysed, and even if recorded may be registered only in a single sample. In the latter case they may not even then be interpreted as a significant event, due to the statistical limitations of the technique.

1.2b Climatic factors

Climatic factors may influence the vegetation of an area at a number of scales, however only the large scale effects of climate on the vegetation are likely to be recognizable in pollen assemblages.

Short term climatic events, including catastrophic events, may at times affect the vegetation of a region. The resultant climatic changes may be of short or long duration. Short term climatic events include hurricanes and storms, which if severe may flatten forests, and droughts. The vegetation may be affected in a minor or major way and the time taken to return to its former state is variable. If it is rapid, a matter of months or a few years, then it is unlikely to be recorded in pollen assemblages. Sometimes the vegetation may take a number of decades to return to its former state, or may be permanently altered, in which case the vegetation changes may register in the pollen assemblages. A short term climatic event having a long term effect on vegetation is illustrated by the 'storm forests' of Kelantan and Trengannu states in Malaysia. These resulted from a hurricane followed by forest fires in 1883 and still apparently lacked some of the typical lowland tree species when described by Wyatt-Smith (1964).

Long term climatic events are more aptly described as climatic changes. These may result in permanent changes to the vegetation of an area, which are then reflected in the pollen assemblages recovered. The effect of such climatic events on the altitudinally zoned vegetation of montane areas may be particularly notable. Long term climatic effects have been recognized in pollen analyses of fossil sequences from all of the tropical regions. The evidence for climatic change in the tropics over the last c.30000 years will be considered in detail in Sections 1.3-1.5. These long term climatic changes appear to be primarily changes in temperature and effective precipitation, which may include changes in seasonality of the latter.

1.2c Volcanic and tectonic factors

Volanic and tectonic activity may result in local or widespread destruction of vegetation. A number of conditions may affect the recovery time of the vegetation. These include: the nature of the event, whether it is followed by subsequent activity, distance from seed sources, and type of substrate produced (in the case of volcanic activity). If the destruction is of a severe and widespread nature, the regeneration of the vegetation may be recognized in pollen assemblages by, perhaps, increased pollen of ephemeral or secondary forest taxa. Again, the time scale of recovery is important since only long term changes are likely to be recorded. In Sumatra and Java Myrica javanica may be an important constituent of seral vegetation on volcanic deposits in montane areas (Backer, 1954). However, since this species is also common in high altitude vegetation, its representation in pollen assemblages may have two possible meanings.

Volcanic activity may wholly or partially destroy vegetation in the area affected. Recovery time, assuming a seed source in proximity, may depend very much on the nature of the substrate. Recolonisation of lavas may take a great time, probably as a result of resistance to weathering and erosion. Loosely consolidated ashfalls and lahars may be colonised rapidly (van Steenis, 1972). An example of this is the recovery of vegetation on the island of Krakatau after total destruction of the vegetation in 1883. This proceeded from bare pumice and ash to a mixed secondary forest within 50 years, despite the great distance from seed sources. However, few characteristic primary forest trees have yet colonised the island, probably largely due to the distance involved and, often, the relatively poor dispersal abilities of many primary forest trees (Flenley and Richards, 1982).

The effect of lavas and lahars may be restricted largely to valleys, whereas ashfalls can also affect vegetation on ridges and slopes. The latter may therefore be capable of affecting a wider range of vegetation types in a single event. Volcanic activity may also sometimes act indirectly upon the vegetation of an area eg. by causing changes in drainage patterns and damming rivers to form lakes.

Tectonic activity may cause landslides and other land movements and may thereby cause destruction of vegetation. If the event is not repeated then regeneration is potentially rapid if soil and a seed source exist. If bare rock is exposed then the process is likely to be slow. Such effects may, however, be local and not easily recognizable in pollen assemblages. More widespread changes of vegetation may occur if the tectonic activity results in altered drainage patterns or elevation, such as causing damming of lakes and swamp formation. Tectonic activity involving tilting of the area at Tasek Bera, Malaysia may have been the cause of a major change in the environment and vegetation. This was altered from a forested valley with a fast flowing stream to an area of slow moving waterways and swamps with some swamp forest (Morley, 1976, 1981a).

Both volcanic and tectonic events occur in Sumatra at present, and have been important throughout the Quaternary. Therefore the possibility of vegetation changes resulting from their effects should be considered when fossil pollen assemblages from the area are interpreted.

1.2d Soil factors

Although the nature of the soil may affect the vegetation growing on it, soils do not appear to be a major factor in this area. Soil variation may not be terribly important in the region, possibly owing to the high rainfall and the tendency for soils to be leached and acidic. One exception might be fresh volcanic soils, none of which were encountered in this study. The effects of these on the vegetation and pollen assemblages were briefly described in the previous section.

1.2e Biotic factors

Few biotic factors are likely to affect the diverse vegetation of a region like Sumatra on such a widespread scale as to be recognizable in pollen assemblages. Although browsing animals occur in the forests, these are not noted for their ability to defoliate large areas. Moreover, herbivorous insects are often species specific and therefore unlikely to cause major damage except to single species stands of vegetation, which are atypical in these areas. Man is by far the most important biotic factor since he has the ability to destroy forests and other vegetation, and in recent decades has done so on a large scale. Where man has destroyed vegetation, then abandoned the land, regrowth communities, which may be recognizable in pollen assemblages, will occur. Eventually the vegetation may revert to its former composition. This process may be very rapid if the degree of interference with the original vegetation was of short duration and if seed sources are close by, as when shifting cultivation is practised. This type of agriculture may have been carried out in South-East Asia and New Guinea for many centuries. Longer term disturbance of the vegetation often leads to deterioration of the soil. Regrowth of vegetation after such an event may be of a different pattern, and a longer period may elapse before something akin to the former vegetation is achieved (Symington, 1933).

Widespread vegetation disturbance by man is often evident in pollen assemblages, although smaller scale interference may be less clear or not evident at all. Many fossil pollen analyses from tropical areas show clear evidence of the effect of man. For example, at Tasek Bera in Penisular Malaysia (Morley, 1976, 1981a) the pollen record provides evidence of a phase of clearance in surrounding dry land forests, followed by a phase of forest recovery, c.600 years ago. Subsequent forest destruction indicated was on an extensive, probably regional scale. In New Guinea there is also palynological evidence of human disturbance from many sites. For example at Sirunki (Walker and Flenley, 1979) pollen assemblages suggest interference from c.4300 years ago, as forest clearance with enhanced growth of ephemeral taxa. Also in New Guinea man may have interfered with the high altitude vegetation by using fires as an aid to hunting, and this may have contributed to a change to more open conditions recorded at Brass Tarn possibly 5000 years ago (Hope, 1976).

1.3 Vegetation history evidence from tropical high montane areas, above c. 2000 m a.s.l.

1.3a South America

Palynological studies of vegetation changes and their relationship to environmental conditions in South America have been concentrated in the Colombian Andes. The work is exemplified by that on the Sabana de Bogota, a dry lake bed at c. 2580 m a.s.l. The deposit is thought to contain about 800 m of sediments (Hooghiemstra, 1984). Currently, these have been cored to a depth of 357 m and extend at least into the Pliocene. They show evidence for many cyclical cold and warm phases. One of the first palynological studies to emerge from South America was an analysis of 33 m of sediments from this site (van der Hammen and Gonzalez, 1960). In age, these sediments extended well into the ultimate cold phase of the Pleistocene. Pollen analysis was used to elucidate the nature of the vegetation around the site. This indicated that both a cold phase, with temperatures estimated at c. 8°C colder than present, and a warm phase, possibly 2-3°C warmer than present, had existed.

At the Laguna de la Herrera, on the western border of the Sabana de Bogota at 2550 m a.s.l., van der Hammen and Gonzalez (1965a) recognized periods of lower lake level within the Holocene. These tied in with lower lake levels in other parts of Colombia. Other work from the same area of the Colombian Andes has clarified the picture of vegetation and climatic changes in the Late Pleistocene and Holocene period. Studies from the El Abra rock corridor (2570 m a.s.l.) indicate a number of phases in the environmental history of the area (Shreve - Brinkman, 1978; van der Hammen, 1978). The earliest phase recognized extends possibly from pre-50000 years B.P., into the penultimate glacial time. During this phase the El Abra valley was mostly covered by dense stands of Andean forest with Weinmannia; conditions fluctuated at this time, with warm and colder phases. In the second phase, the vegetation which prevailed was mostly open in nature, of a subparamo type. Humidity conditions varied from humid to very dry through this phase. One point within the second phase is dated as 28000 years B.P. The third phase, dated as Holocene, saw the valley once again surrounded by Andean forest, with Alnus as a prominent tree.

A 30000 year sequence from Laguna de Fuquene at 2580 m a.s.l. (van Geel and van der Hammen, 1973) indicates that from c. 30000 to c. 25000 years B.P. the altitudinal forest limit lay 800-1000 m below its present level, probably as a result of a cooler climate. This descended to c. 1500 m below its present level after c. 25000 years B.P. and from c. 21000 to c. 13000 years B.P. conditions appear to have been both cold and dry. Mean annual temperatures may have been c. 10^{o}C lower than at present during this period. Forest reinvaded the area from c. 13000 to c. 9500 years B.P. and possibly reached present levels but then appears to have retreated again, and at c. 9500 years B.P. still lay possibly 800 m below present levels. The forest limit rose after c. 9500 years B.P. and from c. 7500 to c. 3000 years B.P. was high, climate being similar or up to 2^{o}C warmer than todays. Since c. 3000 years B.P. the climate appears to have been as at present.

These pollen records clearly show some similarities as regards vegetation changes in response to environmental factors, and parallels are seen in many other pollen diagrams from different altitudes in the Colombian Andes. These include the Sierra Nevada del Cocuy at 3890 m a.s.l. (Gonzalez et al., 1966), Laguna Ciega at 3500 m a.s.l. (van der Hammen et al., 1981), Paramo de Palacio at 3500 m a.s.l. (van der Hammen, 1974) and Laguna de Pedro Palo at 2000 m a.s.l. (van der Hammen, 1974). The diagrams from the Laguna de los Bobos at 3800 m a.s.l. (van der Hammen, 1974) and the Cienaga del Visitador at 3300 m a.s.l. illustrate the influence of local climatic conditions. Laguna de los Bobos lies on the west, wetter side of the Cordillera Oriental. The diagrams from this site show a higher percentage of forest elements in the Holocene, than the diagrams from Cienaga del Visitador, which lies at a lower altitude but in a rain shadow area (van der Hammen and Gonzalez, 1965b). Holocene pollen sequences from the Venezuelan Andes also provide evidence of climatic fluctuations within the period (Salgado-Labouriau and Schubert, 1976, 1977). A pollen diagram from Central America, Vicente Lachner Bog at 2400 m a.s.l. in Costa Rica also shows that altitudinal shifts of vegetation occurred in this area during at least the last 36000 years (Martin, 1964).

1.3b Africa

Much of the palynological evidence for vegetation change in tropical Africa is from East Africa and particularly the highland regions. Much of the early work done was interpreted before surveys of the modern pollen rain and its relationship to the vegetation had been carried out. However, this has largely been reinterpreted in the light of modern pollen studies. Kaisungor Swamp, situated at 2900 m a.s.l. in the Cherangani Hills of north-west Kenya is one such site (van Zinderen Bakker, 1962, 1964; Coetzee, 1967; van Zinderen Bakker and Coetzee, 1972). Two cores span the period back to 27750 ± 600 years B.P. Prior to c. 22750 years B.P. the climate appears to have been warmer than subsequently. From c. 22750 to c. 14500 years B.P. very cold and dry conditions appear to have prevailed and the site was surrounded by afro-alpine vegetation. After c. 14500 years B.P. the temperatures warmed and ericaceous and montane forest vegetation were recorded at the site, although these seemed to be representative of a dry type of vegetation. More humid conditions seem to have occurred after c. 10000 years B.P.

Sacred Lake, a site at 2400 m a.s.l. on Mt Kenya was also examined (Coetzee, 1964, 1967; van Zinderen Bakker and Coetzee, 1972). The basal age of the sediments is 33350 ± 1000 years B.P. Climatic changes interpreted on the basis of the pollen assemblages are very similar to those at Kaisungor Swamp. A cold, dry phase occurred from c. 27000 to c. 14000 years B.P. Prior to this the climate was warmer, but not as warm as the present day. After c. 14000 years B.P. temperatures warmed, and the climate became wetter, and from c. 10000 years B.P. may have been similar to that at present.

Livingstone (1967) examined a series of sites in the Ruwenzori

Mountains of Uganda; these were Mahoma Lake at 2960 m a.s.l., Kitandara Lake at 3990 m a.s.l. and Bijuku Lake at 3920 m a.s.l. The Mahoma Lake record indicated a shift from open vegetation to montane forest around the site at 8000 to 10000 years B.P. Livingstone attributed this largely to an increase in moisture availability rather than temperature, since he considered that a drier climate 12500 years ago would explain the pollen assemblages whereas a colder one would not. The other two sites had relatively short pollen records, and it seemed likely that they had never been surrounded by montane forests. Hamilton (1972) reinterpreted these diagrams in the light of extensive vegetation and pollen rain studies in the region. He concluded that Livingstone's pollen diagrams showed a change at c. 12600 years B.P. from cold, dry to warmer, moister conditions. From c. 6000 to c. 2000 years B.P. the climate may have been slightly warmer and wetter than at present. The pollen record also showed widespread human destruction of forest in the lowlands after c. 1000 years B.P. and less intense disturbance was traceable back to c. 4600 years B.P.

Another record from Uganda comes from Muchoya Swamp at 2260 m a.s.l. (Morrison, 1961, 1968). The oldest sediments have an estimated age of 25000 years. The pollen record shows many similarities with the Mahoma Lake sequence of the same age, and has also been reinterpreted by Hamilton (1972). The similarity of pollen events at the two sites suggests that the changes do relate to regional climatic changes rather than local eg. edaphic factors.

Other evidence from montane East Africa, of climatic change includes work from Ethiopia (Bonnefille, 1973; Lezine, 1982). Evidence also comes from non-palynological features such as moraines on high mountains such as Mt Kilimanjaro and Mt Kenya. These suggest that glaciers were formerly more extensive than at present (Livingstone, 1975).

1.3c Malesia

The floristic province of Malesia (Good, 1947) extends from Sumatra to New Guinea, and includes Malaysia, Indonesia, the Philippines and Papua New Guinea. Initially known as Malaysia, the name was changed to Malesia when the political state of Malaysia was set up, to prevent confusion.

Palynological studies of vegetation change in Malesia are concentrated on two areas, New Guinea in the east and Sumatra and Java in the west, however, none of the Sumatran or Javan studies has been from a high montane area, above c. 2000 m a.s.l.

Some quite comprehensive palynological studies have been carried out in New Guinea. A series of sites were studied on Mt Wilhelm, Papua New Guinea by Hope (1976) at altitudes ranging from 4420m a.s.l. to 2740 m a.s.l. These provide evidence for the movement of the altitudinal forest limit, and deglaciation of the mountain. From a time prior to 22000 years B.P. until c. 10200 years B.P. the altitudinal forest limit was situated below 2740 m a.s.l. From c. 10200 years B.P. it rose gradually, and ice retreated from the mountain. By c. 8600 years B.P. the forest limit lay above its present level but by c. 5000 years B.P. had retreated, presumably to this level. The relatively high forest limit from c. 8600 to c. 5000 years B.P. is consistent with milder conditions than at present. The decline of the forest limit at c. 5000 years B.P. was probably due to climatic deterioration although man may possibly have influenced its level by setting fires for hunting at high altitudes.

A study of three sites, Sirunki, Inim and Birip, in the Wabag area of Papua New Guinea suggests similar climatic changes (Walker and Flenley, 1979). The record available at these sites reaches back much further, to c. 33000 years B.P. Two of the sites, Sirunki and Inim, lie at 2500 m a.s.l., while Birip lies at 1900 m a.s.l. Prior to 27000 IA (= Inferred Age), pollen recovery is low, and between 33000 IA and 30000 IA hardly vegetated conditions are indicated which are difficult to interpret. From 27000 IA to 25500 IA mean annual temperatures indicated by the vegetation appear to have been similar to those today. Temperatures appear then to have fallen irregularly and between 18500 IA and 16000 IA they were probably c. $10^{o}C$ lower than at present as indicated by a downward shift in the position of the vegetation types, with the altitudinal forest limit probably 1500 m below its present level. Upward shifts of vegetation suggest that temperatures subsequently rose and by 13500 IA they were probably within $1^{o}C$ of their present level.

Other work from New Guinea (eg Powell, 1970; Williams et al., 1972) tends to confirm the existence of cold phases coeval with the time of the full glacials of the Northern Hemisphere.

1.3d Other areas

Work is in progress at a number of montane sites in South India, some of which are reviewed by Blasco and Thanikaimoni (1974). To date however, pollen records have been interpreted intuitively since modern pollen rain - vegetation studies have been lacking. Interpretations are therefore very tentative, but indicate that vegetation changes have occurred in the region. How these relate to environment is not clear.

1.3e Conclusions

The evidence for vegetation change in the high montane areas of the tropics during the Late Pleistocene and Holocene is overwhelming. In South America the evidence so far obtained suggests the existence of a colder climate, with altitudinal depression of the vegetation, during the Late Pleistocene. Coldest conditions appear to have been from c. 21000 to c. 13000 years B.P. when mean annual temperatures were possibly c. 10°C colder than present at about 2500 m a.s.l., and the altitudinal forest limit was depressed by perhaps 1500 m. During this period the climate also appears to have been drier than at present as lake levels were generally low. The Holocene period saw a return of warmer, moister conditions, and for a part of the period, perhaps c. 7500 to c. 3000 years B.P. the climate may have been slightly warmer than at present.

In East Africa the picture is rather similar to that from South America, and the vegetation changes similarly suggest a much colder climate c. 27000 to c. 14000 years B.P. The pollen evidence suggests that conditions at this time were also drier. Warmer, more humid conditions prevailed after c. 12000-10000 years B.P.

The evidence from Malesia suggests that from c. 27000 to c. 25500 years B.P. mean annual temperatures were similar to those of today. Temperatures fell after c. 25500 years B.P. and from c. 18500 to c. 16000 years B.P. mean annual temperatures were lower than at present, possibly c. 10°C colder at 2500 m a.s.l. Climatic amelioration may have begun 16000 years ago although evidence of this appears at different times at different places. However, significant climatic amelioration is recognized at most sites by c. 10000 years B.P. Some evidence suggests that the period from c. 8500 to c. 5000 years B.P. may have experienced milder conditions than at present. There is no palynological evidence from the region, as yet, which suggests that the climate was, at any time during the period, significantly drier or more seasonal than at present. However, it is possible that the precipitation in the areas which have so far been studied could be reduced considerably before the vegetation would be affected, since they are extremely wet at present and the dry seasons are not extreme.

The palynological evidence from the tropical high montane areas suggests that cooler conditions than at present prevailed during the Late Pleistocene in montane areas of all three regions. Palynological evidence for drier conditions during this period is convincing only for East Africa. Drier conditions are suggested for montane South America by lowered lake levels during this time, but the vegetation does not appear to have been greatly affected. Evidence for drier conditions during the Late Pleistocene does not as yet exist for the Malesian high montane areas studied.

1.4 Vegetation history evidence from the tropical lowlands below c. 1150 m a.s.l.

1.4a South America

A relatively small number of palynological investigations have been carried out in the lowland areas of South America, but these have produced some interesting results.

A series of boreholes from the coastal plain of Guyana (van der Hammen, 1963) showed, in addition to marine transgressions and regressions, that the vegetation around the site during at least part of the Late Pleistocene was not rain forest, but a grass savanna. This could have resulted from a formerly drier climate. A very recent sequence from the Cienaga de Morrocayal in the Colombian lowlands at 20 m a.s.l. studied by Wijmstra (1967) showed cycles of wetter and drier periods over the last few hundred years. In Surinam (Wijmstra, 1969), savannas and savanna woodlands were present at times when sea level was also lowered. Again this suggests a much drier climate or a more seasonal one. The apparent dominance of savannas in the sites from Guyana and Surinam during the Late Pleistocene does suggest that a change in regional climate is the cause, rather than local factors eg. edaphic factors, although the latter could contribute to the effect.

A study of a sequence from Lake Valencia at 403 m a.s.l. in Venezuela (Salgado-Labouriau, 1980) showed that the end of the Pleistocene in the area was characterized by a dry phase when the lake was reduced to the status of a swamp or intermittent lake, surrounded by semi-arid type vegetation. The permanent lake began to form at the beginning of the Holocene (c. 10000 years B.P.) and rain forest pollen also appeared in the sediments at this time, and therefore seems to have migrated into the area. The actual area where rain forest was present throughout the Late Pleistocene is not known but must have been reasonably close to the site to permit the fairly rapid migration into the area as observed.

Other indications of formerly drier climates during some periods of the Pleistocene come from Rondonia in the Amazon Basin (van der Hammen, 1972, 1974) and the Rupununi savannas (Wijmstra and van der Hammen, 1966; van der Hammen, 1974). Climatic changes are also recognizable in pollen records from Panama (Bartlett and Barghoorn, 1973). Here there is a suggestion of cooler rather than drier conditions.

There is also evidence of climatic change in the Galapagos Islands. The sequence from El Junco (Colinvaux, 1972) indicates that a dry phase occurred, which appears to have lasted from c. 34000 to c. 10000 years B.P. and which was followed by a wetter climate in Holocene times.

1.4b Africa

Palynological evidence of vegetation change during the Late Pleistocene and Holocene is available from both East and West Africa.

The evidence from Lake Victoria, at 1130 m a.s.l. is based partially on pollen analyses but also on mineralogy and chemical analyses (Kendall, 1969). This suggests the occurrence of a dry period from before 14500 years B.P. until c. 12000 years B.P. Subsequently, conditions were much wetter and forest appeared in the region. There may have been a slightly drier period from c. 10500 to c. 9500 years B.P. After c. 6500 years B.P. the climate became drier or more seasonal and the nature of the forest altered, from evergreen to semi-deciduous. During the last 3000 years the likelihood of human disturbance of the vegetation has obscured any climatic interpretations. Evidence from lake levels and pollen from Lake Turkana (Owen _et al._, 1982) shows that this lake expanded periodically during the Early Holocene, but fell to present levels in the Middle Holocene. Pollen spectra from a section dated as 9880 ± 670 years B.P. have abundant regional elements including montane forest and thicket taxa, which are not recorded in modern lake samples. These were probably transported some distance, but may indicate increased runoff and an extension of montane forests at that time. Vegetation changes are also evident in pollen assemblages from the Kalambo Falls in Northern Zimbabwe (Clark and van Zinderen Bakker, 1964).

Analyses of cores from on and offshore Ivory Coast (Assemian _et_ al., 1970) show that by the latest Pleistocene the Ivory Coast had a warm humid climate, but that the forest cover was more open than at present until c. 9000-8000 years B.P. Deep sea cores from offshore Senegal (Rossignol-Strick and Duzer, 1979) indicate a phase of extreme aridity from 19000 to 12500 years B.P. when tropical vegetation belts had migrated southwards.

Elsewhere in West Africa, preliminary results of palynological investigations into cores from Lake Bosumtwi, Ghana (Maley and Livingstone, 1983; Talbot et al., 1984), have proved very interesting. During the period from c. 15000 to c. 8500 years B.P. the pollen record indicates that patches of montane - like forest existed within grassland, around this lowland site. This suggests an extension of montane forests 300-400 m lower than todays levels. Forest replaced the grassland after c. 8500 years B.P. and arboreal pollen dominates the pollen assemblages throughout this period, to the present day.

In the Niger Delta, Sowunmi (1981a, 1981b) has also found evidence of climatic fluctuations in the past, indicative of wet and dry phases. At some time during the period pre-35000 to c. 8000 years B.P. the extent of forest was reduced. It was replaced by a drier savanna type vegetation. From c. 7600 until c. 2800 years B.P. conditions in the area had fluctuated, with rain forest and freshwater swamp forest, and drier savanna varying in extent. Since c. 2800 years B.P. the rain forest has been reduced in extent by man.

1.4c Malesia

Very few palynological investigations have been carried out on sequences from lowland Malesia. Morley (1976, 1982) investigated a site, Danau Padang, at an altitude of 950 m a.s.l. in West Sumatra. The results suggested that from c. 10000 to c. 8600 years B.P. forests of montane, rather than lowland affinity, lay in proximity to the site suggesting depression of vegetation zonation by possibly 500 m. After c. 8600 years B.P. the vegetation indicated by the pollen assemblages was similar to that found at present in the area. By c. 4000 years B.P. some of the forest trees became markedly less common, while regrowth taxa were better represented. This was interpreted as forest clearance by man, followed by regrowth.

A study of a Holocene lowland peat swamp in Kalimantan Tengah, Indonesia (Morley, 1981b) showed that peat formation began abruptly over a topogenous swamp surface in which Gramineae and *Lycopodium cernuum* were conspicuous elements. Swamp forest then developed on these peats. Morley suggests that the early Gramineae - *Lycopodium cernuum* swamp may have existed under more seasonal conditions than those prevalent today, and that the peat formation may have been initiated by a change to a less seasonal climate during the Middle Holocene.

Pollen analysis of bores taken in peat swamps in Sarawak (Muller, 1965, 1975; Anderson and Muller, 1975) illustrated the way in which peat swamp develops at a site. At Marudi the initiation of peat swamp development began c. 4000 years ago and followed a pattern broadly similar to the vegetation zonation across the surface of the peat swamp from its edge to its centre. Bores taken from coastal peat swamps also showed phases when mangrove pollen was important, and this vegetation was presumably growing at the site indicating transgressional phases.

The likely tectonic origins of Tasek Bera (Morley, 1976, 1981a) are also reflected in pollen assemblages, and were described in Section 1.2c.

1.4d Other areas

Although not strictly speaking within the equatorial tropics, studies from rain forest sites in north-east Queensland, Australia, provide some interesting evidence for past climatic change. A series of four sites has been studied by Kershaw (1970, 1971, 1975, 1976, 1983) all of which at present lie within the rain forest zone. Three of the sites are of Holocene age, while the fourth, Lynch's Crater extends to at least 60000 years B.P. All of the sites provide palynological evidence for changes of vegetation type growing in the region. At Lynch's Crater the pollen record suggests that prior to c. 38000 years B.P. rain forest existed near the site. However, the composition of this forest was not entirely similar to that existing in the area today, as it included Araucaria, and apparently a number of taxa which are not now present in north-east Queensland. The forest declined in importance over the period c. 38000 to c. 27000 years B.P. being replaced by sclerophyll woodland. The latter persisted until c. 8500 years B.P. when it was again replaced by rain forest. The Holocene replacement of sclerophyll vegetation is recorded at all four sites although the dates of this event vary slightly. The cause of this change is thought to relate to moisture availability; a phase of reduced moisture availability beginning c. 38000 years B.P., and a major arid phase occurring from c. 15500 to c. 10400 years B.P. (Kershaw, 1983). The different times at which rain forest reappeared at the four sites during the Holocene may be due to the different migration times of rain forest from its Pleistocene refugia, if these existed.

1.4e Conclusions

The relatively few palynological studies from tropical lowland areas do provide some interesting results. In South America the few sites studied provide evidence of much drier climates during the Late Pleistocene, than at present, with moister conditions prevailing during the Holocene.

In East Africa, the small amount of evidence available also points to drier conditions during the Late Pleistocene. In West Africa the available evidence similarly indicates an arid phase at this time, although the Lake Bosumtwi evidence (eg. Maley and Livingstone, 1983) may suggest that this period was also cooler.

In Malesia evidence from 950 m a.s.l. (Morley, 1976) suggests that climate may have been slightly cooler at the beginning of the Holocene, than at present, but results from coastal peat swamps are more difficult to interpret in climatic terms.

In Northern Queensland, there is also evidence of more arid conditions during the Late Pleistocene, but none of cooler conditions, although these might have existed.

The evidence so far available from the tropical lowland areas points, therefore, to the existence of more arid phases during the Late Pleistocene. There are some indications, at a relatively small number of the sites studied, that conditions may have been cooler in the Late Pleistocene and at the beginning of the Holocene, than at present. The work which is currently in progress in some of these areas may help to clarify the situation.

1.5 Vegetation history evidence from the tropical mid-altitude regions, c. 1150-2000 m a.s.l.

Very little palynological work has been carried out on sites at an intermediate altitude in the tropics. In fact, when this research was initiated, results were available only from a single site, Ishiba Ngandu, at 1400 m a.s.l. in Zambia (Livingstone, 1971), although work was in progress in a number of other areas.

The 22000 year record from Ishiba Ngandu is actually very interesting, since the pollen changes in this diagram are very slight and the sequence is dominated throughout by the pollen of grasses. The lack of change indicated is thought to be due to the nature of the arboreal taxa of the area. These are largely Leguminous, entomophilous, low pollen producers. As a result they were extremely under-represented in the pollen spectra and it was not possible on the basis of these to judge the importance of the taxa in the surrounding vegetation; hence the lack of evidence for vegetation change. It was possible that the vegetation in the area had varied in the past but that such changes were not recognizable in the pollen assemblages produced.

More recently, results have become available from a small number of other mid-altitude sites. At Telefomin, 1500 m a.s.l. in Papua New Guinea (Hope, 1983) vegetation changes do occur, but these are less dramatic than at the high altitude sites studied elsewhere in New Guinea (Section 1.3c). Lower montane forests of some sort appear to have existed around the site throughout the 20000 year record. This may indicate a maximum temperature variation of 8^{o}C from present levels, but was probably much less. Changes in the vegetation at this site c. 3000 years ago are thought to be due to human disturbance.

In Sumatra there is also new evidence from two sites in the Toba Highlands (Maloney, 1979, 1980, 1981). At Pea Sim-sim, 1450 m a.s.l., the pollen evidence indicates the possible presence of a mosaic of alpine and upper montane forest vegetation on this plateau area from c. 18500 to c. 16500 years B.P. Subsequently, the pollen assemblages indicate establishment of lower montane forest, from c. 16500 years B.P. Forests similar to those presently found in the region are established after c. 12000 years B.P. These changes may indicate climatic amelioration. A sequence from the nearby Tao Sipinggan, at 1445 m a.s.l. extends to c. 12000 years B.P. and shows similarities with the Pea Sim-sim sequence of the same age (Maloney, 1979, 1981). Both sites show evidence of human disturbance of the vegetation. At Pea Sim-sim increased disturbance indicators and herbaceous non-forest components are found after c. 7500 years B.P. and are interpreted as most probably resulting from human activity (Maloney, 1979, 1980). At Tao Sipinggan the rise of open land indicators occurs after c. 1700 years B.P. although some indications of vegetation disturbance also occur before this time.

Results published from Java are mostly so far of a preliminary nature. Stuijts (1984) studied a site, Situ Bayongbong, at 1250 m a.s.l. in West Java. The record begins at c. 16800 years B.P. and until c. 12360 years B.P. forests like those now found above about 1800 m a.s.l. were found around the site. This suggests that temperatures were several ^{o}C cooler than present during this period. From c. 12360 to c. 10890 years B.P. a shift of vegetation in an uphill direction occurred, indicating climatic amelioration, and forests like those now found above c. 1400 m a.s.l. occupied the area. The uphill migration appears to have continued subsequently until the forests attained their present composition. Elsewhere in West Java two Holocene sequences from 1575 m a.s.l. and c. 1000 m a.s.l. (van Zeist *et al.*, 1979) also indicate changes in forest composition. The cause of these is uncertain and may have resulted from environmental factors such as climate or perhaps human interference.

There therefore seems to be some evidence, at least from Malesia, that mid-altitude sites have also experienced vegetation change during the Late Pleistocene and Holocene, and that this may have been a result of climatic change.

1.6 Other evidence of environmental change in Malesia

There is evidence from several areas of Malesia of more extensive glacial activity than at present, during times roughly coeval with the Northern Hemisphere glaciations.

At present the summit area of Gunung Kinabalu in Sabah, East Malaysia, experiences occasional frosts. Glacial evidence from the summit area of this 4101 m mountain includes polished rock surfaces, corries, grooves and striae. Koopmans and Stauffer (1968) suggest that it was capped by ice at least once during the Pleistocene; this cap possibly covered 5.4 km^2 of the summit area. Evidence of moraines at c. 3050 m a.s.l. and possibly also at c. 2900 m a.s.l. suggests that valley glaciers developed at this time. A minimum age for deglaciation is provided by organic deposits from the Sacrificial Pool at 4000 m a.s.l. on the summit area. This is 9186 ± 120 years B.P., although this is thought to be possibly a slightly young estimate (Flenley and Morley, 1978).

In Irian Jaya (New Guinea) some peaks are sufficiently high to have permanent icefields. Evidence from glacial deposits around Mt Carstensz shows that glaciers formerly extended to much lower altitudes. The lowest deposits known are at 1705 m a.s.l. and provide a minimum age for deglaciation of 10000 ± 130 years B.P. (Peterson and Hope, 1972). Evidence of the presence of ice in areas now lacking it, or its greater extent, during the Late Pleistocene comes also from other high New Guinea mountains (eg. Hope and Peterson, 1975; Loffler, 1972). In some of these areas there is also evidence of minor glacial advances and recessions over the last few hundred years (Peterson et al., 1973). Interpretation of the causes of the glacial advances and recessions must take into account factors of humidity, cloudiness and precipitation as well as temperature changes.

There is also evidence from Sumatra of glaciation during the Pleistocene. This comes from the summits of G. Kemiri, G. Leuser and G. Bandahara in North Sumatra (van Beek, 1983). On G. Leuser the snowline may have lain at 3100 m, and ice may have covered an area of 100 km^2.

Evidence also exists in Malesia of former lower and higher sea levels. Dated horizons suggest sea levels as much as 80 m below present levels at c. 11000 years B.P. (Biswas, 1973). Since much of the Malesian region is surrounded by shallow seas, seldom more than 200 m deep and often less than 100 m, it is clear that lowering of sea levels by 80 m or more would have a considerable effect on the land - sea configuration of the area. There is considerable speculation as to the effect this change might have had on climates of the region in the past, eg. greater continentality of climate might have occurred. However, even if this was the general effect it is unlikely that all areas would have been affected to the same extent. Some places such as West Sumatra, having extremely deep water offshore, may have been affected to a lesser extent than places within the new continental area, far removed from oceanic influences.

Evidence of former high sea levels is not so convincing. Sea levels may have been a few metres higher than present during some parts of the Holocene, as suggested by Nossin (1964). However, sea levels higher than these are unlikely, and the evidence which suggests these may have been affected by subsequent uplift of the land, which has been considerable in some areas. Tjia et al. (1972) calculated uplift rates for parts of Eastern Indonesia and Eastern Malaysia, due to tectonic activity, of 4.5 - 9.0 mm per year, over the last 24000 years. These were based on elevated shorelines. The effects of higher sea levels on climate in this area are however less likely to be of significance, since higher sea levels would not substantially alter the land - sea configuration of the region.

1.7 Conclusions

The evidence so far obtained from tropical areas points to climatic change during the Late Pleistocene and Holocene period. In the high montane areas, above c. 2000 m a.s.l. the evidence is overwhelmingly in favour of cooler conditions during the Late Pleistocene. At 2500 m a.s.l. mean annual temperatures may have been as much as 10°C cooler during the phase of most extreme conditions, possibly during the period from c. 21000 to c. 16000 years B.P. The evidence from tropical montane Africa suggests that the Late Pleistocene cool period was also drier than at present, and evidence from lake levels suggests that this may also have been the case in South America. In the montane regions of Malesia there is no evidence from pollen or lake levels which could only be explained in terms of a drier climate.

The evidence from tropical lowland areas conversely suggests that the Late Pleistocene climates in the tropics were drier than at present. There are slight suggestions, from some areas only, that conditions may have been slightly cooler, but how extensive this was, is not clear. Other evidence, such as that of sea surface temperatures as elucidated from studies of foraminifera and oxygen isotopes in deep sea cores, also provides some evidence about former climates in the tropics. These suggest that sea surface temperatures off New Guinea and Sumatra may have been 2°C colder than at present, at 18000 years B.P. (CLIMAP, 1976; Shackleton, 1978), when sea levels were perhaps 100 m lower.

The apparently different extent of cooling experienced at high altitudes and in the lowlands during the Late Pleistocene led Walker and Flenley (1979) to postulate that lapse rates varied in the past, at least in Malesia. The evidence available suggests that the lapse rate may have been over 0.8°C/100 m at c. 18000 years B.P., rather than c. 0.6°C/100 m as at present. It is of interest that this is closer to the dry adiabatic lapse rate, and might imply drier atmospheric conditions than at present. However palynological studies in Malesia have not as yet revealed any vegetation changes which would be due to a drier climate. There is though, some evidence from firn lines c. 18000 years B.P. which could be interpreted as being caused by a drier climate (Walker and Flenley, 1979). The depression of the altitudinal forest limit in New Guinea c. 18000 years B.P. was by c. 1500 m, but the firn lines were depressed by a much smaller amount. The rather large altitudinal range between the two could be explained by a very low lapse rate, but this would not fit in with the vegetation and other evidence from lower altitudes. It could also be interpreted as being the result of lower precipitation input at high altitudes. This would affect the firn line without necessarily having any affect on the vegetation.

The number of sites which have been examined palynologically in the vast tropical area is still very small when compared with the numbers studied in Europe and North America. As a result, although a picture of the vegetation and climatic changes which have affected the tropical regions is beginning to emerge, there are still many gaps in our knowledge of these areas. For example very few mid-altitude sites have been examined. One question which might be posed is this:

At mid-altitudes, c. 1500 m a.s.l., during the Late Pleistocene and Holocene were there

(a) No vegetation and climatic changes

(b) Changes of temperature only

(c) Changes of wetness only

(d) Changes of both temperature and wetness

And if there was some change, when did this occur, and by how much?

The present study set out to try and provide answers to these questions, at least for a part of West Malesia.

CHAPTER 2

THE LOCATION OF THE FIELD AREA AND ITS PHYSICAL ENVIRONMENT

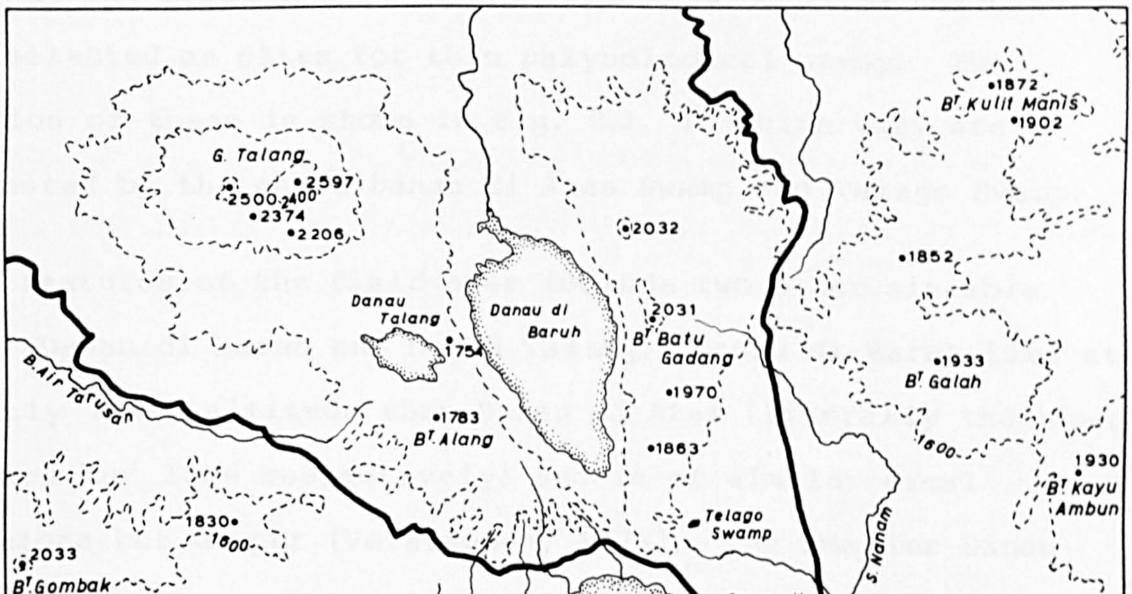
2.1 Introduction

The principal area chosen for this study is the region surrounding Danau di Atas, and the settlement of Alahan Panjang in the West Sumatran Highlands. Some work was also undertaken on surface pollen samples from Gunung Kerinci, which lies about 90 km south-east of the main field area.

Danau di Atas lies c. 50 km east of Padang in the province of West Sumatra at latitude 1^{o} 04'S, longitude 100^{o} 46'E and an altitude of 1535 m a.s.l., in the Barisan Mountain Range. The altitude of the region in which the field area is situated ranges from c. 1200 m a.s.l. to over 2500 m a.s.l. The lake itself is roughly 6 km long by 2 km wide and is thought to be about 40 m deep (Morley *et al.*, 1973). An active volcano, G. Talang (2597 m) lies c. 11 km north-west of the lake (Fig. 2.1).

The topography of the area is generally mountainous with many ridges and steep valleys, although a broad, fairly flat area runs northwards for several kilometres from Danau di Atas and Alahan Panjang. This area is extensively settled and cultivated, although some areas of uncultivated swamp do still remain. Where these have woody deposits at or near the surface, this wood may be collected by the local inhabitants, presumably for use as fuel. Many marginal swamps survive around Danau di Atas, and a number of these and other similar sites in the area were examined by Morley *et al.* (1973) to determine if any were suitable for

Fig. 2.1
The location and relief of the Danau di Atas region


G. Talang
2597
2500
2400
2374
2206
2032
Danau Talang
1754
Danau di Baruh
2031
BT. Batu Gadang
1970
1863
1783
BT. Alang
B. Air Tarusan
1872
BT. Kulit Manis
1902
1852
1933
BT. Galah
1600
1930
BT. Kayu Ambun
S. Nanam
Telago Swamp
1830
1600
2033
BT. Gombak
Danau di Atas Swamp
Danau di Atas
R. Gumanti
Alahan Panjang
1200
B. Air Balang Ngalau
1600
1881
1865
1905
1983
2025
1885
1920
1985
1600
1880
Air Dingin
2070
2090
B. Hari
2000
2160
2370
2200
2337
BT. Air Dingin
0
3
km
SUMATRA
0
300
km
AB.

palynological study. One of these marginal swamps, comprising a tongue of swamp on the eastern side of the lake, and another swamp at the western edge of the flat area north of the lake, were selected as sites for this palynological study. The location of these is shown in Fig. 2.1, in which they are designated by the names Danau di Atas Swamp and Telago Swamp.

Other features of the field area include two other sizeable lakes, Danau di Baruh and Danau Talang. Danau di Baruh lies at a slightly lower altitude than Danau di Atas (literally the 'down' lake and 'up' lake respectively) and is of similar areal dimensions but deeper (Verstappen, 1973). The smaller Danau Talang lies in a graben on the flanks of G. Talang. All three lakes are volcano-tectonic or tectonic in origin.

G. Kerinci, for which surface pollen samples were available, is a volcanic peak, and also the highest mountain in Sumatra, with an altitude of 3800 m. Its location relative to the main field area is shown in Fig. 2.2.

2.2 Geology

The west coast of Sumatra lies at the boundary of two actively converging tectonic plates, the China Plate and the Indian Plate (Fitch, 1972). The Indian Plate is being digested along a zone of subduction. The convergence of these two plates has led to the development of many volcanic arc features along the western side of the island, namely a deep sea trough, mountain orogenesis and volcanic activity. An outer arc of non-volcanic islands, including the Mentawi Islands, Nias and Simalur, lie east of the deep sea trough. An interdeep separates this non-volcanic arc from the volcanic inner arc of the system, which is represented on the Sumatran mainland by the volcanic complexes of the Barisan Range (Verstappen, 1964).

The Barisan Range itself comprises common younger Palaeozoic and Mesozoic sedimentary rocks which have been infolded, overthrust and intruded by Palaeogene and younger granites and granodiorites. Uplift, folding and rifting of the Barisan Range began in the lower Palaeogene. A period of subsidence in the Oligo-Miocene resulted in the deposition of sedimentary rocks of this age east and west of the range and locally in the interior. Subsequent Middle Miocene uplift was accompanied by block-faulting, intense volcanic activity and granodioritic intrusions. A final major orogenic episode took place in the Plio-Pleistocene. Tectonic movements and volcanic activity occur throughout the area to the present day. Volcanic activity is concentrated along fault lines (Verstappen, 1964).

An important feature of the Barisan Range is the well developed Median Graben (also known as the Semangko Fault Zone). This runs the entire length of the island, and is strongly associated with the fault movements and volcanic activity which occur within the Barisan Range to the present day. It is actually situated on the crest of the geanticline which forms the Barisan Range itself (Verstappen, 1973). The Median Graben is well developed in West Sumatra.

The Danau di Atas area lies within the Median Graben, and the latter is also well developed southwards of the area where it forms the Batang (B.) Hari section and, further south, the Kerinci Valley. The graben reaches its highest altitude of about 1500 m a.s.l. at the lakes Danau di Atas and Danau di Baruh. Both lakes are described as being volcano-tectonic in origin, and some of the numerous faults of the Median Graben border them. Some of these faults may have formerly acted as volcanic vents (Verstappen, 1973). The complex fault systems of the area are shown in Figs 2.2 and 2.3.

It has been suggested (Verstappen, 1973) that Danau di Atas was once drained by the Batang Hari, Sumatra's longest river. This now has its source in the mountains south-west of the lake, flows within a few hundred metres of the lake's southern edge, and drains southwards through the Median Graben and eventually eastwards into the Straits of Malacca. The possible former outflow point, at the southern end of the lake, is visible as a shallow saddle, 9 m above the present lake level. The lake is presently drained via the River Gumanti, from a point on its eastern side. Further possible evidence of the lake's capture by the R. Gumanti is provided by terraces around its shores which also indicate a drop of c. 9 m in the lake level (Verstappen, 1973). However, even around Danau di Baruh there is evidence of former higher lake levels. This lake drains towards the north, and lake levels 15 m higher than the present are indicated for this lake by a terrace remnant (Verstappen, 1973). No dates for the change in lake levels, or capture of Danau di Atas by the R. Gumanti have been suggested.

Fig. 2.2
Major geological and relief structures of the West Sumatran Highlands

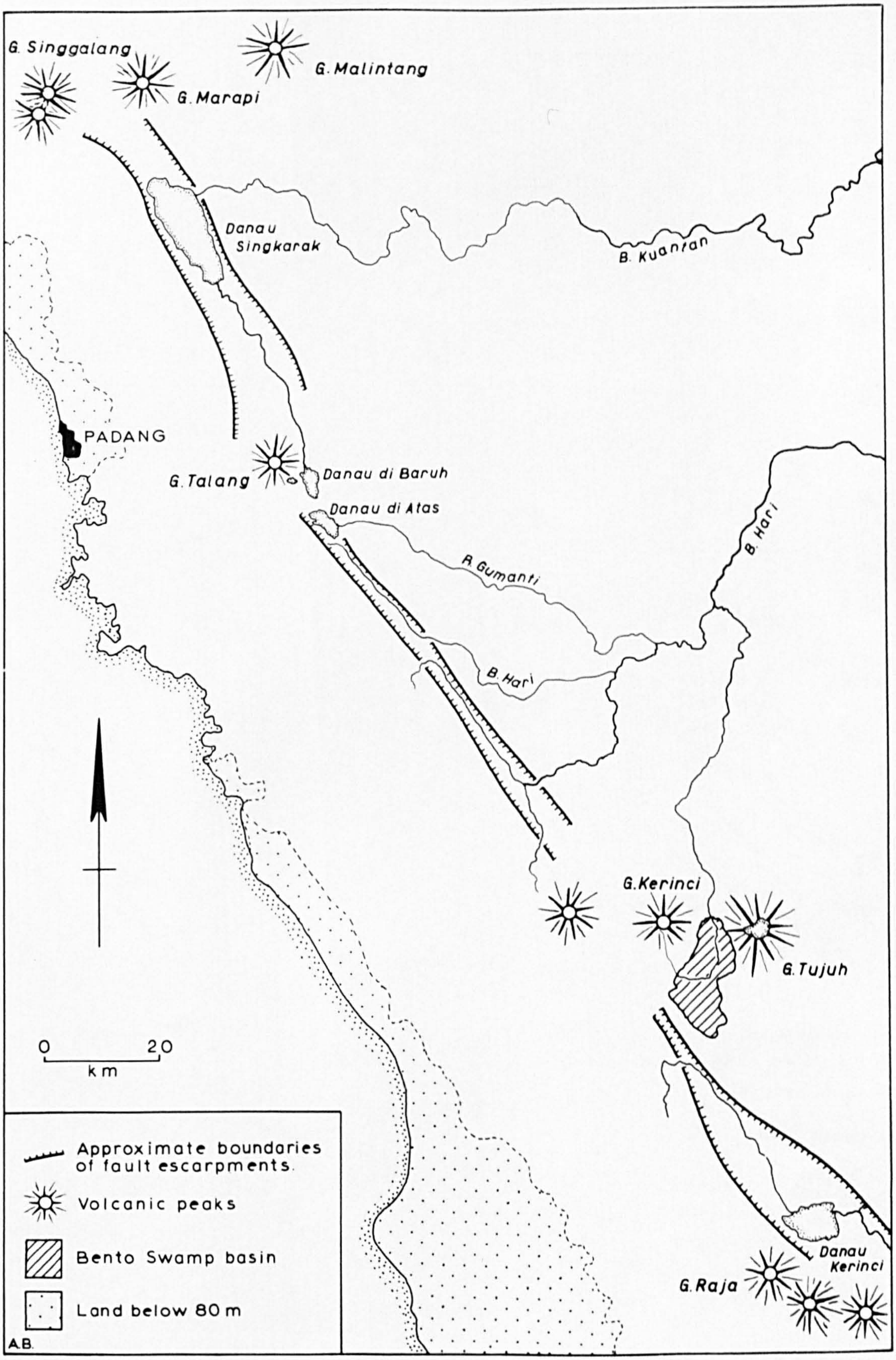
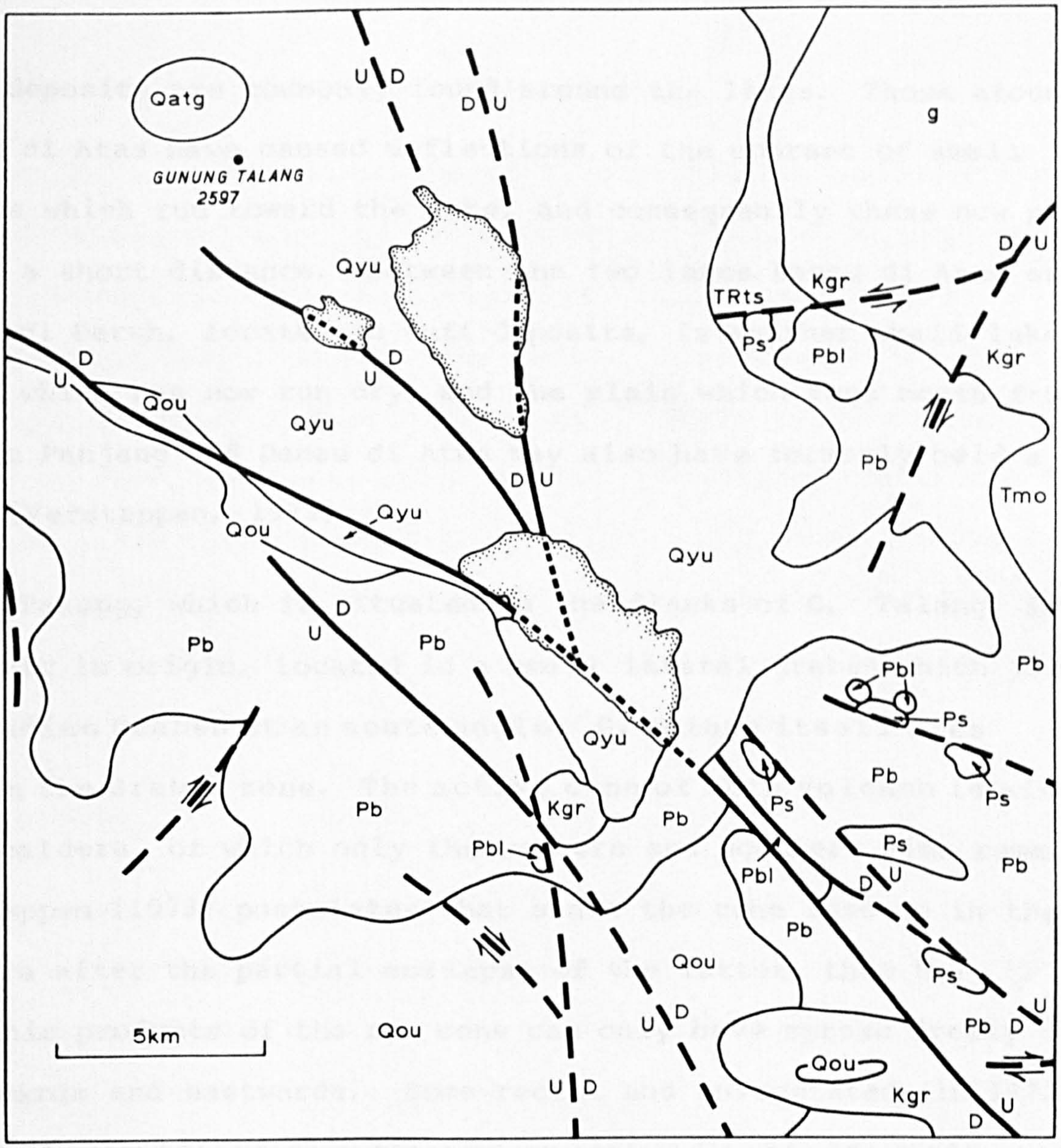

G. Singgalang
G. Malintang
G. Marapi
Danau Singkarak
B. Kuantan
PADANG
G. Talang
Danau di Baruh
Danau di Atas
A. Gumanti
B. Hari
B. Hari
G. Kerinci
G. Tujuh
Danau Kerinci
G. Raja
0 20
km
Approximate boundaries of fault escarpments.
Volcanic peaks
Bento Swamp basin
Land below 80 m
A.B.

Fig. 2.3

Geology of the Danau di Atas region (Based on Geological Survey of Indonesia maps of the region)

Explanation of the geological groups

Tmo	Upper member of Ombilin Formation Claystones, sandstones and conglomerates
Pb	Barisan Formation Phyllite, slate, limestones, hornfels and metagreywacke
Qyu	Undifferentiated volcanic rocks Volcanic breccia, lahars, tuff breccia and tuff, basaltic to andesitic in composition
Qou	Undifferentiated volcanic breccia Tuff breccia, lahar and lavaflows, mostly of andesitic composition
Kgr	Granitic rocks Composition ranges from granodiorite to granite
Qatg	Andesite of G. Talang Breccia, lahar deposits, lava flows, lapilli and tuff, all of basaltic or andesitic composition



──	Contact
━ ━ (U/D)	Fault, dashed where approximately located or inferred. U: upthrow-side; D: downthrow-side.
⇄ ━ ━	Strike slip fault, dashed where approximately located, dotted where concealed. Arrows show direction of relative movement.

Sedimentary rocks

Tmo	Upper member of Ombilin Formation
Pb	Barisan Formation
Pbl	Limestone member of Barisan Formation

Volcanic and intrusive rocks

Qatg	Andesite of Gunung Talang
Qyu	Undifferentiated volcanic rocks
Qou	Undifferentiated volcanic breccia
g	Granite
Kgr	Granitic rocks
Ps	Serpentine diabase

Metamorphic rocks

TRts	Slate and shale member of Tuhur Formation

Tuff deposits are commonly found around the lakes. Those around Danau di Atas have caused deflections of the courses of small rivers which run toward the lake, and consequently these now pass it at a short distance. Between the two lakes Danau di Atas and Danau di Baruh, located in tuff deposits, is another small lake basin which has now run dry, and the plain which runs north from Alahan Panjang and Danau di Atas may also have formerly held a lake (Verstappen, 1973).

Danau Talang, which is situated on the flanks of G. Talang, is tectonic in origin, located in a small lateral graben which joins the Median Graben at an acute angle. G. Talang itself lies within the Graben zone. The active cone of this volcano is sited in a caldera, of which only the western and southern rims remain. Verstappen (1973) postulates that since the cone rose up in the caldera after the partial collapse of the latter, then the volcanic products of the new cone can only have spread freely northwards and eastwards. Some recent and unvegetated (in 1973) lahar flows radiate from the top area of this cone. Lava flows are a dominant feature of the lower slopes of G. Talang. Eruptions are mentioned for this volcano in 1833, 1843, 1845 and c. 1876 (Neumann van Padang, 1951) and more recently in 1963, and from 200 m below the summit on the north-east slope in 1967 and 1968 (Simkin et al., 1981).

The geology of the Danau di Atas area (Fig. 2.3) consists largely of volcanic rocks, breccias, lahars and tuffs derived from the volcanic complexes, and the phyllites, slates, limestones, hornfels and metagreywackes of the Barisan Formation.

The Kerinci volcanic complex also lies within the Median Graben. G. Kerinci is geologically the most recent volcano in the complex, the other volcanic peaks are the now extinct G. Patasembilan, and G. Tujuh. The latter is actually a group of seven peaks formed by the collapse of a former volcanic cone, which now surround a huge caldera lake. No volcanic activity has occurred since this collapse. G. Kerinci is, however, still active, activity being recorded in recent times in 1966, 1967, 1968 and 1971 (Simkin *et al.*, 1981). Verstappen (1973) describes recent ash layers and lavas on its upper, southern face.

2.3 Climate

Much of Sumatra may be classed as humid, as defined by Fontanel and Chantefort (1978), ie. as having a mean annual rainfall of more than 1500 mm. Nearly half of the island may be classed as hyperhumid, with a mean annual rainfall exceeding 3000 mm. Rainfall totals generally increase with altitude over the lower mountain slopes, although at more extreme altitudes may actually diminish with increasing altitude, while reliefs more exposed to rain bearing winds will experience greater amounts of rainfall.

The rainfall regimes experienced in Sumatra are dependent on the wind systems and therefore are linked to movements of the Intertropical Convergence Zone (ITCZ) (Fontanel and Chantefort, 1978). During the northerly monsoon, from approximately November to January, maritime winds bring rain to the whole island.

During the southerly monsoon, when the ITCZ moves north, rainfall decreases. In other parts of the Indonesian archipelago this results in a dry season. In Sumatra, however, these originally dry winds from the Australian region have travelled much further over sea, and are humid enough to produce rain. Most of Sumatra does not experience any dry months, according to the Bagnouls and Gaussen definition as being where precipitation is less than twice the mean temperature in centigrade ($P < 2 \times$ mean $T^{o}C$) (Fontanel and Chantefort, 1978). However, it does experience some seasonality of rainfall as a result of these wind systems. The time for maximum rainfall in central Sumatra is usually November - December, with a second maximum in April - May. Associated with the southerly monsoon is the period of least rainfall, usually June to September. In the montane areas the rainfall regimes are almost the same as those at lower altitudes, except that there is more rainfall, even in the driest months.

According to Fontanel and Chantefort (1978), the Danau di Atas region lies in an area having precipitation of greater than 3000 mm per annum, while the area to the north of Danau di Atas has slightly lower rainfall totals of between 2500 and 3000 mm per annum. However, actual rainfall observations made in the area, from a rainfall gauge in Alahan Panjang, over the period 1879-1928 suggested slightly lower rainfall totals. These, according to Boerema (1931) are 2000 - 2500 mm per annum, mountains and ridges receive considerably more. Boerema suggests values of 3000-3500 mm per annum for the mountains surrounding the area. Results of actual rainfall observations made in the area are summarised in Table 2.1, based on data extracted from Boerema's 1931 rainfall maps. Since the ranges are from isohyet maps they are in multiples of 50 or 100 mm. There is a rainfall station in the area at present, but more recent data were not available to this study. However, Boerema's data clearly illustrate the seasonality of rainfall in the area, linked to the prevalent wind systems. There is a distinct decline in rainfall values from May until September, the time of the southerly monsoon, while peaks occur in October to January and March to April. This same pattern of rainfall seasonality is also reflected in rainfall records from the Kaju Aro tea plantation, south of G. Kerinci (Jacobs, 1958). This data also clearly shows the decline in rainy days per month during the southerly monsoon, May to September. Figure 2.4 shows diagramatically the monthly rainfall patterns for Alahan Panjang and Kaju Aro.

Temperatures in lowland Sumatra are high and uniform. At sea level the mean air temperature is 26-28°C and the diurnal variation is 7-10°C. Mean annual sea surface temperatures at the equator are 28°C with a variation of less than 2°C (Fontanel and Chantefort, 1978). The thermic gradient (lapse rate) with altitude is approximately 0.6°C/100 m but varies with the humidity of the air, and is steeper with dry air. The mean temperature of the coldest month would be expected to be less than 20°C at about 900-1000 m a.s.l., less than 15°C at 1700-1800 m a.s.l., less than 10°C at 2600-2700 m a.s.l. and less than 5°C at 3500-3600 m a.s.l. (Fontanel and Chantefort, 1978). As in the lowlands, the annual amplitude would be less than 2°C, and

TABLE 2.1

Mean monthly rainfall at Alahan Panjang and in the surrounding mountain areas, 1879-1928.

Data are extracted from Boerema (1931)

	Alahan Panjang rainfall (mm)	Surrounding mountain areas rainfall (mm)
January	200-300	300-400
February	150-200	200-300
March	200-300	200-300
April	200-300	300-400
May	150-200	200-300
June	100-150	150-200
July	50-100	100-150
August	100-150	150-200
September	150-200	200-300
October	200-300	300-400
November	200-300	300-400
December	200-300	300-400

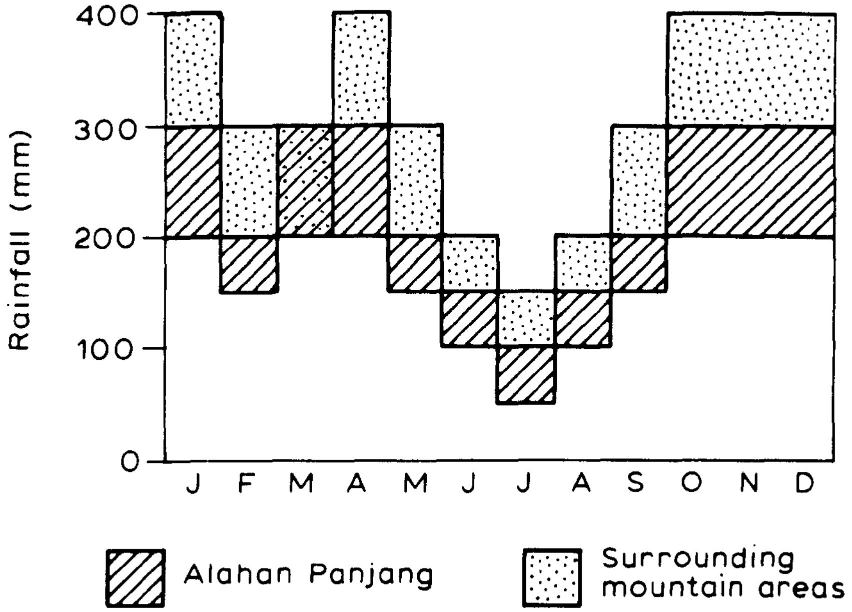
TABLE 2.2

Soil temperatures (°C) at 1m depth, for forested plots in the Danau di Atas region.

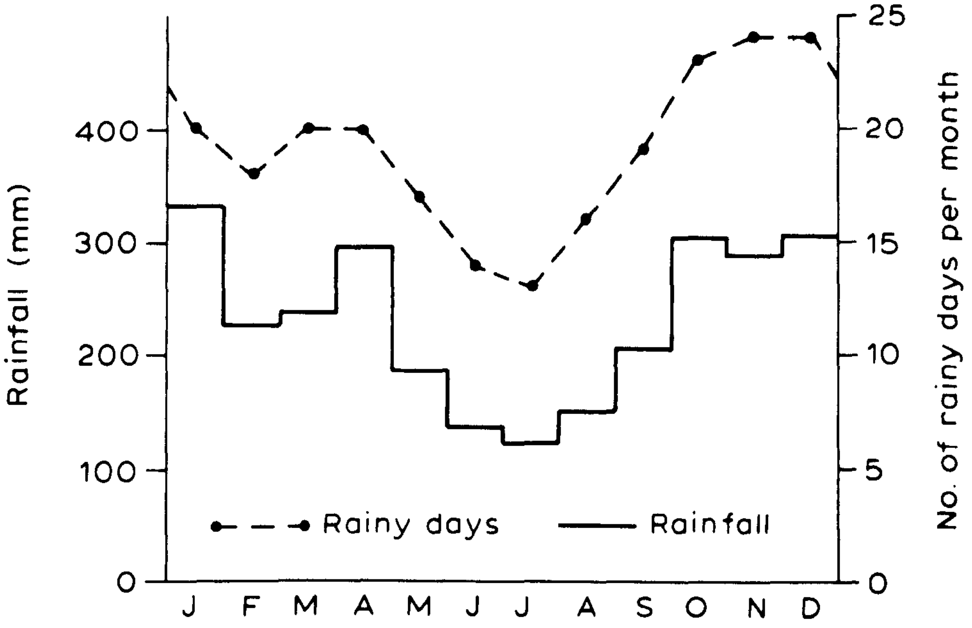
Plot	Altitude (m)	Temperature (°C)
24	1475	17.35
2	1535	17.20
1	1640	16.90
3	1750	16.60
4	1780	15.40

Fig. 2.4
Mean monthly rainfall totals at Alahan Panjang and Kaju Aro, and number of rainy days per month at Kaju Aro

(a) ALAHAN PANJANG : 1879 - 1928
(after Boerema, 1931)



(b) KAJU ARO *(after Jacobs, 1958)*



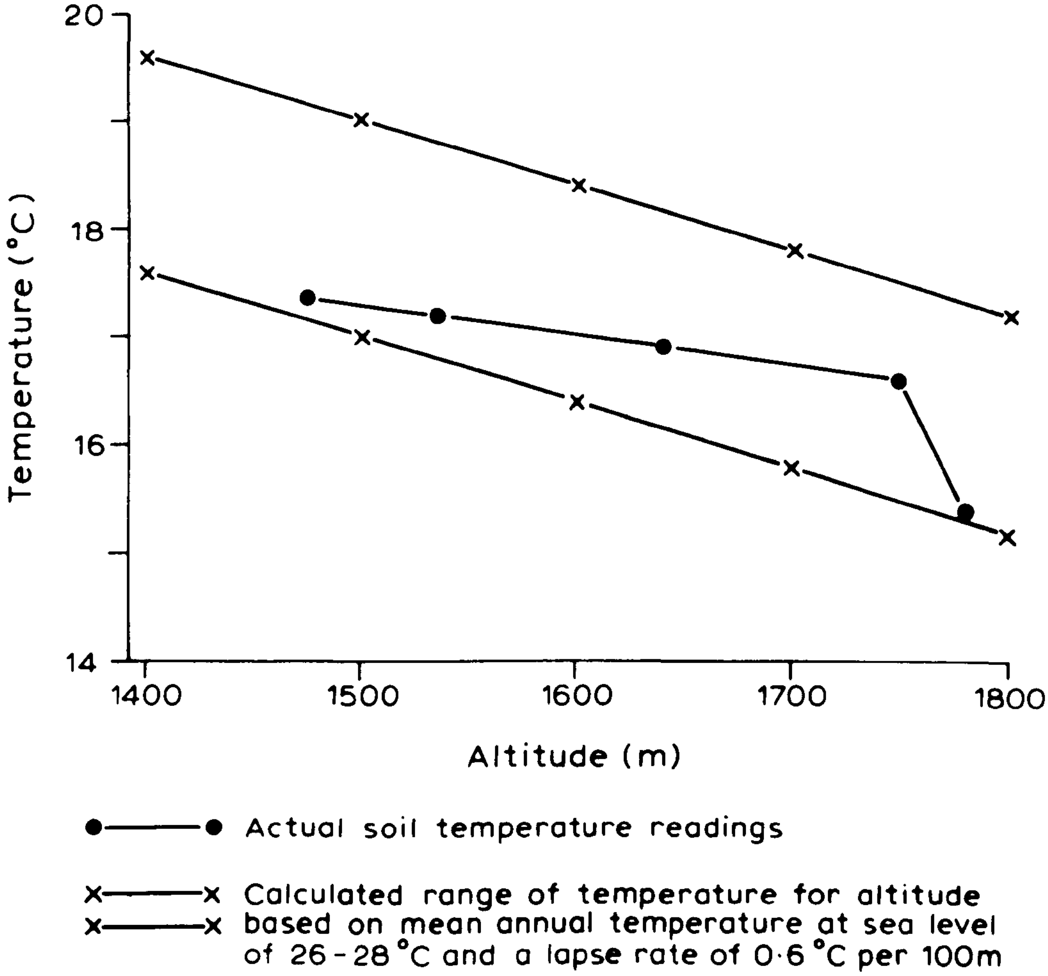
diurnal variation would be of the order of 6-10°C, although the degree of exposure might cause these to vary.

No temperature data were available for the Danau di Atas area, however, based on its altitude (1535 m a.s.l. at the lake) it would be expected to have a mean temperature of the coldest month between 15°C and 20°C. For G. Kerinci the temperatures would be expected to vary with altitude as described above.

According to Braak (1928), soil temperatures recorded at a depth of 0.5m or more in soils under heavy shade or forested conditions in the tropics are constant, and approximately correspond to annual air temperatures. For bare or unshaded soils such temperature recordings are actually 3-4°C higher than average air temperatures. Soil temperature was recorded at a depth of 1m in five of the forested vegetation plots studied in the Danau di Atas area. These measurements are shown, along with the altitudes of the plots, in Table 2.2. Mean annual air temperatures suggested by these soil temperature readings are within the range expected for each altitude, assuming a lapse rate of 0.6°C/100m and mean annual temperature at sea level of 26-28°C (Fig. 2.5). However, the actual drop in temperature with altitude in plots 24, 2, 1 and 3 is rather close to 0.3°C/100m, with a sharp drop in temperature between plots 3 and 4 (1750 m and 1780 m a.s.l. respectively).

Neither humidity nor windspeed values are available from the Danau di Atas area, although the former is likely to be continuously high.

Fig. 2.5
Soil temperature at 1m depth, and altitude, for forested plots in the Danau di Atas region


Temperature (°C)
20
18
16
14
1400
1500
1600
1700
1800
Altitude (m)
●——● Actual soil temperature readings
x——x Calculated range of temperature for altitude
x——x based on mean annual temperature at sea level of 26-28 °C and a lapse rate of 0·6 °C per 100m

2.4 Vegetation characteristics

Much of Sumatra must formerly have been covered by forest of various types, except where environmental conditions were unsuitable for tree growth eg. recent volcanic deposits. Substantial areas of forest have now been removed by man, mostly for timber and agricultural purposes. This has certainly been true of quite considerable areas in the Danau di Atas region. Here, much of the forest in the vicinity of the settlements has been cleared, although steeper slopes, ridges and high areas are generally still forested.

2.4a General features of South-East Asian forests.

The forests of Sumatra are structurally and physiognomically similar to those of the rest of the everwet regions in the South-East Asian tropics; and even to those under similar environments elsewhere in the world. However, they do vary floristically from forests elsewhere. It is useful, therefore, to consider the typical features of such forests as similarities may be a guide for comparison of changes through time to forests both within and outside the study area.

Many of the original studies of forests in South-East Asia and particularly in Malaysia, were done for silvicultural purposes, but such studies nonetheless provided much useful information as to forest structure. Symington (1943) was the first person to describe the rain forest formations in Malaysia using floristic similarities, and his work is still used as the basis of altitudinal rain forest zonation for that country (Table 2.3). Rain forest types or rain forest formation types can be recognized throughout the tropics and are basically divided, in South-East Asia, into three main altitudinal groups, although sub-groups and facies of these may be recognized. These main groups are lowland rain forest, lower montane rain forest and upper montane rain forest. The boundaries between these are rarely sharp and the altitudinal extent of each of these main groups varies from region to region as a result of varying environmental factors. The situation is complicated slightly because different authors have often used slightly different criteria to classify the forest types, and have also sometimes applied different terms to the same formations. The main schemes used to classify altitudinal forest types in Peninsular Malaysia, Sumatra and Java, and their relationship to elevation are summarized in Table 2.3. It is proposed to follow the Kerinci Zonation Scheme (after Morley, 1976, 1982) in this study since this area is also volcanic. In this scheme the ericaceous scrub, ericoid forest and Gleichenia scrub zones form divisions of the Upper Montane Rain Forest Formation, while lower montane forests I and II, and sub-montane forest are divisions of the Lower Montane Rain Forest Formation, as defined by Grubb (1974) and Whitmore (1975). Use of this scheme will enable comparisons with other studies on Sumatran sites.

The depression of the vegetation zone boundaries on some mountains, for example, in Peninsular Malaysia, is thought to be due mainly to climatic factors. The change in the effect of

TABLE 2.3

The main classification schemes for altitudinal forest types in Peninsular Malaysia, Sumatra and Java

Worldwide structural and physiognomic zones applied to Malaysia (after Grubb *et al.*, 1963)	Malayan floristic zones (after Symington, 1943)	Orographic zones, Java (van Steenis and Schippers-Lammertse 1965; van Steenis, 1972)	Sumatran rain forest formation type (Grubb, 1974; Whitmore, 1975)	Kerinci zonation scheme, used in this study (after Morley, 1976, 1982)
			? 3600 m	
		Sub-alpine	Upper Montane RFF	Ericaceous scrub
			3000 m	
		Sub-alpine	Upper Montane RFF	Ericoid forest
			c. 2800 m	
		Sub-alpine	Upper Montane RFF	*Gleichenia* scrub
			c.2400 m	
		Montane	Lower Montane RFF	Lower montane forest II
			c.1800 m	
Upper Montane Rain Forest	Montane ericaceous	Montane	Lower Montane RFF	Lower montane forest I
c.1500 m				
			c.1400 m	
Lower Montane Rain Forest	Montane Oak	Montane Sub-montane subzone	Lower Montane RFF	Sub-montane forest
c.1200 m				
			c.1000 m	
Lower Montane Rain Forest	Upper Dipterocarp	Tropical Colline subzone	Lowland RFF	Lowland forest
c. 750 m				
Lowland Rain Forest	Hill Dipterocarp	500 m		
c. 300 m		Tropical		
Lowland Rain Forest	Lowland Dipterocarp			

RFF = Rain Forest Formation

climatic factors with altitude is not constant and may vary from region to region, and even on different parts of the same mountain chain. The Massenerhebung or mass elevation heating effect is thought to be a major reason for these differences. On large mountain ranges an increased heating effect at high elevations results in a lower temperature lapse rate (Hastenrath, 1968). Therefore, the rate of decrease with elevation of temperature is reduced as is the rate of increase of moistness of air and soil environments. By acting indirectly such as via soil development, or directly, these climatic differences have important effects on the occurrence of different vegetation types. Such an effect might account for the relative depression of altitudinal vegetation zones on the small mountain ranges of Peninsular Malaysia compared with those on the larger Barisan Range of Sumatra, or the mountains of New Guinea (Whitmore, 1975).

2.4b Changes in structure, physiognomy and floristics of the tropical rain forest with altitude.

One of the most striking changes in structure which occurs with increasing altitude is the replacement of mesophyll dominated forest by microphyll dominated forest. This occurs at the lower montane - upper montane forest transition, occurring first on the narrow ridge crests and knolls, and eventually replacing the whole vegetation so that microphyll forest dominates. Lower montane forests which replace the lowland rain forests have a lower canopy (15-33 m compared with 25-45 m) with fewer, smaller, emergent trees. Far less buttressing occurs in these lower montane forests and buttresses, where present, are much smaller. Other differences include a great reduction in the number of woody climbers and an even greater luxuriance of epiphytes with increasing elevation. These epiphytes may include algae, fungi, bryophytes, pteridophytes and flowering plants. However, with increasing altitude the actual number of species present decreases and the vascular epiphytes are increasingly replaced by non-vascular ones, especially bryophytes and filmy ferns (Whitmore, 1975). Other differences between the lower montane forest and the lowland rain forest are the less common occurrence of cauliflory and of species with compound leaves.

The upper montane forest is smaller in stature than the formations below it, being c. 1.5-18 m high. The shorter facies are often referred to as 'elfin woodland'. If cloud cover is prevalent at a particular elevation then the increased moistness may result in a facies extremely rich in non-vascular epiphytes, often referred to as 'mossy forest'. The altitude at which the microphyll dominated upper montane forest first occurs may be related to a complex of factors in which climatic effects are dominant. Whitmore and Burnham (1969) have suggested that edaphic factors, including development of iron pans and peat formation might have considerable influence on the occurrence of upper montane forest. It is suggested that the increased leaching, less intense weathering and organic matter production, and less effective soil mixing, which they found with increasing elevation in Malaysia, might eventually favour microphyll dominated vegetation. As these factors are probably themselves a result of the changing temperatures and moistness with altitude, then climate appears to be acting indirectly on the vegetation in this case.

Above the uppermost limit of the upper montane forest, a forest of very reduced stature is replaced at the altitudinal forest limit (tree line) by a variety of 'alpine' vegetation types. In New Guinea, where altitudes are sufficiently high for these to be well developed in places, these 'alpine' vegetation types include dwarf shrub heaths, moss tundra and short alpine grassland. The altitudinal forest limit in New Guinea lies at c. 3800 m (Walker and Flenley, 1979). Few summits lie above the altitudinal forest limit in Sumatra; the bare volcanic peaks there are largely the result of frequently renewed supplies of volcanic products. However the summit area (above c. 3400m) of the non-volcanic G. Leuser in North Sumatra bears open vegetation including Rhododendron scrub, and taxa such as Gentiana quadrifaria (van Steenis, 1938). This possibly indicates a lower altitudinal forest limit in Sumatra than in New Guinea. The actual altitudinal forest limit in Sumatra is not defined, possibly G. Kerinci lies above it, although the lack of vegetation at the summit of this peak appears to be at least partly controlled by its volcanic activity.

Changes in structure and physiognomy from the lowland to lower montane forest formations are gradual, occurring over a wide ecotone. From the lower montane to upper montane forest formations the changes are generally more abrupt although the ecotone is still broad (Whitmore, 1975).

Floristical changes also occur with increasing altitude. The boundary between lowland and lower montane forest is in fact largely floristical (van Steenis, 1972) while the boundary between lower and upper montane forest also exhibits floristical changes. The changes within the lowland-lower montane forest take the form of reduced frequency of lowland species with increasing elevations and the appearance of species absent in the lowlands. Below c. 1000 m a.s.l. the families present are of predominantly tropical distribution. They include Anacardiaceae, Burseraceae, Combretaceae, Dilleniaceae, Dipterocarpaceae, Flacourtiaceae, Myristicaceae and Rhizophoraceae (Whitmore, 1975; van Steenis, 1972). Families of predominantly temperate distribution tend not to occur, or are rare, below c. 1000 m a.s.l. but become increasingly common with altitudes above this elevation. These include the Ericaceae, Fagaceae, Lauraceae, Myrtaceae, Podocarpaceae, Symplocaceae and Theaceae (Whitmore, 1975).

In terms of geographical affinities the lowland rain forests of South-East Asia have a flora in which Indo-Malayan genera predominate. The montane forests however also include elements of Australasian and North Temperate origin (Richards, 1952). With increasing altitude there is also a reduction in the total number of species present and especially of tree species.

The structural, physiognomic and floristic characteristics of the forest formations are summarized in Table 2.4.

TABLE 2.4

Summary of the structural, physiognomic and floristic characters of the main altitudinal vegetation formations in Sumatra (after Grubb *et al.*, 1963; Whitmore, 1975)

Rain Forest Formation type	Height	Leaves	Climbers	Epiphytes	Buttresses	Other	Floristics
Lowland	25-45 m Emergents characteristic	Mostly mesophyll. Compound leaves common	Large woody climbers common. Bole climbers abundant	Vascular and non-vascular epiphytes common	Frequent and large	Cauliflory common	Families with predominantly tropical distribution. Large number of species. Indo-Malayan genera
Lower Montane	15-33 m Emergents uncommon, numbers decrease with increasing altitude	Mostly mesophyll. Compound leaves less common than in lowland	Large woody climbers uncommon. Bole climbers frequent to abundant	Vascular and non-vascular epiphytes are abundant	Uncommon or small	Cauliflory rare	Increase in families with predominantly temperate distribution. Reduction in total number of species. Increased Australasian and North temperate elements
Upper Montane	1.5-18 m Emergents usually absent	Predominantly microphyll	Large woody climbers are uncommon or absent (except for *Gleichenia* in *G.* scrub belt on Gunung Kerinci). Very few bole climbers	Non-vascular epiphytes very abundant. Vascular epiphytes common	Absent	Cauliflory absent	Increase in predominance of temperate families and genera. Few tropical families. Reduction in total number of species.

CHAPTER 3

ECOLOGICAL AND PALAEOECOLOGICAL METHODS

3.1 The field methods available for surveying vegetation

There are a number of possible approaches for studying the vegetation of an area. All involve some form of vegetation sampling in order that the vegetation may be assessed, without the need for a detailed study of it all. The choice of one of the numerous methods available is governed by the purpose of the study, the type of vegetation being studied, and environmental or other constraints. The basic types of approach are outlined in the following sections.

3.1a Plotless sampling or distance methods

These usually involve measurements of distances between two trees or a fixed point and one or more trees, which are nearest neighbours (eg. Cottam and Curtis, 1949). The method usually involves walking in a straight line for a pre-determined number of paces (or similar units) between each sampling point. Identification and measurement of the trees is then made in order to calculate frequency and density of each species. Cottam and Curtis (1956) modified the basic method to form the point centred quarter method in which distance from a sampling point to the nearest tree in each quadrant was measured. Again frequency and density could be calculated. Although these methods may be very successful for some applications, the method is really only suitable for forest studies, and in these, only for trees.

Herbaceous vegetation presents problems as identification of separate individuals may be difficult, especially where vegetative reproduction occurs. Its applicability in tropical forest is reduced by the occurrence of non-random or contagious distributions (Poore, 1964), and it is difficult to apply if there is a dense undergrowth, which is hard to penetrate. However, it was used successfully on a species poor pine forest, which had little undergrowth, in the Philippines by Kowal (1966). These techniques were not considered further for use in this study because they were inapplicable in non-forest vegetation, and would also be difficult to apply in the montane forests of Sumatra.

3.1b Point quadrat methods

These are essentially quadrat methods, in which the quadrat size is approaching zero. Usually, a fine needle is stuck into the ground at a large number of randomly selected sites. Species in contact with it are recorded and percentage cover may be calculated (eg. Greig-Smith, 1983). Since the method is really only applicable in grassland and similar vegetation types, it was not considered further for use in this study.

3.1c Transects

These may involve linear arrangements of sample areas (see 3.1d) or may be line transects which involve recording of contacts along, for example, a piece of string. Problems may arise if there is a linear vegetation gradient and the transect is taken along this, although using transects perpendicular to a known gradient can produce useful results. Line transects could have been used to determine cover values for the forest vegetation but would have been a difficult technique to apply in non-forest vegetation where species intermingle. A linear arrangement of sample plots could have been used in the present study, but because of field work constraints, notably time, and aims, which were to study principally the pollen production by the vegetation, this was rejected in favour of a simple method involving plots.

3.1d Plot or sample area methods

These involve the recording and enumeration of vegetation within a given sized plot. Problems arise as to selection of site, number of plots to be studied, and their size and shape.

Selection of sites may be subjective, a regular arrangement, random, or restricted random. Subjective methods of site selection may produce a rapid assessment of vegetation types, but are open to observer bias. Areas chosen by the observer may not be totally representative of the vegetation as a whole, and the technique may also lead to recognition of clear cut vegetation types with neglect of intermediate types. However, if vegetation types are likely to be distinct, a subjective approach may be used successfully. This was the method employed by Braun-Blanquet (1932).

Sampling sites may be placed in a regular arrangement, for example, if the aim is to produce a vegetation map. This systematic sampling may involve siting plots along a transect line or grid. However, there is a risk that some vegetation types may be omitted using this method.

Random siting of plots involves the use of random number tables to select sites on a pre-determined pair of perpendicular axes, perhaps on a map or an aerial photograph. Sites are then located using successive random numbers as x and y co-ordinates. This method removes subject bias and gives every part of an area an equal chance of being sampled. However, there is still a risk that vegetation types may be omitted. Practicalities in the field may further reduce the usefulness of this method eg. by making access to sampling areas difficult. On occasions it may be impossible to locate the sampling site in the field eg. if it is in a dense forest.

Regular and random siting may be combined in restricted random sampling. This method divides the area under study into equal sized blocks, and sites are then randomly located within each block. This method reduces the likelihood of a particular type of vegetation being completely omitted from the study.

The number of sites used may relate to their size, the aims of the study and the complexity of the vegetation.

The size of the site is important as it should be large enough to contain a representative sample of the vegetation while not being so large as to be inefficient as regards sampling time. It may be chosen so as to fit the concept of 'minimal area' (eg. Hopkins, 1957), the minimum size considered to be representative of the whole vegetation stand. This is related to the number of species which are recorded as the sample plot is increased in size. However, the definition of 'minimal area' itself can be extremely difficult (Goodall, 1952; Hopkins, 1957).

Plot shape is usually square or rectangular. Clapham (1932) suggested that an elongate rectangle was most efficient. However, such a shape has more edge effect, that is, the subjective inclusion or exclusion of individuals near the edge of the plot. A circular plot would have least edge effect but large plots of this shape are difficult to set up in the field.

Within a sample plot it is possible to record the characteristics of the vegetation in a variety of ways. Recording may be of structural features or floristical characteristics and depends, once again, on the aims of the study. Normally the species themselves are recorded as this allows for finer ecological classification. The recordings may be simply presence-absence or they may be quantitative, for example, density, cover and frequency (Greig-Smith, 1983). Frequency is usually determined by dividing the sample site into smaller equal sized units, the proportion of these in which a species occurs represents its frequency, usually expressed as a percentage. Percentage cover is the percentage of the ground in the sample site covered by a vertical projection on it of a given species. The sum of all values of cover for a site may well be over 100% since vegetation may be layered. Density is a measure of the number of individuals of a species per unit area, and can only be determined if individuals of a species can be distinguished, for example, trees in a forest, although even here seedlings smaller than a certain size may be excluded from the analysis. For studies of forest, basal area of different species may be used rather than cover, since this is easier to measure. Basal area is usually determined from circumference or diameter measurements of trees at breast height, and provides a measure of total basal area for each species per unit area of ground. It can also be used for species having tussock form (Greig-Smith, 1983).

Environmental recordings of those factors which may be of significance ecologically are also normally taken, within the plot. If a plotless method is used then a decision has to be made as to where environmental readings should be taken.

3.2 Field methods utilized in this study

Before a method or methods for surveying the vegetation of the field area could be chosen, it was necessary to consider the actual purpose of the survey. The primary aim of this was to elucidate the pollen deposition patterns at various forest and non-forest sites, noting relationships to the vegetation present. A comprehensive study of the vegetation types present was not a major aim as limited time was available for the vegetation survey and was clearly insufficient for carrying out a detailed ecological study.

Methods of vegetation survey involving the use of plots were chosen for this study. In this case the advantage of the method was that moss polsters or surface samples could be taken for palynological analysis from within the plot. Pollen composition could then be compared with the composition of the surrounding vegetation, to provide information about the nature of the pollen rain. Plots could equally well be applied in both forest and non-forest vegetation although slightly different measures were made in each to assess the importance of different taxa in the vegetation.

The field work was undertaken in September and October, 1979, which coincided with the end of the driest time of year, and the very beginning of the wettest.

3.2a Forest vegetation

The forest vegetation was studied with the following aims:-

i) To assess the importance of the different species which form the canopy of the forest vegetation of the area, and to note any relationships between species and altitude, disturbance or other environmental variables;

ii) In order to compare the composition of the forest with composition of the pollen deposited within it. From this the pollen production of individual taxa or groups of taxa, and contributions from the canopy of the forest, and other strata, to the pollen rain can be assessed.

The plots used to survey the forest vegetation were sited subjectively, since access to randomly selected points in these forests, on often steep terrain would have been extremely difficult and time consuming. This would have been particularly so if a track to the randomly selected sites also had to be cut. Previous work in Sumatra (Morley, 1976) and New Guinea (Flenley, 1969) has shown that two major factors influencing vegetation type in montane areas are altitude and disturbance. Thus plots were subjectively sited so as to cover as wide a variety of altitudes as possible, although they also encompassed different degrees of disturbance. Aerial photographs of the region were used to locate suitable areas in which plots could be sited, these areas were then located in the field, and a plot was sited subjectively in each.

Different workers studying tropical forest vegetation have suggested a variety of plot sizes necessary to sample the forest vegetation adequately. A minimum area of 2 hectares was suggested as being barely adequate for tropical lowland forest (eg. Poore, 1968) but Ashton (1964, 1965) suggested that 0.4 hectare was the largest size practicable if the site was to cover a relatively homogenous environment. This plot size was used in Sumatra by Morley (1976) although he recognized that even the less diverse sites had a considerable intake of new species at the sample limit. Because of the time constraint in this study a smaller plot size of 0.2 hectare was chosen, however this was considered adequate for the purposes of this study.

Difficulties can arise in setting out a large rectangular sized plot in the forest, and this may also be very time consuming particularly if subplots are needed for convenience of recording. This problem was reduced in the study by use of existing forest tracks as the baseline of the long axis of the plots, which were 100 m by 20 m. The 100 m measure was laid out along the track, which was selected to be as straight as possible, and the plot consisted of a strip 10 m wide on each side of the baseline. This facilitated rapid assessment as there was no need to cut a track to reach the end of the plot, and individual trees were generally easily accessible.

Other work on the palynology of tropical forests (Morley, 1976; Kershaw and Hyland, 1975) has shown that forest pollen which becomes part of the regional pollen rain is derived largely from the canopy trees, while lower trees contribute little to the pollen record beyond the local area. This probably relates to air movements in these forests, with virtual absence of movements through the trunk space, but more significant air movements above the canopy (Morley, 1976). As the prime interest of this study was in pollen production and deposition patterns only the larger trees present in the plots were recorded. These were those having a girth, at breast height, of 30cm or more. Ground flora and epiphytes were not recorded, other than in a general description. From measurements of girth the basal area of each species within the plot, and total basal area of the plot could be easily calculated. Data on density of species were also available using this method of enumeration.

At each of the forest sites studied, a number of environmental variables were recorded. Altitude was recorded using an altimeter calibrated in feet. This was later recalculated to the nearest 5 m above sea level. Aspect of the plot was judged using a prismatic compass. Slope was measured using an abney level, to the nearest degree. The soil was augered at each site, to a depth of 1 m, if possible, and the texture and appearance of the different horizons were noted. Soil temperature at 1 m depth was recorded using a battery operated soil temperature meter (results were presented in Table 2.2). Soil pH at rooting depth, usually c. 10 cm depth was measured using a barium sulphate pH kit and BDH soil indicator. An estimate of the effectiveness of drainage was also made. Other characteristics of the plots recorded included presence of epiphytes, ground flora and any observable signs of human interference other than the track.

Moss polsters were collected for pollen analysis as these act as effective pollen traps (Chapter 5). These were collected from a minimum of 5 sites well distributed along the length of each plot, and were bulked for processing. This was done to obtain a pollen sample representative of the whole plot, rather than just one part of it.

Plant specimens were collected in the field for identification purposes. Each collection was allocated a number, and voucher specimens were prepared for identification at the Herbarium Bogoriense. In addition a sample was set aside and mounted on a card for incorporation in a field herbarium, which was used to aid recognition of taxa in the field. Flowers and fruit were collected if available, as they are often of great importance for identification to species level. However, these were not always available, and many tree identifications are to generic level only as a result of this. Initially, the voucher specimens were preserved by placing them between sheets of newspaper, then putting a number of these into a heavy duty polythene bag, soaking in alcohol and sealing well. They were transported to the Herbarium Bogoriense at Bogor, Java in this state; there they were dried out and identified by Mr Nedi. Duplicates of all collections are now distributed at Hull and Bogor herbaria. A list of all taxa identified from the field area is given in Appendix 1. Occasionally, a tree would be recorded in a plot for which it did not prove possible to make a voucher specimen. These specimens were allocated a number in the collection system although clearly no identification could be obtained.

3.2b Non-forest vegetation

A study of the non-forest vegetation types in the area was carried out with the following aims:

i) In order that those taxa which occur in non-forest vegetation would be recognized;

ii) So that moss polsters and surface samples could be examined, from sites of known floristic composition in order to study the pollen production of these vegetation types and pollen deposition within them.

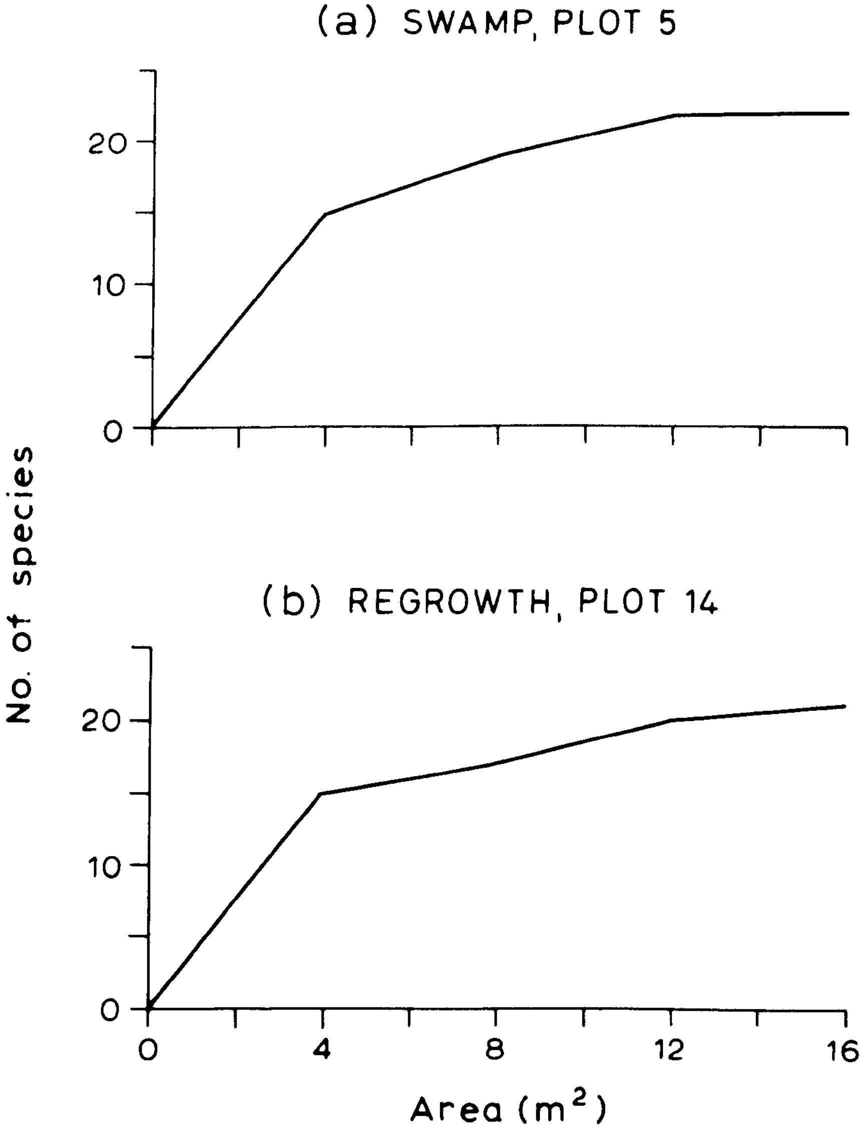
For all sites studied methods involving plots were chosen as outlined previously. Sites covered a wide variety of vegetation communities including several types of regenerating vegetation, swamp communities and fields and gardens.

To determine a suitable plot size for swamp and regrowth vegetation communities, a species area graph was plotted for one site in each type of vegetation. This was done by recording, firstly, all species present in a 2 m x 2 m plot. A second 2 m x 2 m plot was then set up adjacent to the first and any new species present were recorded. This was repeated a third and fourth time, by which time the plot consisted of a square, 4 m x 4 m. The species area graphs for both the swamp and regrowth sites are shown in Fig. 3.1. Both show considerable levelling off with use of a total plot size of 4 m x 4 m. This was therefore chosen as the standard plot dimension for the study of non-forest vegetation. It was thought that all but the rarest species in an area of homogenous vegetation would be found in a plot of this size. An exception to the use of this plot size was made for the study of ricefield weeds. In this case all taxa present in a ricefield were recorded, since due to terracing the ricefields were quite small.

The plots were sited subjectively, in order that the maximum number of different vegetation types could be surveyed in the time available. Each plot was sited in an area of apparently homogenous vegetation, in order that typical regrowth and swamp communities would be sampled.

In all plots, all pteridophytes and higher plants present were recorded, and percentage cover for each species was estimated, this being the percentage of the ground covered by a vertical projection of each species present.

Fig. 3.1
Species-area graphs for a swamp and a regrowth plot



(a) SWAMP, PLOT 5

(b) REGROWTH, PLOT 14

At each site with the exception of the ricefield and dryland gardens (plots 21-23, 25-27) moss polsters were taken for pollen analysis. Where these were available, if possible a minimum of 4 were taken from different sections of the plot and bulked for processing. Where moss polsters were not available a surface soil, or sediment sample was collected, again from several points within the plot; however soil samples rarely contained any pollen. Environmental variables were recorded, where possible, for each plot, as for forest sites (Section 3.2a). However, soil temperatures were not recorded from these generally unshaded plots, since results obtained would not be an accurate representation of mean annual air temperature, as described in Section 2.3.

Before the floristic details of each plot were studied, a collection of the 'new' taxa occurring in the location was made, and a field herbarium prepared. This both facilitated the identification of taxa when the plots were studied, and permitted identification of species present in the vegetation which were not recorded in the plots themselves, thus providing additional information as to the composition of non-forest vegetation. Plants collected in the field were prepared as voucher specimens using the method previously described in Section 3.2a. All taxa identified from the field area are listed in Appendix 1.

3.2c The vegetation of Gunung Kerinci

No survey of the vegetation of G. Kerinci was carried out for the purpose of this study. However, prepared surface pollen samples from a variety of altitudes were available and were used to elucidate the nature of the modern pollen rain on the mountain. These surface samples, comprising moss polsters, were collected by Dr J. R. Flenley during 1976. At several of the collection sites the vegetation was surveyed using plots, and this data set was also available to the present study. The data recorded in each plot varied with altitude since the structure of the vegetation altered considerably.

For a forest plot at 2700 m the girth at breast height of all trees of girth > 20 cm was recorded. In addition, the importance of trees present as 'poles' only was estimated. The plot size used was 30 m x 5 m.

In low forest, at 3010 m, estimates of percentage cover of all species present were made, in a plot 30 m x 4 m.

At the upper limit of continuous vegetation, at 3315 m the percentage cover of all species in a plot 20 m x 20 m was estimated.

Environmental variables recorded at each site were the slope, soil pH at rooting depth, soil texture and appearance and soil temperature (variable depth). In addition a general description of the vegetation was made. Voucher specimens of the taxa present were prepared. These were later identified at the Australian National University, Canberra.

3.3 Field methods used for palaeoecological studies

The cores used in the palaeoecological studies were collected by Dr J. R. Flenley (Danau di Atas) with Dr R. J. Morley and M. K. Kardin (Telago). Details of the methods used in sample collection are described in Sections 6.1 and 7.1 for the Danau di Atas and Telago cores respectively. Prior to examination all fossil and modern material, with the exception of the G. Kerinci surface samples, was transported to Hull University and stored at c. 5°C. Core sections from Danau di Atas were kept in plastic drainpipe halves wrapped in heavy duty polythene to prevent water loss. Small core sections from Telago, and modern surface material, were stored in airtight plastic bags.

The G. Kerinci surface samples collected by Dr J. R. Flenley in 1976 were transported to the Australian National University at Canberra, where they were prepared by D. Moser.

3.4 Sediment characteristics

The Danau di Atas core was examined for stratigraphical changes in the laboratory. This could not be investigated for the Telago samples since the core was not transported whole from the field. However, the stratigraphy of this core was described well in the field.

The percentage weight loss on ignition was calculated for all depths at which a sample was taken for pollen analysis. The method used was as follows.

After removal of 1 cm^3 of material from each sampling depth for pollen preparation, the remaining sample was oven dried overnight at 105°C. The dry sample was then weighed, and placed in a muffle furnace for ignition at 375°C for 16 hours. The weight loss on ignition, as percentage weight loss, under such conditions, is directly proportional to the organic carbon content of the original sample (Ball, 1964). The use of ignition at 375°C for 16 hours is preferable to rapid ignition at higher temperatures eg. 30 minutes at 850°C, since it does not cause significant loss of CO_2 from carbonates, or loss of structural water from clay minerals (Ball, 1964). Since only relative measures of the organic carbon content of samples were required for the purpose of this study, it was not deemed necessary to apply Ball's regression equations to the percentage weight loss on ignition values. Relative changes of organic carbon content in the two cores are amply demonstrated by these percentage weight loss on ignition values as shown in Figs 6.2 and 7.1.

3.5 Sample preparation techniques for absolute pollen analysis

Present views stress the importance of estimates of absolute pollen influx to a site for the interpretation of pollen assemblages in terms of vegetation history. The two sets of fossil material were therefore prepared using techniques which allow estimation of absolute pollen frequency. Such techniques must enable an estimate of numbers of grains per unit volume (or weight) of sediment to be made, and if influx values are to be calculated they must include age determinations on the sediment. The latter condition is usually satisfied by 14_C dating. The techniques which enable estimates of absolute pollen frequency to be made are briefly outlined below, with some comments as to their advantages and disadvantages, and suitability for use in this study.

The volumetric approach best described by Davis (1965) involves preparation of a known weight or volume of sediment. A known volume of the prepared sample is then used to make up slides for counting. The major disadvantage of this technique concerns the accurate measurement of the extremely small aliquot volumes required for the final slide preparation. A second problem is the maintenance of a homogenous suspension of sample material in a mixture of benzene (as originally used) and silicone oil, while the sample aliquot is withdrawn. Peck (1974) also noted that the evaporation technique used in slide preparation, in which the benzene evaporated leaving behind the sample in silicone oil, tended to result in non-random grouping of grains near the edge of the slide. Because of the problems inherent in this technique it was not considered further for use in this study.

The weighing technique as described by Jorgensen (1967) and Peck (1974) avoids the inaccuracies associated with aliquot measurement of the volume technique. This method relies on weighing the initial dry sample prepared, the final prepared sample and the prepared sample transferred onto slides. As with the volume technique, the area of each slide actually counted also needs to be known. The major drawbacks with this method are the need for accurate weight measurements. Both the volume and weighing techniques share one other major problem which is that extreme care must be taken at all stages of preparation that none of the sample is lost. Filtering to remove large pieces of debris from the sample may also result in the loss of unknown quantities of pollen and spores. Despite these problems this technique was used initially to prepare 4 samples from the Danau di Atas core.

The third main method for estimating absolute pollen frequencies is by the addition of known quantities of exotic pollen to the sediment prior to preparation. Techniques have been described by Benninghoff (1962), Matthews (1969) and Bonny (1972). The exotic pollen used has varied and has included Nyssa sylvatica (Matthews, 1969) and Ailanthus glandulosa (Bonny, 1972). Normally a known amount of exotic pollen is added to a known amount of sediment, and the sample is then prepared using standard techniques. Both the fossil pollen and the exotic pollen are counted in the subsequent analysis, and frequencies of the pollen types can be expressed as number of grains per unit of sediment. Clearly, a prerequisite of this technique is the availability of an exotic pollen type which is distinctly different from any pollen types likely to be encountered in the fossil material. Errors inherent in the sample counting are greater than for other techniques since counts of both the fossil and exotic pollen are subject to sampling error. However the loss of small amounts of material during sample preparation no longer presents a serious source of error, so long as the exotic and fossil pollen are well mixed. Initially, a major problem was the need to prepare a suspension of exotic pollen of known concentration, prior to addition to the fossil sample. It is now possible, however, to use tablets containing a known quantity of *Lycopodium clavatum* L. spores as a source of exotic marker grains (Stockmarr, 1971) thus removing one of the major difficulties.

With the exception of 4 samples prepared using the weighing technique, all core samples were prepared using the addition of *L. clavatum* in tablet form. It is possible that *L. clavatum* may occur naturally in fossil pollen samples and modern pollen samples from Sumatra as the species does occur there. However, the use of *L. clavatum* as an exotic marker was not considered likely to cause major errors in calculation of absolute pollen frequencies at the two sites for the following reason. Stockmarr's tablets contain acetolysed spores of *L. clavatum* which are dark brownish in colour (Stockmarr, 1971). They are subsequently acetolysed a second time during preparation, causing further darkening of the grains. Naturally occurring *L. clavatum* is acetolysed once only and is lighter in colour. Naturally occurring *L. clavatum* can be distinguished from the exotic grains on this basis.

Full details of the techniques used for preparing fossil pollen samples, and also for preparing modern samples and reference material are given in Appendix 2. Absolute pollen frequencies were calculated only for the fossil pollen assemblages. Since deposition time for modern samples was unknown these were prepared using the standard preparation technique only.

The details of the methods used to calculate absolute pollen frequencies are provided in Appendix 3.

3.6 Pollen Counting

3.6a Techniques

Pollen and spores were counted using a Zeiss Photomicroscope at a magnification of x 320, using a x 25 plan-apochromatic objective, x 8 eyepieces and a x 1.6 optovar magnification. Identifications were made at x 400, by increasing the optovar to x 2, or under oil immersion using a x 100 plan-apochromatic objective, giving a total magnification of x 1600 with the optovar set at x 2. A Wild comparison eyepiece attached to a Meopta microscope enabled direct comparison of fossil and reference material.

Traverses were evenly spaced on each slide, normally 1 mm apart to avoid the risk of overlapping fields of view, and thus counting a grain more than once. The whole slide was counted to avoid any non-random distribution of grains on the slide. Usually four slides were prepared and counted for each sample, occasionally extra slides had to be prepared. If the samples were particularly rich in pollen and spores the traverses were spaced more widely to compensate. Two slides of each sample were available for the G. Kerinci surface samples, some were so rich in pollen and spores that only one slide was counted. Where a grain lay at the edge of the field of view it was counted in a travese only when at least half of it was visible.

3.6b Count size

Faegri and Iversen (1964) state that a minimum pollen count of 150 grains is required for analysis of samples from temperate areas. Because of the greater diversity of species present in the tropics, a larger pollen count is necessary, particularly if a representative count is to be obtained for those taxa recorded as low percentages. Morley (1976) showed in a pollen trapping study in hill Dipterocarp forest at Uli Gombak, Malaysia, that while common taxa were well represented with counts of 150 grains, the percentages of rare types did not stabilize until 300-500 grains had been counted. Similar conclusions were reached by Hamilton (1972) who suggested that 500 grains would have to be counted to give accurate frequencies for rarer pollen types.

In view of these results, a minimum of 300 pollen grains, excluding aquatics and pteridophyte spores was counted for all samples where possible. Occasionally the counts were smaller than this, particularly for some of the surface samples but also for a small number of fossil pollen samples from the Danau di Atas core. This pollen sum, of all pollen counted excluding that from aquatic taxa and pteridophyte spores was termed the Total Dry Land Pollen (TDLP). Clearly a proportion of this pollen is likely to have originated in swamp vegetation, but since many swamp taxa either occur in suitable localities outside swamps or have pollen indistinguishable from some dry land taxa it was thought more acceptable to include these within the dry land pollen sum.

3.7 Determination of pollen and spores

Pollen and spores were determined by comparison with modern reference material, largely derived from herbaria specimens. The Hull Laboratory possesses a large collection of reference slides, particularly of pollen, from South-East Asia. Determination of spores presented more problems since the reference material was more restricted, and also many spores readily lose their exosporium which can make determination beyond a general level impossible.

Photographs of many Sumatran taxa are available in Morley (1976) and Maloney (1979) and their descriptions of pollen, and identification keys were also very useful.

A modification of the Benninghoff and Kapp (1962) notation was used to denote the level of identification of the pollen and spore taxa.

If a taxon is named without a suffix then the identification is certain.

If a named taxon is followed by the suffix 'comp.' then the pollen type compares favourably with that indicated but cannot be conclusively assigned to it.

If a named taxon is followed by the suffix 'sim.' then it is similar to the taxon indicated, but this is or is suspected of being representative of several indistinguishable taxa.

Photographs of a number of the pollen taxa identified in this study but which are not described or shown elsewhere (eg. Morley, 1976; Maloney, 1979) are included in Appendix 4.

Appendix 5 shows the level of identification of pollen and spore taxa, and suggests possible sources for these. Appendix 6 provides details of the pollen counts for all samples examined.

3.8 Statistical errors inherent in the pollen analytical techniques used, as they apply to absolute pollen frequencies

In the calculation of absolute pollen frequencies it should be remembered that a number of errors are inherent in the techniques used. Some of these are of greater significance than others.

Errors may be involved in:

i) Estimating the ratio of indigenous to exotic grains, where the technique involves the addition of 'exotic' grains.

ii) Estimating the number of 'exotic' grains added to a preparation.

iii) Measurement of the volume of sediment prepared. This is a greater problem where the sediment is heterogenous in character, and has large particles.

iv) Inaccuracies of weighing, of particular significance where a weighing technique is used to estimate absolute pollen frequencies. Problems may arise due to the very small amounts of material transferred onto the slides, which must be accurately measured.

v) Counting, particularly where it is necessary to know exactly the proportion of slide area which has been counted, such as is required when the weighing technique is used.

vi) Non-random distribution of grains on a slide; decisions as to whether a grain should be counted if more than half of it is missing, or less then half is within the traverse; identification problems. All of these are applicable to pollen analysis as a whole and are not restricted to absolute pollen analysis.

vii) Estimation of accumulation rates based on ^{14}C dates from a relatively small number of points within the sedimentary profile; ^{14}C analysis is itself subject to errors and accumulation rates may not be constant between dated horizons.

Maher (1981) discusses the problem of how many 'exotic' marker grains should be added to achieve the most precision in estimating the absolute pollen frequencies, for the least work. Although a ratio 1:1 of indigenous pollen: exotic marker grains gives the most precise results, a lot of time is spent counting marker grains. He suggested a ratio of 2:1 indigenous pollen: exotic marker grains, which reduces the counting effort while still giving good precision in estimating concentrations of indigenous taxa. In practice, maintaining such a ratio in actual counts is difficult since the indigenous pollen concentration is unknown prior to the addition of the exotic marker grains. The only way of overcoming this problem is by preparing a preliminary set of samples from the fossil core, with added exotic pollen, in order to give a rough estimate of the pollen concentration. Thereafter it is possible to add sufficient marker grains to give a ratio approximating to 2:1. This method was not employed in the present study. Pollen concentrations proved to be very variable, even between adjacent sampling points and a result was that the ratio of indigenous : exotic grains was not always ideal. It did approximate to 2:1 in a number of samples, but often the ratio was greater than this.

Stockmarr (1971) suggested that the actual pollen count of indigenous taxa is also important in assessing the magnitude of error in the final pollen frequency estimates. The greater the number of indigenous pollen grains counted, then the greater the part of the error due to the use (in this case) of tablets containing Lycopodium clavatum spores, although the total error involved in the estimate decreases. He also showed that the greater the number of L. clavatum spores counted, then the less is the error due to use of these exotic marker grains.

Estimating the number of 'exotic' grains added to the preparation also presents some problems, since even where the grains are added in tablet form, there is variation in the spore content of the tablets. However, the mean content ($\overline{Y}$) and standard deviation (S) are stated with each batch.

The standard deviation of a group of tablets N each having standard deviation S varies according to the following formula:

$N\ s\ /\ \sqrt{N}$ or $\sqrt{N}.s$ (Maher, 1981)

while the coefficient of variation for a group is

$100\ s/\overline{Y}$ (Maher, 1981)

where s is standard deviation of the group, and $\bar{Y}$ is its spike mean. Table 3.1 shows the spike mean N $\bar{Y}$, standard deviation s, and coefficient of variation for various sized groups of tablets. It can be seen from this data that the standard deviation becomes relatively less if more tablets are added, and the coefficient of variation also decreases. This suggests that more than one tablet should be used in preparation of samples if possible, to reduce the error in estimating the actual number of exotic grains added. In fact 2-4 tablets containing _L. clavatum_ were used in the preparations in this study.

TABLE 3.1

Standard deviation and coefficient of variation for different sized groups of *Lycopodium clavatum* tablets

	No. of Tablets	Spike mean ($N \bar{Y}$)	Standard deviation ($Ns / \sqrt{N}$)	Coefficient of variation *
Batch no. 212761				
$\bar{Y}$ = 12500	1	12500	500	4.00%
s = 500	2	25000	707	2.83%
	4	50000	1000	2.00%
'Cambridge' batch				
$\bar{Y}$ = 10850	1	10850	200	1.84%
s = 200	2	21700	283	1.30%

*$\frac{100 \times \text{standard deviation}}{\text{spike mean}}$(of group of tablets)

CHAPTER 4

THE PRESENT VEGETATION OF THE DANAU DI ATAS REGION

4.1 The forests

The limited time available for field work was sufficient for the study of only six forest plots; however, these were sited so as to cover as wide a range of potential variation as possible as described in Section 3.2a. The altitudinal range of the plots was from 1475 m to 1970 m a.s.l.

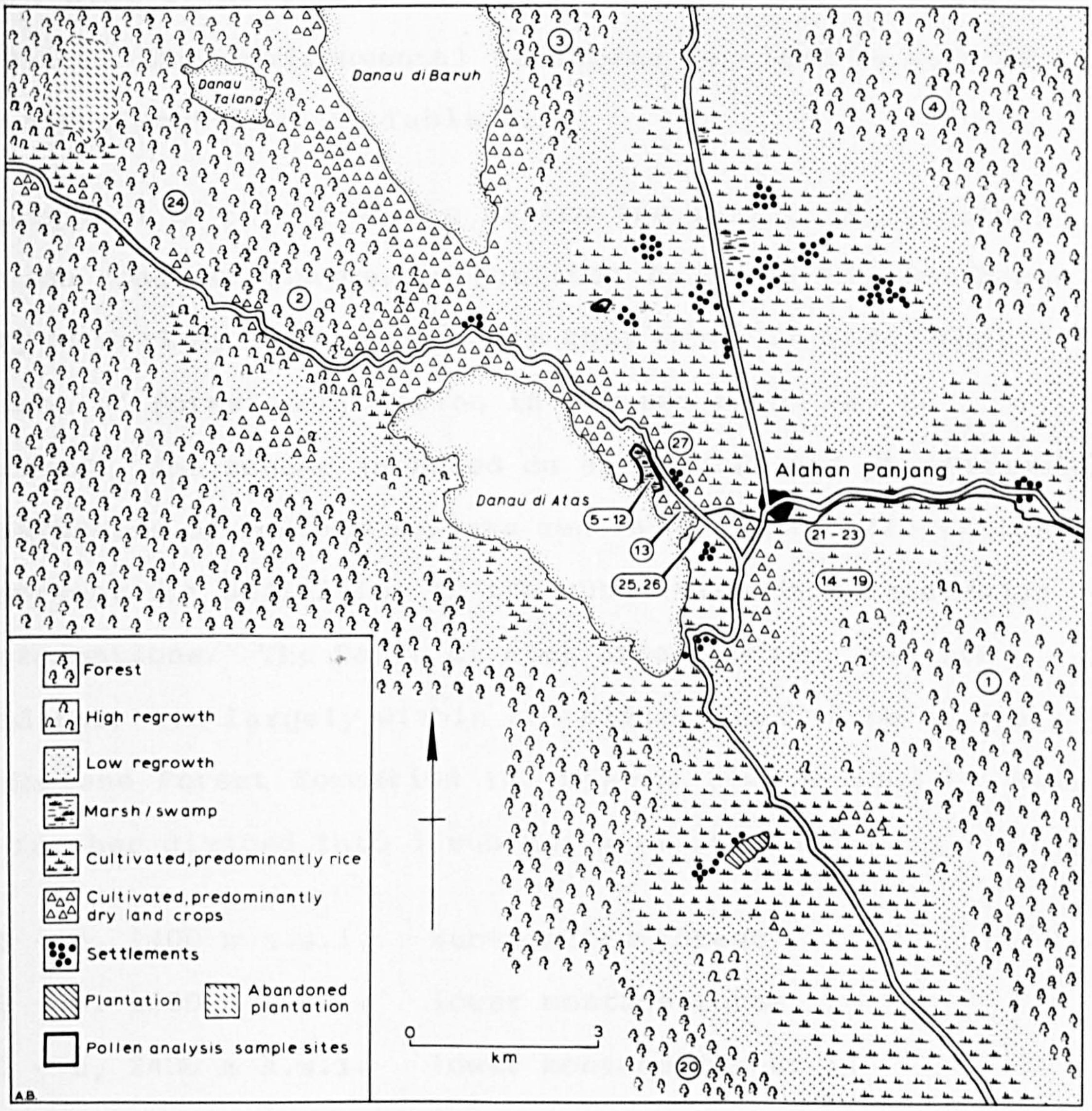
Forests in the study area have largely been cleared for agriculture below c. 1600 m a.s.l. Some forest does remain at altitudes lower than this, mostly in the region west of Danau di Atas; much of this has however been disturbed to a greater or lesser extent by man. The forest remaining in the area which lies above c. 1600 m a.s.l. is much less disturbed by human interference. Plots were thus located in forests which had been subjected to varying amounts of human interference.

Locations of all study plots, both forest and non-forest are shown in Fig. 4.1. The forest plots are numbers 1-4, 20 and 24. Plot 1 was located in forest to the south-east of Danau di Atas at an altitude of 1640 m a.s.l.; plot 2 was located north-west of the lake at 1535 m. Both areas had been subjected to considerable human interference. Plots 3 and 4 were located in the mountains north of Danau di Atas at altitudes of 1750 and 1780 m a.s.l. respectively and showed minimal or no signs of human interference, other than the track used as the baseline of the plot. Plot 20 was located south of the lake at an altitude

Fig. 4.1

Major vegetation types of the Danau di Atas region, showing the locations of study plots.

Vegetation distribution is based on air photographs of the region taken by Riotinto Bethlehem, Indonesia, 1970-71.


Danau Talang
Danau di Baruh
Danau di Atas
Alahan Panjang
3
4
24
2
27
5 - 12
13
25, 26
21 - 23
14 - 19
1
20
Forest
High regrowth
Low regrowth
Marsh / swamp
Cultivated, predominantly rice
Cultivated, predominantly dry land crops
Settlements
Plantation
Abandoned plantation
Pollen analysis sample sites
0
3
km
A.B.

of 1970 m a.s.l. in an extensive area of apparently undisturbed forest. Plot 24 was located north-west of the lake, relatively close to plot 2, at 1475 m a.s.l., and showed limited signs of disturbance. The environmental variables recorded at each of the forest sites are shown in Table 4.1.

It is proposed in this study to follow the Kerinci altitudinal vegetation zonation scheme, as outlined in Table 2.3, and based largely on work by Morley (1976) in that area, in order that comparison of forest composition in the two areas may be facilitated. The scheme is based on structural and physiognomic characteristics of montane forests generally, while floristics are important for definition of the sub-divisions of the major forest formations. The Danau di Atas area studied, and its surroundings, lie largely within the altitudinal range of the Lower Montane Forest Formation (c. 1000-c. 2400 m a.s.l.). This can be further divided into 3 sub-zones as follows:

c. 1000 - c. 1400 m a.s.l.	sub-montane forest
c. 1400 - c. 1800 m a.s.l.	lower montane forest I
c. 1800 - c. 2400 m a.s.l.	lower montane forest II

The plots studied in the Danau di Atas region have been provisionally grouped according to this scheme. On the basis of this, plots 1-4 and 24 theoretically lie within the lower montane forest I while plot 20 lies within the lower montane forest II. The plots which lie within lower montane forest I may also be divided into disturbed sites and little disturbed or undisturbed sites. Details of the floristic composition of the six forest

TABLE 4.1

Environmental variables recorded in forest plots

Plot	Altitude (m)	Soil pH (rooting depth)	Soil temperature at 1m depth (°C)	Soil texture and appearance	Drainage (estimated)	Aspect	Topography and slope	Description and human interference
20	1970	5.2 (10cm)	-	0-2 cm Leaf litter 2-10 cm Humus with living roots forming dense mat 10-35 cm Mixed clay/loam/gravel and stones, some weathered. Medium brown but variable colour 10YR 3/3 35 + cm Large stones	Good	NE	Steep 39°	No signs of human disturbance Lower Montane Forest II
4	1780	5.5 (10cm)	15.4	0-5 cm Leaf litter 5-10 cm Humus, many roots 10-15 cm Dark brown loam, 10YR 3/3 15-35 cm Loamy clay, yellowish brown, 10YR 5/6 35-90 cm Yellowish brown clay, 10YR 5/6 some parent material increasing down the profile. Quartzite? 90-100 cm Yellowish red clayey matrix 10 YR 5/8	Good	Variable E-W	Variable ridgetop 0-10°	Undisturbed ridge forest Lower Montane Forest I
3	1750	5.5 (10cm)	16.6	0-2 cm Leaf litter 2-8 cm Humus 8-15 cm Humic clay, dark brown 7.5 YR 3/2 15-100 cm As above, orange 10 YR 4/4 grading to 10YR 5/6	Good	NE	Gentle slope, hillside 10°	Very slight human interference Lower Montane Forest I
1	1640	5.7 (15cm)	16.9	0-5 cm Leaf litter 5-20 cm Clayey 10YR 3/3 20-70 cm Clayey 10YR 5/8 70-100 cm Coarser material, clay and fine sand 10YR 5/8	Medium	W	Gentle slope 5°	Interference by timber removal Lower Montane Forest I
2	1535	5.7 (10cm)	17.2	0-1 cm Leaf litter 1-5 cm Dark brown humus 7.5 YR 3/2 5-15 cm Greyer brown material 15-100 cm Orange 7.5 YR 5/8. Slight gleying 100 cm Stone	Poor	-	Negligible slope 0-1°	Very poor (structurally) forest with considerable human interference Lower Montane Forest I
24	1475	5.3 (10cm)	17.35	0-1 cm Leaf litter 1-5 cm Humus and root mat 5-40 cm Dark yellow brown loam, 10YR 4/4 40-70 cm Transition to: 70-100 cm Yellow brown clay 10YR 5/4	Good	SE	Steep, hillside 21°	Slight disturbance recognized Lower Montane Forest I

plots are provided in Tables 4.2-4.4. Authorities for all species mentioned in the following sections are as shown in Appendix 1, unless otherwise stated.

4.2 Descriptions of the forest plots

4.2a Undisturbed, or little disturbed lower montane forest I

Undisturbed, or minimally disturbed lower montane forest I sites examined were plots 3, 4 and 24, all of which were located in the northern part of the area. Plot 3 was situated on a gently sloping hillside, plot 24 on a steep hillside and plot 4 on an undulating ridgetop. All three sites appeared to be well drained, with a well developed soil profile.

The three sites showed considerable diversity of arboreal taxa as indicated by their Simpson's index of diversity (Table 4.6), having values of greater than 20. Plot 3 appeared to be extremely diverse, having a value of 46.2, although this possibly was an artificially high value resulting from the large number of identifications of trees to generic level only, in this plot, since these were treated as seperate species.

General characteristics of the forest at these sites were the abundance of bryophytes, including terrestrial species, and of epiphytes generally; ferns were also abundant. There was an absence of trees with buttresses, most having straight boles. The canopy height at plots 3 and 24 was estimated as 20-25 m, with some higher emergent individuals. The canopy at plot 4 appeared to be lower, generally less than 20m, but emergent trees were also present. Understory palms were also common at this site.

The only parts of the forest to be studied in detail, floristically, were arboreal taxa of girth at breast height greater than 30 cm, details of which are presented in Table 4.2. Both the percentage basal area (% b.a.) and the number of individuals (n) are given for each taxon.

Plot 3 was dominated by the four families Fagaceae, Theaceae, Lauraceae and Myrtaceae (Table 4.5). These together accounted for over 70% of the total basal area recorded at the site. In terms of large, individual trees the Theaceae were particularly notable, as three specimens of Schima wallichii ssp. noronhae accounted for almost 22% of the total basal area of the plot. Fagaceae were also represented by a number of large trees. This is of particular significance in a palynological study, since it is the large, canopy-reaching trees which seem to produce the bulk of the dispersed pollen (eg. Kershaw and Hyland, 1975).

Plot 4 (Plate 1) was dominated by Fagaceae, which, with the Myrtaceae, Lauraceae and Hamamelidaceae accounted for over 65% of the basal area. Although no particular species of tree was as noticeably dominant as was Schima wallichii ssp. noronhae at plot 3, Lithocarpus sp. (18) was quite common, twelve individuals being recorded in the plot, and accounting for almost 12% of the basal area. A single large specimen of Symingtonia populnea also accounted for almost 10% of the basal area of the plot.

Plot 24 (Plate 2) yielded a great variety of families (Table 4.5)

TABLE 4.2

Floristic composition of undisturbed or little disturbed lower montane forest I plots

Collection Number	Family	Name	Plot 3 % b.a.	Plot 3 n	Plot 4 % b.a.	Plot 4 n	Plot 24 % b.a.	Plot 24 n
52/58	Alangiaceae	Alangium rotundifolium	0.49	2				
84	Anonaceae	Goniothalamus sp.			2.92	6		
77	Araliaceae	Schefflera sp.			3.64	7		
3/62	Aquifoliaceae	Ilex cymosa	5.32	1				
276	Combretaceae	Terminalia sp.					1.28	1
24/101	Cunoniaceae	Weinmannia blumei			0.41	1	24.77	8
81	Elaeocarpaceae	Elaeocarpus glaber			1.44	3		
42/266		E. ovalis	4.47	1			1.72	1
75		E. punctatus			7.60	7		
267		E. sp.					0.42	2
4/262		Sloanea sigun					1.20	4
45	Euphorbiaceae	Drypetes sp.	8.23	2				
274		Glochidion sp.					1.03	1
53		Macaranga tanarius	0.45	1				
271		M. triloba					3.19	1
50/265	Fagaceae	Castanopsis lucida	8.31	1			1.15	1
65		Lithocarpus javensis	3.84	2				
72		L. elegans	0.23	1				
17		L. sp.	1.81	1			2.78	1
18		L. sp.	0.81	1	11.68	12	0.53	2
41		L. sp.	8.58	2				
82		L. sp.			4.27	1		
88		L. sp.			2.49	1		
89		L. sp.			2.79	2		
255		L. sp.					1.42	1
28/86/261		Quercus lineata			9.23	6	13.22	3
273	Guttiferae	Cratoxylon arborescens					1.28	1
46		Garcinia lateriflora	0.52	4	2.42	4	5.86	2
256		G. sp.					0.51	1
96/244	Hamamelidaceae	Rhodoleia championi			5.70	4		
95		Symingtonia populnea			9.61	1	1.28	1
26/76	Icacinaceae	Platea excelsa var. riedeliana			0.59	3		
36	Lauraceae	Actinodaphne sp.	0.73	2				
272		Cinnamomum sp.					0.43	1
39		Cryptocarya sp.	0.10	1				
40		C. sp.	0.74	2				
48		C. sp.	2.59	3				
70		C. sp.	0.32	2				
264		C. sp.					0.13	1
44		Endiandra sp.	0.23	1				
49		E. sp.	0.33	1				
102		E. sp.			0.42	1		
13/54/55/69		Lindera novoguineensis	1.87	5				
8		Litsea sp.			0.96	1		
71		L. sp.	5.77	1				
100		L. sp.			0.13	1		
98		Neolitsea sp.			1.18	1		

TABLE 4.2 continued

Floristic composition of undisturbed or little disturbed lower montane forest I plots

Collection Number	Family	Name	Plot 3		Plot 4		Plot 24	
			% b.a.	n	% b.a.	n	% b.a.	n
67	Melastomataceae	Medinilla sp.	0.95	2				
268		Pternandra sp.					7.13	6
66	Meliaceae	Dysoxylum sp.	0.92	1				
74		D. sp.	0.31	1				
20	Myrtaceae	Eugenia sp.	3.00	2				
57		E. sp.	1.33	1				
73		E. sp.	0.96	1			2.40	1
78		E. sp.			2.53	6		
87		E. sp.			0.18	1		
90		E. sp.			6.69	8		
91		E. sp.			1.54	2		
260		E. sp.					0.23	1
59/245		Syzygium racemosum	9.42	4				
33		Tristania bakhuizenii					0.70	1
68	Oleaceae	Olea javanica var.?lanciflora	0.75	1				
247	Podocarpaceae	Dacrycarpus imbricatus					0.70	1
79	Rhizophoraceae	Carallia brachiata			4.57	7		
63		Gynotroches axillaris	0.23	1				
1/85	Rosaceae	Prunus arborea			0.97	3		
56	Rubiaceae	Timonius cf. sericeus	0.15	1				
83/93	Rutaceae	Tetractomia holtumi			1.72	2		
29/34		T. obovata			0.87	3		
269	Sapindaceae	Mischocarpus sundaicus					0.23	1
7	Staphyleaceae	Turpinia sphaerocarpa					2.82	3
21/258	Styracaceae	Styrax paralleloneurum					2.74	4
43	Symplocaceae	Symplocos cf.?baratogi	0.75	1				
259/275		S. henscheli var. maingayi?					0.78	2
97		S. sp.			0.50	1		
51/282	Theaceae	Schima wallichii ssp. noronhae	21.99	3	4.79	3	18.30	2
94		S. sp.			0.29	1		
47/64/80		Ternstroemia patens	0.21	1	5.80	2		
60	Uncollected	-	0.92	1				
61		-	3.00	1				
99		-			1.94	2		
257		-					1.26	2
270		-					0.51	1

but was dominated by Fagaceae, Theaceae and Cunoniaceae, which contributed over 60% of the basal area. *Schima wallichii* ssp. *noronhae* was once again notable, two specimens accounting for over 18% of the basal area, while eight specimens of *Weinmannia blumei* contributed almost 25% of the basal area. Other families represented in the plot were Staphyleaceae, Styracaceae, Sapindaceae and Combretaceae.

These plots therefore appear to be characterized by the importance of Fagaceae, which comprised c. 19-30% of the basal area of the plots examined. Common taxa were members of the genus *Lithocarpus*; *Lithocarpus* sp. (18) being found in all three plots examined. *Quercus lineata* and *Castanopsis lucida* were also important at some of the sites. Theaceae were another important group in the sites examined, comprising c. 10-22% of the basal area, and *Schima wallichii* was present in all plots examined. Myrtaceae, Lauraceae and Elaeocarpaceae were represented at all sites but the importance of these at individual sites was variable. For example, Lauraceae were particularly well represented at plot 3, and Myrtaceae at plots 3 and 4. Other apparently characteristic taxa encountered in these sites were *Garcinia lateriflora*, *Eugenia* spp., *Symplocos* spp. and *Elaeocarpus* spp. Table 4.5 gives details of the composition of all forest plots in terms of families and selected species.

Girth class frequency distributions for these plots are shown in Fig. 4.2. A balanced size distribution can be envisaged for a forest, in which the numbers of individuals in each successive girth class decreases in such a manner that the quotient between the numbers of trees in successive girth classes approaches a constant value (Meyer, 1952). In reality most forests do not have this distribution, but may be converging towards it.

Plots 3 and 24 had girth class frequency distributions which were not very dissimilar from that expected, with numerous individuals in the smaller girth classes but significant numbers also in the larger girth classes. The latter was particularly notable at plot 3. Plot 4 was slightly unusual as it had numerous trees in the girth classes 1-3, but virtually none in the higher girth classes. This pattern may have been linked to the ridge-top location of this plot; possibly some environmental factor is limiting growth at this site.

The total basal area of each 0.2 hectare plot, and the projected basal area in m^2 per hectare is shown in Table 4.7. The projected basal areas of 28.0 - 43.05 m^2/hectare compare well with values from other primary forests in South-East Asia. For example, at Sungei Menyala in Malaysia the basal area/hectare for trees of girth greater than 30 cm in a lowland Dipterocarp forest varied from 32.0 - 34.9 m^2/hectare over a period of several years (Whitmore, 1975). The relatively low value recorded at plot 24 may be the result of removal of a very small number of medium sized trees as indicated by the presence of cut tree stumps.

4.2b Disturbed lower montane forest I

The disturbed lower montane forest I sites examined were plots 1 and 2. Plot 1 was situated to the south-east of Danau di Atas on a gently sloping hillside and appeared to be moderately well drained. Plot 2 was located to the north-west of the lake on an area of negligible slope and appeared to be poorly drained. Both sites possessed a well developed soil profile and at both considerable evidence of timber removal was apparent. At plot 2 the canopy was often broken, and the abundant light penetrating to the forest floor had resulted in the development of dense low growth in parts of the plot. Floristic details of the plots are provided in Table 4.3.

Epiphytes were abundant at both sites, comprising pteridophytes and bryophytes as well as some higher plants. The ground floras were also quite rich and polster forming mosses were commonly observed. The canopy height was estimated as 20-25 m at plot 1 and 15-20 m at plot 2. Emergent trees were rare at both sites.

The diversity of arboreal taxa, as measured using Simpsons' index (Table 4.6) was low at both sites, values being 10.7 and 8.3 for plots 1 and 2 respectively. This is almost certainly a reflection of the degree of human interference in these forests.

At plot 1 the forest, though degraded, was still dominated by Fagaceae and Lauraceae, with these two families accounting for more than 60% of the basal area (Table 4.5); taxa represented included Lithocarpus spp., Beilschmiedia sp., Litsea sp. and Lindera novoguineensis. Other taxa represented in the plot were

TABLE 4.3

Floristic composition of disturbed lower montane forest I plots

Collection Number	Family	Name	Plot 1		Plot 2	
			% b.a.	n	% b.a.	n
3/62	Aquifoliaceae	Ilex cymosa	1.14	2		
32	Compositae	Vernonia arborea			3.75	3
25		V. arborea var. javanica			1.58	2
24/101	Cunoniaceae	Weinmannia blumei			0.41	1
4/262	Elaeocarpaceae	Sloanea sigun	2.38	6		
2	Euphorbiaceae	Claoxylon longifolium	0.31	1		
15		Macaranga sp.	2.89	3		
5	Fagaceae	Lithocarpus sp.	4.16	2		
17		L. sp.	17.96	8		
18		L. sp.	5.01	6	12.86	12
28/86/261		Quercus lineata			25.63	3
14	Flacourtiaceae	Flacourtia rukam	1.10	1		
36	Lauraceae	Actinodaphne sp.			0.31	1
6		Beilschmiedia sp.	19.75	17		
13/54/55/69		Lindera novoguineensis	9.67	8		
8		Litsea sp.	4.88	5		
35	Loganiaceae	Fagraea sp.			0.64	1
9	Myrsinaceae	Ardisia sp.	8.37	4		
16	Myrtaceae	Eugenia sp.	0.86	1		
20		E. sp.	1.94	1		
23		E. sp.			35.73	12
33		Tristania bakhuizenii			1.38	3
22	Oleaceae	Linociera oxycarpa			10.72	5
1/85	Rosaceae	Prunus arborea	1.55	1		
30/153/242	Rubiaceae	Tarenna fragrans			1.44	2
29/34	Rutaceae	Tetractomia obovata			0.68	2
7	Staphyleaceae	Turpinia sphaerocarpa	2.36	2		
21/258	Styracaceae	Styrax paralleloneurum			0.72	1
10	Symplocaceae	Symplocos fasciculata	1.48	2		
31		S. sp.			1.85	1
37	Theaceae	Adinandra sp.			2.07	1
38		A. sp.			0.23	1
19	Cyatheaceae	Cyathea sp.	0.38	1		
11	Uncollected	-	0.89	1		
12		-	12.93	1		

Prunus arborea, *Sloanea sigun*, *Turpinia sphaerocarpa*, *Ardisia* sp. and *Eugenia* sp.

The degraded forest at plot 2 was still dominated by Fagaceae and Myrtaceae which accounted for 75% of the basal area (Table 4.5). These included *Lithocarpus* sp. (18), *Eugenia* sp. (23), *Quercus lineata* and *Tristania bakhuizenii*. Other taxa represented included *Linociera oxycarpa*, *Vernonia arborea*, *Symplocos* sp. and *Adinandra* spp.

Fagaceae were well represented at both sites, comprising c. 27% and c. 38% of basal area respectively (Table 4.5). Lauraceae were also very important at plot 1, where they accounted for c. 34% of basal area, but were much less important at plot 2. Conversely the Myrtaceae comprised 37% of the basal area at plot 2 and yet were relatively uncommon at plot 1. Some of these differences in floristic composition at the two sites might be related to drainage conditions. The Myrtaceae include some species of *Eugenia* which can tolerate extremely wet soil conditions, and may occur in swamp forests. Plot 2 appeared to be badly drained and this might account, in part, for the importance of Myrtaceae at this site. It is of interest that the Theaceae are poorly represented at these sites, and that *Schima* is absent, whereas in the undisturbed sites they were important contributors to basal area. This is despite the fact that *Schima* may rapidly regenerate in depleted forest (van Steenis, 1972).

Girth class frequency distributions (Fig. 4.2) of these plots illustrate the effects of timber removal. At both sites few trees occur in the larger girth classes, although there are numerous individuals in the smaller classes and especially in girth class 1 (30-60 cm). This pattern is particularly striking for plot 2. Thus, it appears that medium to large girthed trees have been preferentially removed, leaving smaller girthed trees, while any regeneration occurring will emphasize this pattern.

The effect of timber removal is also quite evident in the values of total basal area (m^2) for these plots and projected basal area per hectare (Table 4.7). These values are very low, from 15.55 - 17.70 m^2/hectare, compared with those from undisturbed or little disturbed plots, which are approximately double these figures.

4.2c Undisturbed lower montane forest II

This was represented only at plot 20 (Plate 3), which was located in the south of the area, on the steeply sloping flanks of Bukit Air Dingin, at an altitude of 1970 m. The site appeared to be well drained, and had a well developed, shallow soil profile.

This plot exhibited considerable diversity of arboreal taxa and had a Simpson's index value of 22.7 (Table 4.6). This was comparable with the diversity of the undisturbed lower montane forest I plots. Epiphytes, including pteridophytes and bryophytes were abundant, as was the ground flora which included many polster forming mosses. Canopy height was estimated at 20-25 m with some emergent individuals.

The plot was slightly smaller than the others studied, and covered an area of 0.16 hectare instead of 0.2 hectare.

TABLE 4.4

Floristic composition of an undisturbed lower montane forest II plot

Collection Number	Family	Name	Plot 20	
			% b.a.	n
243	Araliaceae	Schefflera sp.	2.10	2
24/101	Cunoniaceae	Weinmannia blumei	2.69	1
17	Fagaceae	Lithocarpus sp.	3.88	1
18		L sp.	18.84	2
96/244	Hamamelidaceae	Rhodoleia championi	31.14	2
95		Symingtonia populnea	9.03	2
27	Lauraceae	Cinnamomum sp.	1.20	1
59/245	Myrtaceae	Syzygium racemosum	2.15	2
247	Podocarpaceae	Dacrycarpus imbricatus	21.13	1
30/153/242	Rubiaceae	Tarenna fragrans	7.41	2
19	Cyatheaceae	Cyathea sp.	0.43	1

TABLE 4.5

Percentage basal area for selected families and species in forest plots

	Percentage basal area					
	Plot 20 1970m	4 1780m	3 1750m	1 1640m	2 1535m	24 1475m
Fagaceae	22.72	30.46	23.38	27.13	38.49	19.10
Lauraceae	1.20	2.69	12.68	34.10	0.31	0.56
Myrtaceae	2.15	10.94	14.71	2.80	37.11	3.33
Theaceae		10.88	22.20		2.30	18.30
Schima sp. (Theaceae)		5.08	21.99			18.30
Hamamelidaceae	40.17	15.31				1.28
Symingtonia populnea (Hamamelidaceae)	9.03	9.61				1.28
Dacrycarpus imbricatus (Podocarpaceae)	21.13					0.70
Weinmannia blumei (Cunoniaceae)	2.69	0.41			0.41	24.77
Elaeocarpaceae		9.04	4.47	2.38		3.34
Euphorbiaceae			8.68	3.20		4.22
Claoxylon longifolium (Euphorbiaceae)				0.31		
Rosaceae		0.97		1.55		
Rhizophoraceae		4.57	0.23			
Guttiferae		2.42	0.52			7.65
Turpinia sphaerocarpa (Staphyleaceae)				2.36		2.82
Styrax paralleloneurum (Styracaceae)					0.72	2.74
Ilex cymosa (Aquifoliaceae)			5.32	1.14		
Ardisia sp. (Myrsinaceae)				8.37		
Symplocaceae		0.50	0.75	1.48	1.85	0.78
Tarenna fragrans (Rubiaceae)	7.41				1.44	
Rubiaceae (Other)			0.15			
Rutaceae		2.59			0.68	
Flacourtiaceae				1.10		
Melastomataceae			0.95			7.13
Sapindaceae						0.23
Combretaceae						1.28
Araliaceae	2.10	3.64				
Icacinaceae		0.59				
Annonaceae		2.92				
Alangiaceae			0.49			
Oleaceae			0.75		10.72	
Meliaceae			0.92			
Vernonia arborea (Compositae)					5.33	
Loganiaceae					0.64	
Cyathea sp.	0.43					

TABLE 4.6

Simpson's index of diversity for forest plots

This is calculated from the following equation

$$D = \frac{N\ (N - 1)}{n\ (n - 1)}$$

Where N = Number of individuals per sample
n = Number of individuals of each species
D = Index of diversity

From Simpson (1949)

Plot	Altitude (m)	Index of diversity, D
20	1970	22.7
4	1780	22.5
3	1750	46.2
1	1640	10.7
2	1535	8.3
24	1475	24.7

TABLE 4.7

Total basal areas of forest plots

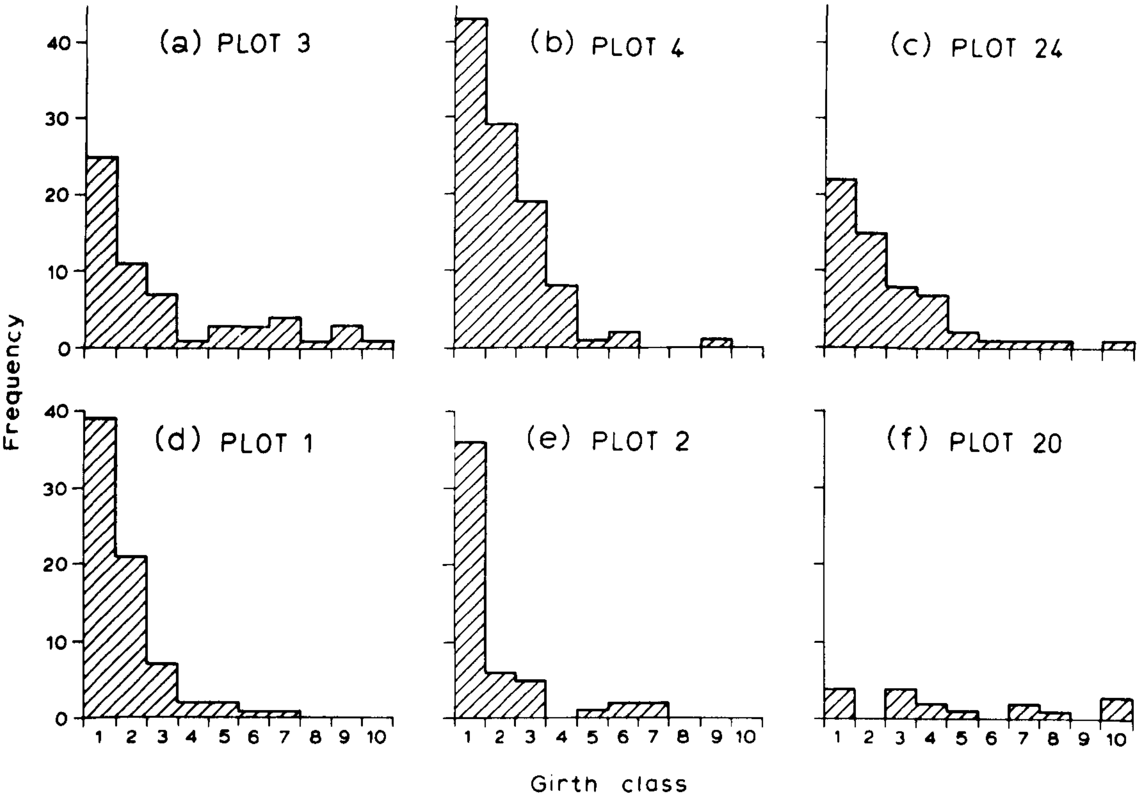
Plot	Altitude (m)	Basal area of plot (m^2)*	Projected basal area per hectare (m^2)
20	1970	6.64	41.50
4	1780	6.72	33.60
3	1750	8.61	43.05
1	1640	3.54	17.70
2	1535	3.11	15.55
24	1475	5.60	28.00

* The area of the plots was 0.2 hectare, with the exception of plot 20 which was 0.16 hectare

Fig. 4.2

Girth class frequency distributions in the forest plots

Girth class	Girth at breast height (cm)
1	30- 60
2	61- 90
3	91-120
4	121-150
5	151-180
6	181-210
7	211-240
8	241-270
9	271-300
10	> 301


(a) PLOT 3
(b) PLOT 4
(c) PLOT 24
(d) PLOT 1
(e) PLOT 2
(f) PLOT 20
Frequency
0
10
20
30
40
1 2 3 4 5 6 7 8 9 10
Girth class

Hamamelidaceae, represented by Symingtonia populnea and Rhodoleia championi, comprised about 40% of the basal area of the plot. Podocarpaceae, represented solely by Dacrycarpus imbricatus contributed a further 21% to the basal area (Tables 4.4 and 4.5). These two families therefore appeared to dominate the plot examined, with Fagaceae, represented by Lithocarpus spp. Myrtaceae and Lauraceae were minor components of the plot, while Theaceae were not recorded. Other common taxa in this plot included Weinmannia blumei and Tarenna fragrans.

The girth class frequency distribution for the site was interesting as few small girthed trees were recorded, although large girthed individuals were relatively common (Fig. 4.2).

The total basal area of the plot, and projected basal area per hectare (Table 4.7) are high. The projected basal area per hectare is 41.5 m^2, comparable with values for undisturbed lower montane forest I.

4.2d Other taxa collected from forests in the Danau di Atas region

A number of specimens which either were collected outside the six forest plots studied or else were collected within the plots but had a girth of less than 30cm, were identified from the region, and are listed in Table 4.8.

Numbers 241, and 248, Dodonaea viscosa and Albizia lophantha were collected in the vicinity of plot 20 but at a slightly lower altitude.

TABLE 4.8

Other taxa collected from forests in the Danau di Atas region

Collection Number	Name	Family	Collection Location
241	Dodonaeaviscosa	Sapindaceae	Close to plot 20
246	Ardisia javanica	Myrsinaceae	Small tree in plot 20
248	Albizia lophantha	Leguminosae/ Mimosoideae	Close to plot 20
277	Lithocarpus sp.	Fagaceae	Collected at c. 1725 m on Bukit Air Dingin
278	Viburnum beccarii	Caprifoliaceae	"
279	Symplocos laeteviridis var.laeteviridis	Symplocaceae	"
280	Psychotria divergens	Rubiaceae	"
281	Viburnum coriaceum	Caprifoliaceae	"
282	Schima wallichii ssp. noronhae	Theaceae	"
283	Engelhardtia spicata	Juglandaceae	"
284	Vaccinium sp.	Ericaceae	"
285	Helixanthera parasitica	Loranthaceae	" 1.
286	Castanopsis malaccensis	Fagaceae	"
287	Haemocharis sp.	Theaceae	"
288	Omalanthus populneus	Euphorbiaceae	"
289	Viburnum sp.	Caprifoliaceae	"
290	Pyrus granulosa	Rosaceae	"
291	Taxus baccata	Taxaceae	"
292	Adinandra villosa	Theaceae	"
293	Eurya sp.	Theaceae	"

1. Hemiparasite on tree

Number 246, Ardisia javanica, was a small (< 30 cm girth) tree occurring in plot 20.

The sequence 277-293 were collected from a patch of badly disturbed, possibly regenerating forest at c. 1725 m altitude on Bukit Air Dingin, south of Danau di Atas.

It was hoped that these would provide further information about the species composition of the forests in the area, and they included several species which were not recorded in the six forest plots studied.

4.3 Analysis of data from forest plots using reciprocal averaging

4.3a The choice of reciprocal averaging analysis for use in this study.

Statistical analysis of complex data sets may reveal otherwise unrecognized relationships between samples or sites. Of the two main types of approach to multivariate statistical analysis, one is classification, eg. association analysis, which groups 'like' species or sites together. The other main approach is by ordination eg. polar ordination, and principal components analysis. Ordination arranges samples (sites or species) along axes. The continuous variation shown implies environmental control and the environmental parameters involved are the interest of the ordination.

Multivariate techniques can be very useful for the analysis of large or otherwise complex data sets in which interpretation is difficult 'by eye'. Reciprocal averaging (R.A.) (Hill, 1973) was the technique chosen for use in this study. This is a type of indirect ordination related to principal components analysis (P.C.A.), and other eigenvector techniques. R.A. works by weighting species along a supposed gradient, from which can then be calculated a stand order and a corresponding weighting of stands. From these the species weightings can be corrected, giving them average values for the stands in which they occur. With the resultant new set of species weightings the stand scores can be corrected. This reiterative process continues until it reaches a unique stabilized score. The effect is to arrange the order of species and stands and the distances between them so that the correlation between species and stand scores is maximized. In this way the first ordination axis is obtained; the process is repeated to obtain other axes. One of the strengths of the technique is that it simultaneously ordinates both the species and stands (Hill, 1973).

Floristic data does tend to produce certain problems when used in ordinations, some of which are considered by Gauch et al. (1977) who tested three techniques, polar ordination (P.O.), P.C.A., and R.A. with simulated and field data sets. The R.A. technique dealt with a number of these problems more successfully than P.C.A., and often than P.O. It also appeared to be less susceptible to distortion by sample clusters, sample error and outlier samples i.e. deviant samples of unusual composition, perhaps having one species strongly dominant, although it was recommended that outliers should be removed from the sample set.

Species ordinations using R.A. also appeared to be superior to those of P.C.A. and P.O. (Gauch et al., 1977). The reciprocal averaging technique reveals in its first axis a major direction of sample variation which often corresponds to environment. The second axis may sometimes also reveal a second direction of sample variation, but often this axis is a function of the first axis and any ecologically meaningful gradient is shifted into higher axes (Gauch et al., 1977; Hill, 1973). Reciprocal averaging does appear to be relatively well adapted to the non-linearity of ecological data but does have some limitations. Although strong gradients do not come out reflexed as they do for some of the other ordination techniques, they still tend to be arched and therefore need two axes to display them. Also, the scale of the axes has no defined meaning and R.A. analysis tends to produce axes which are contracted at both ends, causing some distortion of the pattern. Hill (1979) produced a revised procedure 'DECORANA', to deal with some of these limitations, but this was not accessible for this study when the analyses were carried out. However, the drawbacks of R.A., the 'arch' effect and scaling problem, are not important for the aims of this analysis.

4.3b Results using reciprocal averaging analysis on forest plot data

The reciprocal averaging procedure was used to analyse data in quantitative standardized form from all six forest plots. Quantitative, standardized data was preferred since it was thought that the abundance of a species would be important in relation to environmental gradients, thus presence - absence data alone would not hold all the ecological information that might be important. It was envisaged that even using a fairly robust technique such as R.A. there might still be problems in the analysis related to the nature of the data itself. The very small number of plots was one unavoidable problem, and the rather large numbers of taxa recorded at one site only was another potential problem. Linked with the latter was the problem of identification level, which had resulted in a large number of taxa being determined to the generic level only, and clearly it was possible that in some cases the same species might be represented in the analysis as a separate taxon at different sites. Nonetheless, the analysis was carried out to determine if there were any interpretable patterns in the data, particularly to see if species composition of the sites would relate to environmental gradients such as altitude or disturbance as the plots had provisionally been grouped according to both.

The result of site ordination on axes I to III is shown in Fig. 4.3.

Axis I: Although the arrangement of sites is so as to maximise the correlations between species and stand scores, the results are not easily interpretable in terms of any of the environmental gradients recognized in the field area. Clearly the floristic differences between sites may relate to some other factor, if indeed the pattern is of real significance, rather than simply an

Fig. 4.3
Forest plots, results of reciprocal averaging analysis: site ordination on axes I-III

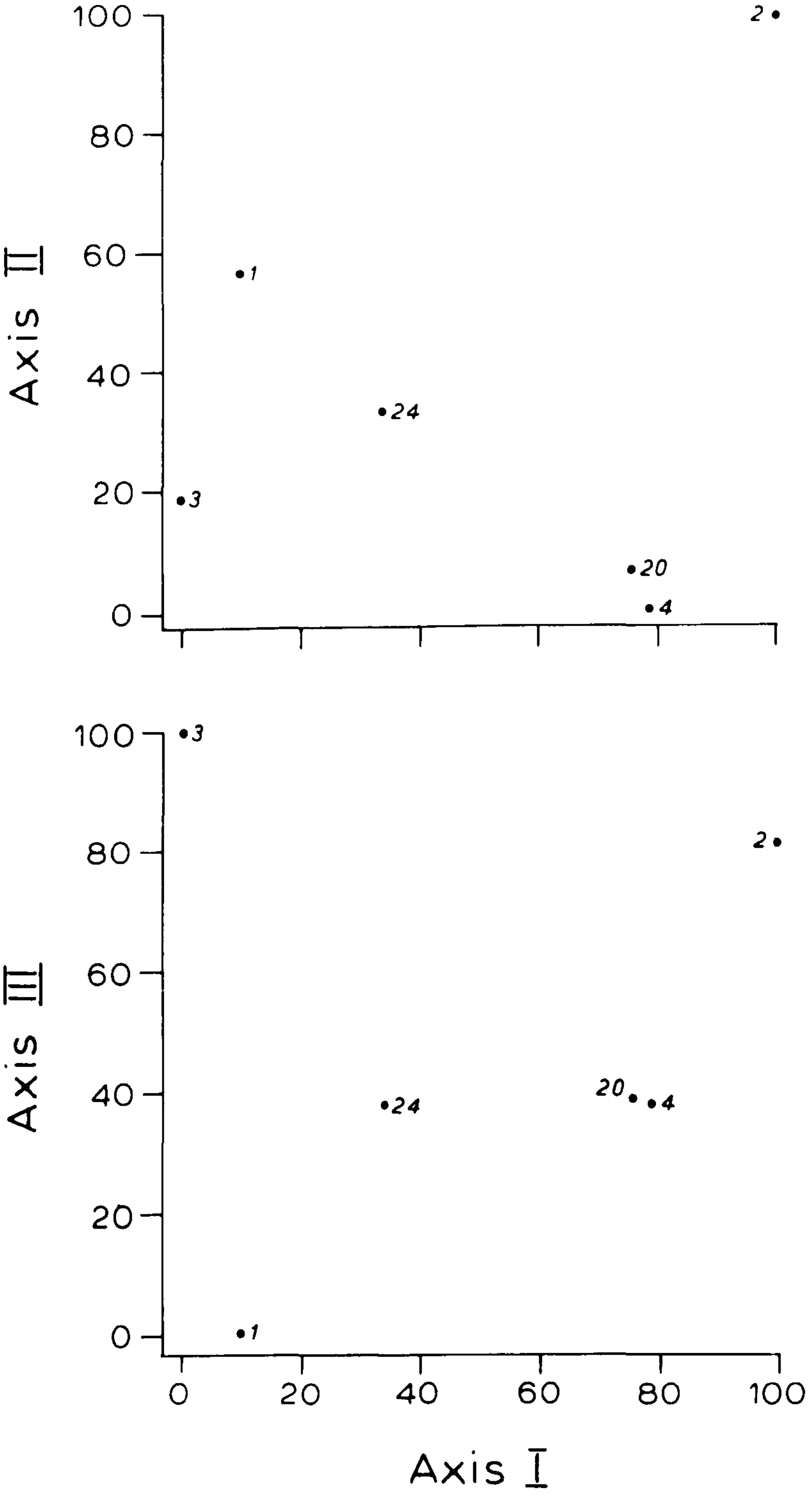
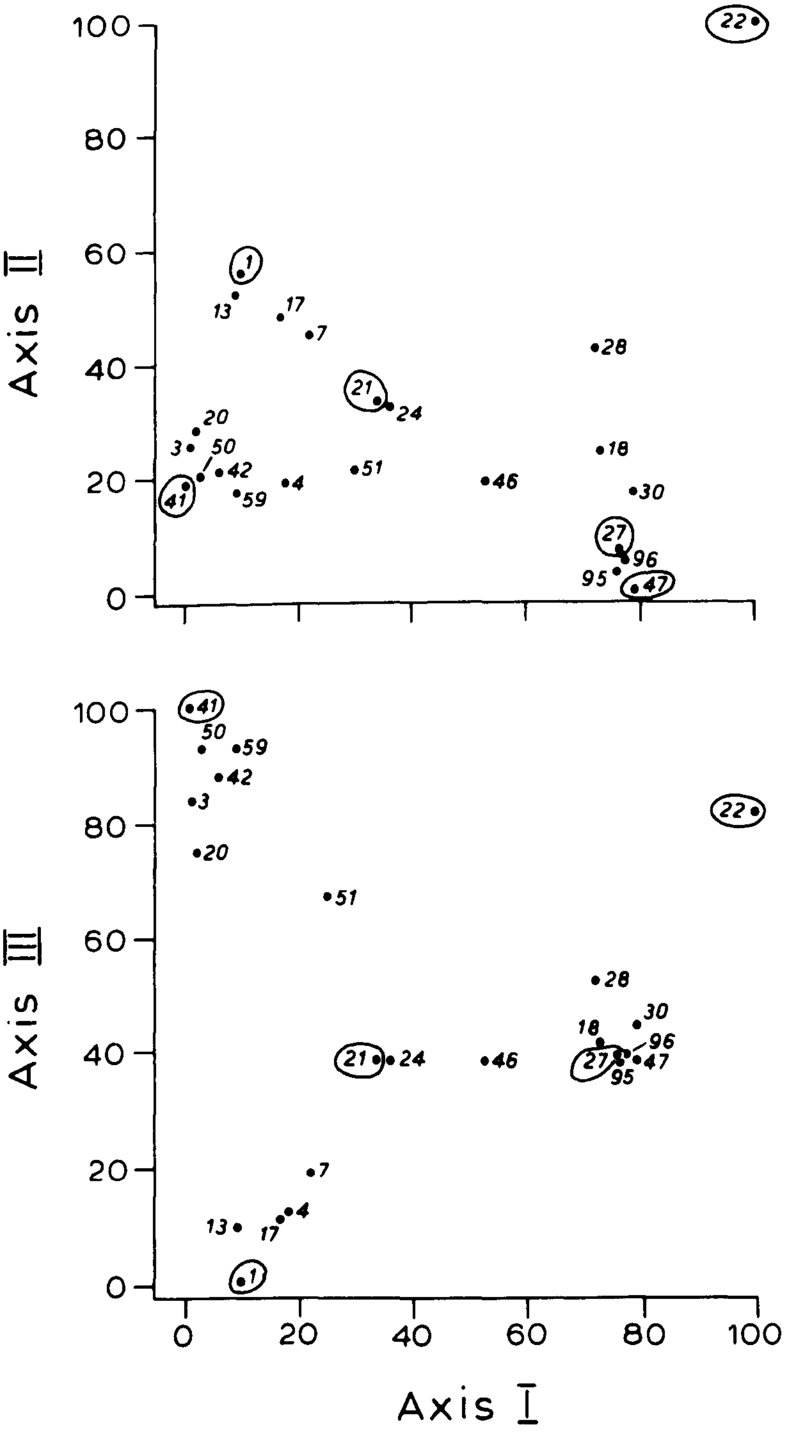

Axis II
Axis III
Axis I
0
20
40
60
80
100
1
2
3
4
20
24

Fig. 4.4
Forest plots, results of reciprocal averaging analysis: species ordination on axes I-III



N.B. 1 includes 1, 5, 6, 8, 9, 10, 12, 14, 15
21 " 21, 73, 255, 257, 268, 271, 273, 274, 276
22 " 22, 23, 25, 31, 32, 33, 37
27 " 27, 243, 247
41 " 41, 45, 48, 57, 61, 65, 71
47 " 47, 75, 77, 78, 79, 81, 82, 83, 84, 88, 89, 90, 91, 98, 99

expression of the patchiness of these diverse forests.

Axis II: The distribution of sites on axis II is suggestive that they might relate to degree of disturbance, since the most disturbed sites seem to have higher stand scores than less disturbed sites. However, this is a rather tentative interpretation and may prove to be incorrect. There is a chance that the pattern is a result of dependence of the second axis on the first.

Axis III: Again the axis is not interpretable in terms of any of the environmental gradients recognized in the field.

Of particular interest are the similar site scores of plots 20 and 4 on the first 3 axes, which suggests a degree of floristic similarity between these sites not found between any of the other sites or pairs of sites.

The result of species ordination on axes I to III is shown in Fig. 4.4, in which numbers refer to collection numbers. Again no clearly interpretable patterns emerge.

The analysis was not particularly useful since it did not reveal any interpretable gradients in the floristic data of the six sites. Possibly this is because these sites, although quite diverse, do not cover a sufficiently wide span of environmental gradients to produce meaningful results. All sites are from within lower montane forest (and most are within lower montane forest I) and demonstrate the floristic variation within such forest. Floristic composition may relate broadly to environmental variables, as many taxa do have environmental constraints on their growth, for example climate, acting through altitude does influence the distribution of species. It may however be the case in this instance that environment does not vary much at the different sites examined, with the result that floristic composition is also influenced by chance events to a large extent, thus masking any patterns in the data which relate to environmental variables. Examination of a larger number of plots covering a wider range of environments would quite possibly have produced more interpretable results with the reciprocal averaging analysis.

4.4 The nature of forest vegetation in the Danau di Atas area

All of the forest sites studied in the area, between 1475 m and 1970 m a.s.l. are of lower montane forest affinity.

Members of the Fagaceae were well represented in all of the plots studied. This is much as expected since parts of the lower montane forest in the region eg. Malaysia are often referred to as Montane Oak Forests (Table 2.3). The Fagaceae recorded in the area often included some of the larger girthed forest trees.

Members of the Lauraceae were also represented at all of the sites examined, but their contribution to the total basal area of these sites was very variable (Table 4.5), although they were locally abundant.

Myrtaceae, represented largely by Eugenia spp. was the only other family represented at all of the sites, and like the Lauraceae was rather more variably represented, in basal area terms, than was the Fagaceae.

Members of the family Theaceae, although not recorded at all sites examined, were present in four of them, and may have been quite a common component of the forests of the area generally. Their absence from the lower montane forest II plot examined, plot 20, is unlikely to be an indication that they are absent from this forest type generally, as only one plot was examined. They are in fact, quite common in the plots which lie close to the lower montane forest I/II transition at altitudes of 1780 m and 1750 m a.s.l. Schima spp., particularly Schima wallichii, are apparently well distributed with altitude. This genus is often represented by large trees which form a significant percentage of the basal area of the plots. Morley (1976) found that the distribution of Schima wallichii in the Kerinci area was related to soil and altitudinal factors. It was present at altitudes from 1230 to 2190 m a.s.l. and thus appears to be found within almost the whole altitudinal range of lower montane forest. This is likely to have been the case here also.

The Hamamelidaceae appear to have been better represented at higher altitude sites (1780 m, 1970 m) and with one exception were absent from forest sites below 1780 m a.s.l. Symingtonia populnea occurred in plot 24 (1475 m a.s.l.) but its percentage basal area was low at this site. Morley (1976) found that this taxon occurred in the Kerinci area at altitudes between 1990 m and 2190m, and was absent at lower altitudes. It appears likely therefore that this taxon is most commonly found within lower montane forest II (c. 1800 m - c. 2400 m a.s.l.) although it occurs, more rarely, at lower altitudes. Plot 4, at 1780 m a.s.l., appears to be at an altitude close to the theoretical lower montane forest I/II transition and it is not therefore surprising that certain taxa more typically associated with lower montane forest II also appeared in this plot.

Dacrycarpus imbricatus (= *Podocarpus imbricatus*) was the only member of the Podocarpaceae recorded in the plots examined and was important in basal area terms only in plot 20, although it did occur in one other plot, at 1475 m a.s.l. As with *Symingtonia populnea* this appears to be common within the lower montane forest II, and Morley (1976) records it only at altitudes from 1990 to 2190 m a.s.l. in the Kerinci area. It occurs, but probably only rarely, at lower altitudes.

Weinmannia blumei (Cunoniaceae) appeared to be distributed throughout the lower montane forest I and II and was particularly common in plot 24 at 1475 m a.s.l. Morley (1976) found that in the Kerinci area this occurred in the altitudinal range 1990m to 2190 m a.s.l., and he considered it to be indicative of lower montane forest II. However, in view of the abundance of this taxon at lower altitudes than these, in the Danau di Atas area, here at least it appears to be also indicative of lower montane forest I.

Elaeocarpaceae, Euphorbiaceae and Rosaceae did not show any notable relationships with altitude, occurring in many lower montane forest I plots, with variable representation. Absence from the lower montane forest II site, plot 20, could not be taken as an indication that they are wholly absent from this forest formation, due to the limited sample size. Staphyleaceae were represented occasionally in the plots examined by only one species, Turpinia sphaerocarpa. Although this was found only at the lower sites studied, at 1475m and 1640m a.s.l., Morley (1976) records this over the altitudinal range 1530 m to 1990 m a.s.l., and it therefore appears to be present in lower montane forest I and II, and might occur also in sub-montane forest although it was not recorded there.

A number of other taxa and families occurred less frequently in the plots studied, and bore no apparent relationship with environmental factors such as altitude. They included Ilex cymosa (Aquifoliaceae), Ardisia sp., (Myrsinaceae), Styrax paralleloneurum (Styracaceae), Rutaceae, and Rubiaceae. Symplocaceae, represented by the genus Symplocos was present in five of the six plots examined although it was nowhere common in percentage basal area terms. No Symplocaceae were recorded in the lower montane forest II site, plot 20, but the family is known to occur throughout forests at these altitudes in Java (Backer and Bakhuizen van den Brink, 1965).

Claoxylon longifolium (Euphorbiaceae) was recorded only at plot 1 (1640 m a.s.l.) in the Danau di Atas region, and appears to have been a minor component of the forest. Morley (1976) describes this as occurring at altitudes from 1230 m to 1650 m a.s.l. in the Kerinci area, and it therefore seems likely that this may be most common in lower montane forest I and sub-montane forest. Tarenna fragrans (Rubiaceae) was found at 1535 m and 1970 m a.s.l. (plots 2 and 20) in the Danau di Atas area, while Morley (1976) found it from 1320 m to 2190 m a.s.l., and its occurrence there was related to soil and altitudinal factors. However, this taxon appears to occur throughout the lower montane forest formation if other factors are suitable.

Morley also found that the distribution of Vernonia arborea related to soils and altitude, ranging from 1000 m to 2190 m a.s.l. It appears to be a minor forest component in the Danau di Atas region, being recorded in only one plot. It appears however, based on Morley (1976) that this species occurs throughout lower montane forest.

4.5 Non-forest vegetation

Most of the lower-lying parts of the Danau di Atas area have been cleared of their original forest cover, and much of this cleared land is now put to agricultural use. The flat area which runs north from the village of Alahan Panjang is intensively cultivated, predominantly for rice but also for other crops such as sugar cane and potato. A similar pattern is found in the valley running southwards from Danau di Atas. Other land under agricultural use in the area is found around the larger lakes, Danau di Atas and Danau di Baruh, and along the roads.

However, in some areas the forest has been cleared and used only temporarily for agricultural purposes before being abandoned.

These widespread areas now bear regenerating vegetation of a variety of types, mostly herbaceous or shrubby. They generally extend in a broad belt between the intensively cultivated agricultural land and the remaining forests. The extent of the various types of vegetation in the region is shown in Fig. 4.1, which is based on aerial photographs of the area.

A number of these non-forest vegetation types were studied using the techniques described in Chapter 3. These sites included regenerating vegetation on abandoned gardens and other cleared areas, swamp vegetation, and several ricefields and dry land gardens; in the case of fields and gardens the interest was in finding which species occurred as weeds.

Locations of the plots are also shown in Fig. 4.1. Plots 5-13 were sited on swamps, plots 5-12 being sited on various parts of the Danau di Atas Swamp, while plot 13 was located on a swamp in the lake outlet bay. Plots 14-19 were in regrowth vegetation and were located in an extensive belt of this south of Alahan Panjang village, with intensively cultivated land to the north and forest to the south. Plots 21-23 were wet ricefields located south of Alahan Panjang village. Plots 25 and 26 were old gardens, one wet rice and one dryland close to Danau di Atas, in the lake outlet bay. Plot 27 was a dry land field between Alahan Panjang and Danau di Atas.

Environmental variables recorded at the plots are given in Tables 4.9, 4.11 and 4.13. Details of floristic composition of the plots are given in Tables 4.10, 4.12 and 4.14. Authorities for all species mentioned in the following sections are as given in Appendix 1 unless otherwise stated.

4.6 Regrowth vegetation on dry land

Plots 14-19 were situated south of Alahan Panjang village c. 3-6 km away from Danau di Atas, and encompassed a variety of regenerating vegetation types. The belt of regenerating vegetation in which the plots were sited was more than 1 km wide in places. The sites themselves ranged from a recently abandoned garden (plot 14), to quite high, shrubby regrowth (plot 19). It was hoped that these would form a representative sample of the types of regrowth communities found in the area. Details of environmental variables and floristic composition at each site are provided in Tables 4.9 and 4.10 respectively. A sketch map showing in more detail the locations of the sites is also provided (Fig. 4.5). Plates 4-8 show views of the vegetation in which some of the regrowth plots were sited.

Plot 14 was situated on apparently well drained soil which was moderately acidic at rooting depth, on a gently sloping hillside at an altitude of 1440 m. The site was that of a recently abandoned garden and the low regrowth was dominated by *Pteridium aquilinum* (37% cover). The plot also had considerable areas of bare ground. Several species of Gramineae, Cyperaceae and Compositae were present. They included *Cymbopogon* sp., *Imperata cylindrica*, *Rhynchospora rugosa* and *Eupatorium inulifolium*. All of these were present in small amounts only. In all twenty one

Fig. 4.5
Sketch map showing locations of regrowth plots

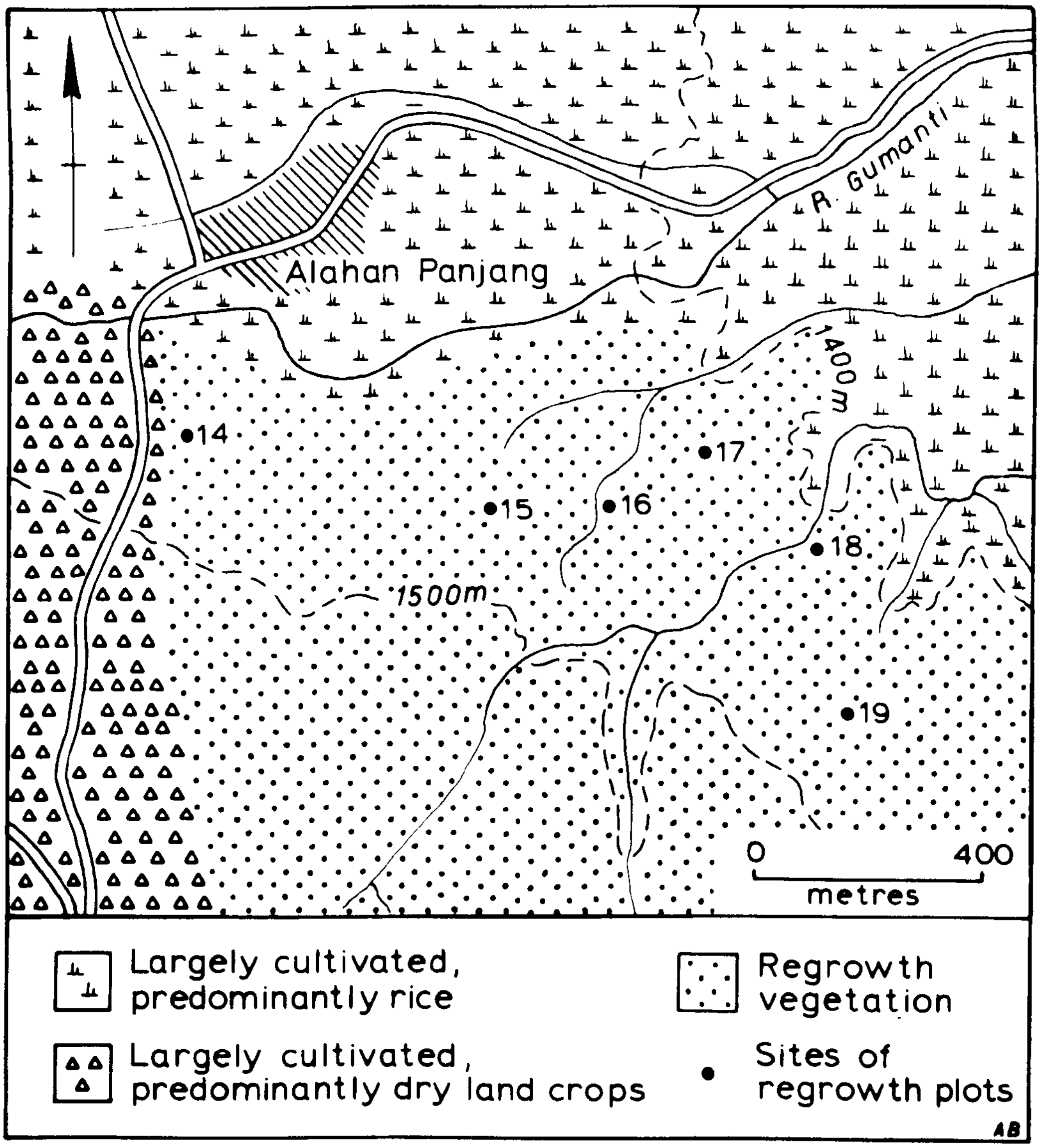

Alahan Panjang
R. Gumanti
1400m
1500m
14
15
16
17
18
19
0
400
metres
Largely cultivated, predominantly rice
Largely cultivated, predominantly dry land crops
Regrowth vegetation
Sites of regrowth plots
AB

TABLE 4.9

Environmental variables recorded in dry land regrowth plots

Plot	Altitude (m)	Soil pH (rooting depth)	Soil texture and appearance	Drainage (estimated)	Aspect	Topography and slope	Description
14	1440	5.7 (10cm)	No leaf litter or humus 0-21cm Dark brown loam, 10YR 3/2 with numerous roots 21-50+cm Yellowish brown 10YR 5/6	Good	NE	Gently sloping hillside 10°	Recently abandoned garden still with much bare ground
15	1470	5.4 (10cm)	0-25cm Black humic loam 10YR 2/1 25-40+cm Yellowish brown clay 10YR 5/6	Good	ESE	Gently sloping hillside 8°	Regrowth on the site of an abandoned garden
16	1440	6.7 (10cm)	0-38cm Brown loam 10YR 4/3 38-60+cm Wet grey clay 10YR 3/1	Poor	NW	Sloping valley bottom 15°	Regrowth on the site of an abandoned garden in a valley bottom, adjacent to a stream
17	1440	5.8 (10cm)	No leaf litter 0-18cm Dark brown loam 10YR 3/3 18+cm Stony	Good	NW	Steep valley side 33°	Shrubby regrowth on a well drained valley slope with stream
18	1430	5.5 (5cm)	No leaf litter 0-5cm Brown loam 10YR 4/3 5-38cm Dark yellowish brown clay 10YR 4/4 with coarse gravel 38-45cm ? Buried soil. Loamy 10YR 4/3 45-70+cm Yellowish brown clay 10YR 5/6, with weathered stones	Good	W	Sloping valley bottom 15°	Well grazed abandoned terrace close to a stream
19	1450	4.5 (5cm)	0-5cm leaf and twig litter with living roots in lower part 5-10cm Dark brown loam 10YR 3/3 10-40+cm Yellowish brown clay 10YR 5/8	Good	W	Gently sloping hillside 13°	Shrubby regrowth in an area which had apparently been burned over

TABLE 4.10

Floristic composition of dry land regrowth plots

Collection Number	Family	Name	Percentage cover in plot 14	15	16	17	18	19
193	Amaranthaceae	Amaranthus hybridus			<1			
232	Araliaceae	Schefflera sp.						2
136	Caryophyllaceae	Drymaria cordata			<1			
175	Commelinaceae	Murdannia nudiflora			<1	<1	<1	
141	Compositae	Ageratum conyzoides			<1		<1	
171		Bidens pilosa	<1		<1		<1	
179		Blumea lacera	<1		<1			
185		Emelia sonchifolia		<1				
172		Erigeron sumatrensis	<1		<1		1	
168		Eupatorium inulifolium	1		70	35	3	
191		Tithonia diversifolia			<1			
212	Cyperaceae	Carex cruciata				1		
143		Cyperus kyllingia					<1	
154/220		Fimbristylis dichotoma					16	
107/164		Rhynchospora rugosa	2	2				
207	Elaeagneaceae	Elaeagnus latifolia				2		
229	Ericaceae	Rhododendron sp.						1
230		Vaccinium sp.						5
201	Euphorbiaceae	Breynia microphylla			<1	<1		
210/288		Omalanthus populneus				1		
166	Gramineae	Arthraxon hispida ssp.?langsdorfii	<1				30	
150		Axonopus compressus			1		20	
184		Chrysopogon aciculatus					30	
159		Cymbopogon sp.	4					
161		Digitaria violascens	1	3	<1			
190		Eleusine indica			<1			
163		Imperata cylindrica	3	20		40		1
211		Isachne albens				2		
112		Paspalum orbiculare	1	2			1	
169		Pogonatherum saccharoideum	<1	<1				
183		Schizachyrium brevifolium		<1				
214		Setaria palmifolia				1		
160		Sporobolus berteroanus	1	<1			8	
		hirsute grass			<1			
135	Guttiferae	Hypericum japonicum		<1				
96/244	Hamamelidaceae	Rhodoleia championi						70
180	Labiatae	Basilicum polystachyon	<1					
204	Leguminosae /Caesalpinoideae	Cassia floribunda			<1			
165	Leguminosae/ Papilionatae	Crotalaria chinensis		<1				
194		Desmodium repandum			1			
233		D. triflorum					5	
215	Liliaceae	Dianella ensifolia				<1		<1
209		Disporum cantoniense				<1		
189	Lythraceae	Cuphea balsamona			1			

TABLE 4.10 Continued

Floristic composition of dry land regrowth plots

Collection Number	Family	Name	Percentage cover in plot					
			14	15	16	17	18	19
176	Malvaceae	Urena lobata			<1	<1	<1	
173	Melastomataceae	Melastoma affine				3		2
217	Moraceae	Ficus ribes				3		
233	Orchidaceae	Arundina graminifolia						<1
148/174		Spiranthes sinensis	<1					
		Sterile orchid			<1			
198	Oxalidaceae	Oxalis corniculata			<1	<1		
213	Passifloraceae	Passiflora edulis				1		
188	Plantaginaceae	Plantago major			<1			
139	Polygalaceae	Polygala paniculata	<1	<1	<1	<1	<1	
197	Rosaceae	Rubus alceaefolius			2	<1	<1	
224	Rubiaceae	Borreria laevis					1	
182		Hedyotis verticillata	<1					
228		Wendlandia glabrata						10
208	Saurauiaceae	Saurauia vulcani				10		
162	Solanaceae	Solanum nigrum			<1			
234	Symplocaceae	Symplocos cochinchinensis ssp. laurina var. laurina						2
231	Theaceae	Eurya sp.						4
129	Umbelliferae	Centella asiatica	<1			1	3	
167	Urticaceae	Gonostegia hirta	<1		1	<1	<1	
122	Violaceae	Viola pilosa	<1					
	Dennstaedtiaceae							
203	subf. Davallioideae	Humata sp.				<1		
158	subf. Pteridioideae	Pteridium aquilinum	37	20	<1	10	1	5
225	Equisetaceae	Equisetum debile					1	
124	Gleicheniaceae	Dicranopteris curranii	<1	30		3		5
125	Thelypteridaceae	Cyclosorus sp.				2		
199		Cyclosorus sp.			<1			

species were identified at this site. The genus *Cymbopogon* includes a number of useful plants including 'lemon grass' which is used for culinary purposes, and other species used in the production of oils such as 'citronella oil'. Presence of a *Cymbopogon* sp. in the plot may therefore be related to cultivation. *Eupatorium inulifolium* is an introduced species, from South America, which arrived in Java in the late 19th Century (Backer and Bakhuizen van den Brink, 1965). Its time of arrival in Sumatra may have been more recent, it is often referred to there as 'Japanese weed'.

Plot 15 (Plate 4) had fairly similar environmental conditions to those at plot 14, again it was apparently well drained, with moderately acid soil at rooting depth, on a gently sloping hillside at 1470 m a.s.l. At this site however the vegetation cover was much denser, although the site was also that of an abandoned garden. The low regrowth was relatively species poor, apparently being co-dominated by three species, *Dicranopteris curranii*, *Pteridium aquilinum* and *Imperata cylindrica*. These three species may form quite dense shade. *Imperata cylindrica* has been found elsewhere to be a very agressive dominant in the early stages of vegetation regeneration (Symington, 1933), rapidly taking over an area and forcing out less robust colonisers. It is co-dominant at this site, but a combination of dense growth of the three species involved may be reflected in the quite low number (ten) of other taxa present. These generally contributed less than 3% cover, and included *Digitaria violascens*, *Rhynchospora rugosa*, *Hypericum japonicum*, *Polygala* *paniculata*, *Crotalaria chinensis* and *Emelia sonchifolia*.

Plot 16 (Plate 5) exhibited different environmental characters from the previous two sites, being an apparently poorly drained valley bottom adjacent to a stream at 1440 m a.s.l. The soil pH at rooting depth was neutral. Once again the site was an abandoned garden. It was dominated by one species, the introduced *Eupatorium inulifolium* which provided 70% cover. Nonetheless, the site showed a considerable diversity, twenty five species were collected and identified in addition to a sterile orchid and hirsute grass which were recorded but not collected. Taxa present included *Rubus alceaefolius*, *Bidens pilosa*, *Erigeron sumatrensis*, *Urena lobata*, *Blumea lacera*, *Plantago major* and *Polygala paniculata*. These and other taxa each provided 2% cover or less.

Plot 17 (Plate 6) was located on an apparently well drained steep valley side at 1440 m, its soil was moderately acid at rooting depth. The vegetation possessed some shrubby elements although it was dominated by *Imperata cylindrica* (40% cover) and *Eupatorium inulifolium* (35%). *Pteridium aquilinum* and *Saurauia vulcani* were also quite important, each contributing 10% cover. Once again there was considerable diversity in the plot, a total of twenty five species being recorded. Taxa present in small amounts (< 3% cover) included *Dicranopteris curranii*, *Melastoma affine*, *Ficus ribes*, *Elaeagnus latifolia*, *Omalanthus populneus*, *Polygala paniculata* and *Rubus alceaefolius*. In addition *Passiflora edulis*, the passion fruit, was also recorded, this was most likely a remnant from cultivation.

Plot 18 was at 1430 m a.s.l. on an apparently well drained, sloping, valley bottom. Its soil was moderately acidic at rooting depth. The site was an abandoned garden, but regeneration of the vegetation was being held in check by grazing. Possibly as a result of this the site was dominated by a number of species of Gramineae, the most important being *Arthraxon hispida* ssp.? *langsdorfii* (30% cover), *Chrysopogon aciculatus* (30%), the introduced *Axonopus compressus* (20%) and *Sporobolus berteroanus* (8%). The sedge *Fimbristylus dichotoma* was also important, providing 16% cover. A total of twenty one species were recorded at the site, less common taxa (<5% cover) included *Desmodium triflorum, Eupatorium inulifolium, Pteridium aquilinum, Borreria laevis* and *Polygala paniculata*.

Plot 19 (Plate 7 and 8) was located in an area of high, shrubby regrowth on an apparently well drained, gently sloping hillside at 1450 m a.s.l. The soil at rooting depth was distinctly acidic (pH 4.5), being more acidic than at any of the other sites examined. No visible signs of previous cultivation remained in the area, although evidence of past burning showed as blackened trunks of some of the shrubs. The site was dominated by *Rhodoleia championi* (70% cover); other species recorded included *Wendlandia glabrata* (10%), *Vaccinium* sp. (5%), *Pteridium aquilinum* (5%) and *Dicranopteris curranii* (5%). A total of only thirteen species was recorded in the plot. This might be due to dominance of the large shrubs or alternately destruction of less fire resistant species by burning. Other taxa recorded included

Eurya sp., *Schefflera* sp., *Melastoma affine*, *Symplocos cochinchinensis* ssp. *laurina* var. *laurina*, *Rhododendron* sp. and *Imperata cylindrica*. This site appeared to be the most advanced stage of regrowth vegetation studied and it included some taxa, or members of genera, which were commonly found in the forests of the region, such as *Rhodoleia championi*, *Symplocos cochinchinensis*, and *Schefflera* sp. In addition some typical regrowth species such as *Imperata cylindrica* and *Pteridium aquilinum* were also present.

The regenerating vegetation types examined ranged from low regrowth to shrub dominated scrub. Much of the extensive areas of low regrowth present, appeared, from this study, to be dominated or co-dominated by one or more of three species. These were *Imperata cylindrica*, *Pteridium aquilinum* and *Eupatorium inulifolium*. However, this dominance was not apparent where more specific controls were applied to the vegetation as at plot 18. This was quite different in character from the other regrowth sites, being dominated not by any of the three species above, but by a mixture of quite different Gramineae, and Cyperaceae. Grazing appeared to be the controlling factor at this site, as this was observed in the area. Where regrowth had developed to form a much higher, shrubby vegetation, as at plot 19, again none of these species appeared to dominate, possibly due to shading. *Imperata cylindrica* appears not to be able to tolerate shade (Henderson, 1954). This plot had evidently been burned and the large shrubs appeared to have been able to tolerate this, although probably seedlings and many ephemeral species would not tolerate burning. Some species, such as I. cylindrica have extensive rhizomes which resist fire and they are thus able to regenerate after fire damage. This particular species was also present in plot 19, although it was not dominant.

The actual composition of high regrowth in the area is probably quite variable, and time did not permit a detailed study of this vegetation type. A variety of genera may occur in this vegetation and some of these may also be found in forest vegetation. Rhodoleia championi and Wendlandia glabrata may be locally important in the high regrowth as is suggested by their abundance at plot 19. R. championi was also found as a canopy tree in montane forests of the area, while Morley (1976) recorded W. glabrata growing as an understory tree in forests in the Kerinci area. He also recorded Ficus ribes in a similar situation. Genera such as Symplocos, Rhododendron and Saurauia are also commonly associated with forest vegetation in central Sumatra. The type of vegetation recorded at plot 19, and to a lesser extent at plot 17 appears therefore to be a possible precurser of a return to forest vegetation.

Symington (1933) studied the progression of regrowth on abandoned gardens in lowland Malaysia and concluded that the first colonisers, ephemeral, herbaceous weeds and grasses were replaced after about a year by Imperata cylindrica with woody species. The I. cylindrica would then dominate except where shaded by woody species, until the woody species themselves became dominant. Where woody species did not establish themselves before the I. cylindrica became dominant then the grassy regrowth could persist for a number of years.

Such results are not directly applicable here as this was a montane site and several of the numerically important species such as *Dicranopteris curranii* and *Pteridium aquilinum* were not found in the Malaysian succession. However, a general pattern of presumed regrowth succession can be constructed which is broadly similar to that found by Symington (1933).

Colonisation of abandoned, cleared land may be by a variable mixture of taxa, depending on factors such as seed source, and the nature of the vegetation already growing in the area; some taxa may already be well established, as weeds, at the time of abandonment. Colonisers may include ephemeral weeds, seedlings of trees and shrubs and other taxa such as those spread by rhizomes. As time passes it seems likely that the ephemeral species are replaced by perennial species such as young shrubs and also taxa such as *Imperata cylindrica*, and *Pteridium aquilinum*. The latter two species, while they may become dominant in the vegetation, are susceptible to shading, so if seedlings of shrubs or trees are present in an area, and without constraining factors such as burning, it seems likely that as these develop then shade intolerant taxa will decline in importance. At plot 19, in which shrubs were well developed, *Imperata cylindrica*, and *Pteridium aquilinum* were present but in much reduced amounts compared with in the unshaded plots such as plot 15.

A number of other taxa which were often found in regrowth sites but were nowhere dominant included *Polygala paniculata*, Gonostegia hirta, Centella asiatica, Rubus alceaefolius, Urena lobata, Murdannia nudiflora, Bidens pilosa, Erigeron sumatrensis, Sporobolus berteroanus and Paspalum orbiculare. Each of these occurred in at least three of the regrowth plots examined.

4.7 Swamp vegetation

Plots 5 and 13 were sited on two swamps adjacent to Danau di Atas, plots 5 to 12 were on the Danau di Atas Swamp from which cores had previously been taken for the palaeoecological study. Plot 13 was sited on a swamp in the lake outlet bay.

Details of the environmental variables recorded at each site, and floristic composition are given in Tables 4.11 and 4.12 respectively. A sketch map showing the locations of plots 5 to 12 on the Danau di Atas Swamp is also provided (Fig 4.6). Plates 9 and 10 provide a general view of the vegetation on the Danau di Atas Swamp.

All of the nine sites were at 1535 m a.s.l. on unshaded, badly drained areas of negligible slope, with moderately acidic soil conditions at rooting depth. Vegetation at all sites was almost entirely herbaceous in nature, as no swamp forest remained in the area, although the stratigraphy (Chapter 6, Table 6.1) showed it had formerly existed.

Plot 5 was dominated by two species of Gramineae, Panicum repens and Leersia hexandra which comprised 48% and 29% cover at the site respectively. Despite the overall dominance of Gramineae (>80% cover) at the site, many other taxa were recorded in the

Fig. 4.6
Sketch map showing locations of swamp plots 5-12 on the Danau di Atas Swamp

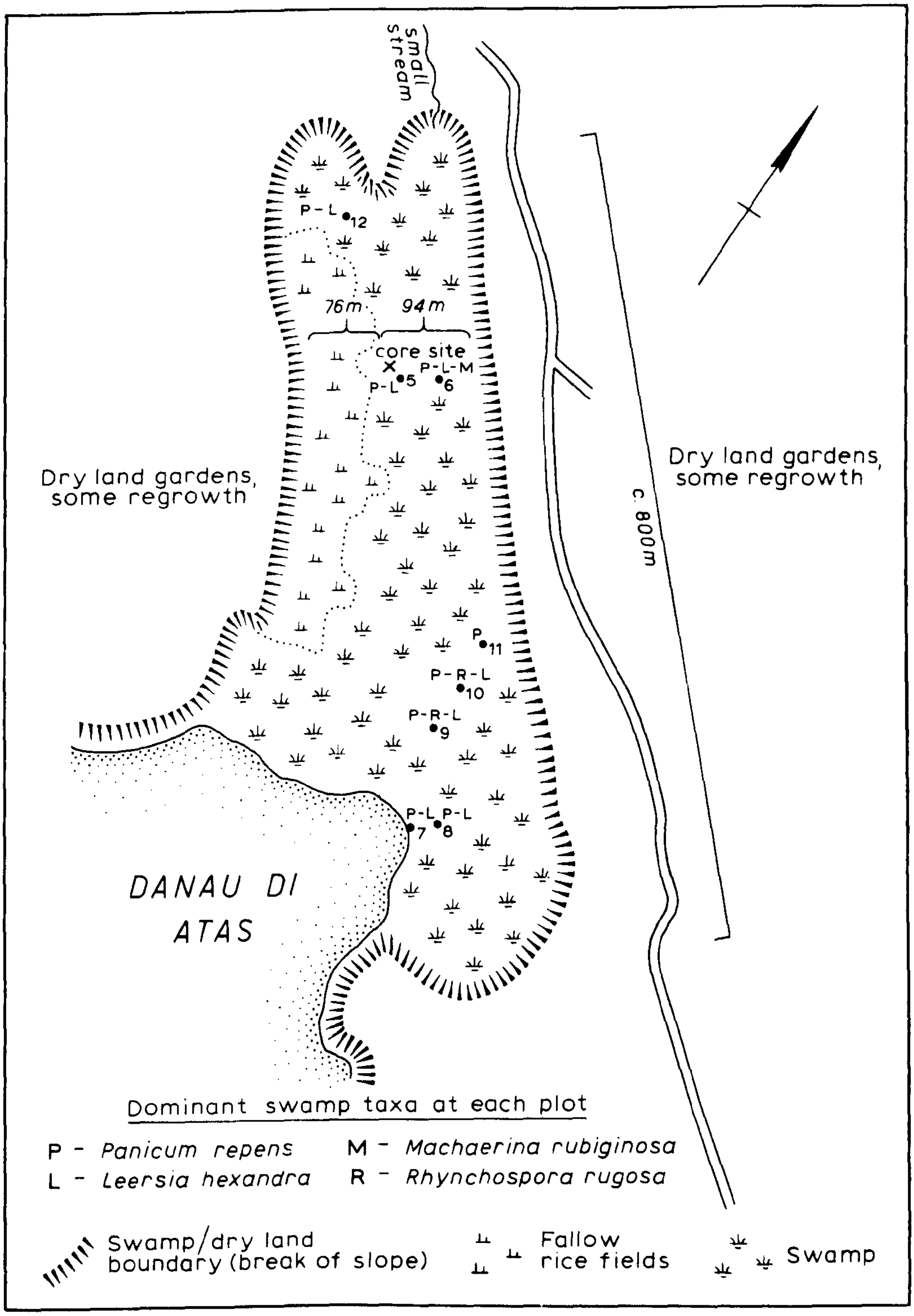

small stream
P-L 12
76m
94m
core site
P-L-M 6
P-L 5
Dry land gardens, some regrowth
Dry land gardens, some regrowth
c. 800m
P 11
P-R-L 10
P-R-L 9
P-L 7
P-L 8
DANAU DI ATAS
Dominant swamp taxa at each plot
P - Panicum repens
L - Leersia hexandra
M - Machaerina rubiginosa
R - Rhynchospora rugosa
Swamp/dry land boundary (break of slope)
Fallow rice fields
Swamp

TABLE 4.11

Environmental variables recorded in swamp plots.

Plot	Altitude (m)	Soil pH (rooting depth)	Soil texture and appearance	Drainage (estimated)	Aspect	Topography	Description
5	1535	5.6 (5cm)	Soft detritus mud with roots	Very poor	-	Swamp surface	Unshaded swamp
6	1535	5.6 (5cm)	Floating vegetation mat	Very poor	-	Swamp surface	Unshaded, floating swamp vegetation
7	1535	5.5 (5cm)	0-40cm Dry herbaceous peat 40cm Water table 40-70cm Wet herbaceous peat 70-130cm Lake mud No wood remains in profile	Very poor	-	Swamp surface	Unshaded swamp, adjacent to the lake, Danau di Atas
8	1535	5.5 (5cm)	0-60cm Peat/lake mud with roots 60-130cm Peat/lake mud with wood fragments	Very poor	-	Swamp surface	Unshaded swamp surface with tussocky vegetation
9	1535	5.7 (5cm)	0-55cm Peat with living roots 55-95cm Soft peat with roots and woody fragments 95-100cm Harder, drier peat penetrated by vertical roots	Very poor	-	Swamp surface	Apparently grazed, unshaded swamp
10	1535	5.7 (5cm)	0-60cm Very soft peat with living roots 60+cm Soft detritus	Very poor	-	Swamp surface	Unshaded, tussocky swamp
11	1535	5.5 (5cm)	Fine, very soft, detritus mud	Very poor	-	Swamp surface	Unshaded, floating swamp vegetation
12	1535	5.9 (5cm)	Herbaceous peat, no wood	Very poor	-	Swamp surface	Unshaded, previously burned swamp vegetation
13	1535	5.5 (5cm)	Soft, monocotyledonous peat	Very poor	-	Swamp surface	Unshaded swamp in the lake outlet bay

TABLE 4.12

Floristic composition of swamp plots

Collection Number	Family	Name	Percentage cover in plot 5	6	7	8	9	10	11	12	13
108	Burmanniaceae	Burmannia disticha	<1			<1	2	2			<1
140	Compositae	Spilanthes iabadicensis	<1				<1	<1			
144	Cyperaceae	Carex cf. dimorpholepis			10						
116/117		Cyperus cf. flavidus				<1				<1	
143		C. kyllingia		<1							
145		Eleocharis retroflexa			15						
146		E. tetraquetra			6						
154/220		Fimbristylis dichotoma							<1		
114		Fuirena sp.		1	<1						
115		Lipocarpha chinensis	<1	1		<1	2	<1			
113		Machaerina rubiginosa	1	25					5		2
107/164		Rhynchospora rugosa	4	10	2	10	15	30	5	3	10
105		Scirpus mucronatus	2				<1	1			1
103	Eriocaulaceae	Eriocaulon brownianum	<1	1					2		
134		E. heterolepis var. nigricans					<1		<1		<1
150	Gramineae	Axonopus compressus					<1				<1
142/297		Coelachne infirma							<1		
111		Hymenachne sp.	1		1	3	2	<1	1		
128		Isachne globosa	5	1	2	2	1	1		1	
110/251		Leersia hexandra	29	25	35	15	10	20		15	
106/252		Panicum repens	48	25	30	60	60	60	80	70	30
112		Paspalum orbiculare			5	2		<1			
135	Guttiferae	Hypericum japonicum					<1	<1	<1		
138	Haloragaceae	Laurembergia coccinea				<1	1				
120	Juncaceae	Juncus prismatocarpus var. leschenaultii			1						
109	Lentibulariaceae	Utricularia bifida	<1	<1		<1	1	1	<1		<1
173	Melastomataceae	Melastoma affine								<1	<1
148/174	Orchidaceae	Spiranthes sinensis					<1				
188	Plantaginaceae	Plantago major	<1								
130	Rubiaceae	Galium innocuum						<1			
123		? Oldenlandia agrostemmoides	<1				1	<1			
129	Umbelliferae	Centella asiatica	<1			4	1		1	<1	
121		Hydrocotyle sibthorpioides	<1			1	1	<1		<1	
122	Violaceae	Viola pilosa	<1			<1	<1	<1			
104	Xyridaceae	Xyris capensis var. schoenoides	4	2		2	3	2	1	<1	2
126	Dennstaedtiaceae Subf. Oleandroideae	Nephrolepis cordifolia	<1								1
124	Gleicheniaceae	Dicranopteris curranii	<1								
133	Lycopodiaceae	Lycopodium cernuum					<1				
127	Shizaeaceae	Lygodium microphyllum	<1					<1			
125	Thelypteridaceae	Cyclosorus sp.	<1					<1			
		Sphagnum spp.									30

plot, mostly occurring in small amounts. They included Xyris capensis var. schoenoides, Eriocaulon brownianum, Burmannia disticha, Utricularia bifida, Viola pilosa and Plantago major. Cyperaceae were represented by several species including Rhynchospora rugosa and Scirpus mucronatus.

Plot 6 was located on a floating vegetation mat, and was dominated by a mixture of Panicum repens (25%), Leersia hexandra (25%), and Machaerina rubiginosa (25%). Rhynchospora rugosa was also important with 10% cover. Gramineae were less important overall, and sedges more important in this plot than in plot 5, perhaps a reflection of the highly waterlogged soil conditions at this site. The total number of species, eleven, recorded at this site was also lower. This might also have been related to the slightly different environmental conditions at the site. Other taxa recorded included Xyris capensis var. schoenoides, Eriocaulon brownianum and Utricularia bifida.

Plot 7 was composed entirely of monocotyledonous plants of the three families Cyperaceae, Gramineae and Juncaceae. Panicum repens (30%) and Leersia hexandra (35%) dominated in the plot. Others of the eleven species recorded included Eleocharis retroflexa, E. tetraquetra and Juncus prismatocarpus var. leschenaultii.

Somewhat more diversity was seen at plot 8 although again Panicum repens was dominant (60% cover) with Leersia hexandra (15%) and Rhynchospora rugosa (10%). Fifteen species were recorded in the plot and also included Centella asiatica, Hydrocotyle *sibthorpioides*, *Xyris capensis* var. *schoenoides*, *Burmannia disticha* and *Laurembergia coccinea*.

Plot 9 was situated in what appeared to be a grazed area of the swamp, as the grasses particularly appeared to have been eaten. It was dominated by *Panicum repens* (60% cover) with *Rhynchospora rugosa* (15%) and *Leersia hexandra* (10%). It was quite diverse, and a total of twenty one species were recorded. These included *Burmannia disticha*, *Utricularia bifida*, *Hydrocotyle sibthorpioides*, *Laurembergia coccinea* and *Lycopodium cernuum*.

At plot 10 a total of nineteen species were recorded in an area of tussocky swamp vegetation. *Panicum repens* (60%) dominated, with *Rhynchospora rugosa* (30%) and *Leersia hexandra* (20%). Other taxa present included *Burmannia disticha*, *Utricularia bifida*, *Hydrocotyle sibthorpiodes*, *Cyclosorus* sp. and *Lygodium microphyllum*.

Plot 11 was relatively species poor, a total of only twelve being recorded. It was sited on a floating vegetation mat, thought possibly to overly a channel which runs along the eastern edge of the swamp. The plot was dominated by *Panicum repens* (80%) with *Rhynchospora rugosa* (5%) and *Machaerina rubiginosa* (5%). Other taxa present included *Eriocaulon brownianum*, *Centella asiatica*, *Utricularia bifida*, *Fimbristylis dichotoma* and *Hypericum japonicum*.

At plot 12 the swamp was very species poor, and showed signs of having been recently burned. It was dominated by *Panicum repens*

(70%) with Leersia hexandra (15%). Other taxa of the total of nine recorded included Rhynchospora rugosa, Xyris capensis var. schoenoides and Melastoma affine.

Plot 13 was situated on a swamp in the lake outlet bay, and exhibited some differences from the plots on the Danau di Atas Swamp. Notable was the abundance of Sphagnum spp., which were not discerned in any of the other plots, but here provided 30% cover. Panicum repens (30%) was still common, as was Rhynchospora rugosa (10%). Leersia hexandra, widespread throughout the Danau di Atas Swamp was absent. The plot was not very diverse, and the eleven species recorded (excluding Sphagnum spp.) also included Machaerina rubiginosa, Melastoma affine, Utricularia bifida and Nephrolepis cordifolia.

The two swamps studied both had a largely herbaceous vegetation cover. The whole of the Danau di Atas Swamp appeared to be relatively homogenous in nature, and was dominated largely by Gramineae although in places Cyperaceae co-dominated. On the swamp in the outlet bay, the area studied was also dominated by these families, but Sphagnum spp. were also important.

The dominant species of grass over most of the Danau di Atas swamp was Panicum repens, which had percentage cover values of 25-80% in the plots examined, Leersia hexandra was frequently a co-dominant or of secondary importance. Cyperaceae were widespread, and of these one species, Rhynchospora rugosa, was particularly common. Machaerina rubiginosa was also important in some, apparently wetter, parts of the swamp.

A considerable number of other species were widespread over the swamp, although they never contributed a large percentage cover. These included *Xyris capensis* var. *schoenoides*, *Utricularia bifida*, *Hymenachne* sp., *Lipocarpha chinense*, *Hydrocotyle sibthorpioides* and *Isachne globosa*.

A number of other species also occurred on the swamp; distribution and cover of these varied. Some are particularly noteworthy as they have distinctive pollen or spores, for example, *Eriocaulon* spp., *Burmannia disticha*, *Lycopodium cernuum*, *Laurembergia coccinea* and *Cyclosorus* sp. (125).

Despite the relatively homogenous nature of the vegetation on the two swamps, minor variations were distinguishable, and some of these appeared to relate to factors such as relative wetness, grazing pressure and burning. For example, *Machaerina rubiginosa* seemed to be more common on the wetter areas of the swamp, particularly where the substrate was a floating vegetation mat (plots 6 and 11), than elsewhere. Such wet areas all had relatively few species growing on them. A burned area was also low in total number of species whereas a grazed area was still floristically fairly diverse.

It seems very likely, in view of the presence of wood in the stratigraphy of the site (Chapter 6) and the presence of tree roots and stumps observed in eroded deposits at the lake edge near the site of plot 7, that the Danau di Atas Swamp originally bore some sort of swamp forest. Man has undoubtedly played an important part in shaping the present swamp surface, and apart from timber removal, conversion of limited areas of the swamp for rice cultivation has also occurred. The bunds of these seasonally abandoned ricefields can be seen along the western edge of this swamp. Other evidence of a former swamp forest or woody vegetation cover over at least some parts of the swamp, is the presence of rare, cut tree stumps on the swamp surface. Moreover one of these had sprouted leaves which were collected and identified. It proved to be a species of *Glochidion*, a genus which includes some swamp forest species, although some species also occur in dry land forests (eg. plot 24). The lack of swamp forest in this area, and the relatively homogenous nature of the swamp vegetation is in contrast with results of studies carried out around Danau Padang, south of G. Kerinci, detailed by Morley (1976). He recorded six distinct types of swamp vegetation around Danau Padang of which three were swamp forest communities, the remaining three being largely herbaceous in nature. Morley termed these communites *Ilex cymosa* swamp forest, *Myrsine* swamp forest, *Euodia* (= *Evodia*) swamp forest, *Machaerina* swamp, *Pteridium aquilinum* swamp, and abandoned ricefield vegetation. He recorded a species of *Glochidion*, *G. brunneum* HK.f. in both the *Myrsine* swamp forest and in *Euodia* swamp forest. It seems quite possible that the few tree stumps remaining on the Danau di Atas Swamp are all that remains of some type of swamp forest vegetation, comparable to that existing in 1972 at Danau Padang.

4.8 Ricefield and garden colonisers

Plots 21-23 and 25-27 were studied in order that taxa which were common weeds of cultivation could be elucidated. These are often the primary colonisers of abandoned land, and may already be established before the abandonment takes place. One common feature of all plots was that they had recently been under cultivation and were now fallow, or were being cultivated at the time of the study. Due to the excessive disturbance by man, some of the environmental variables were not recorded at all sites, for example soil profile in ricefield plots. In the latter example it was thought that the soil under such cultivation would be totally disturbed. Nor were surface samples collected for pollen analysis.

All plots were located fairly close to the village of Alahan Panjang, and lake, Danau di Atas. Plots 21, 22 and 23 were in wet ricefields north-west of the broad band of regenerating vegetation in which regrowth plots 14-19 were sited. Plots 25 and 26 were sited on terraced fields adjacent to Danau di Atas, in the lake outlet bay. Plot 25 was a fallow ricefield and plot 26 a fallow dry land garden. Plot 27 was situated between Danau di Atas and Alahan Panjang, and was a dry land garden.

Environmental variables recorded at the sites are given in Table 4.13 and floristic composition is shown in Table 4.14. Plot dimensions for ricefields were variable; these are included in Table 4.13.

Plot 21, a ricefield of dimensions 6 m x 9 m, had a lot of bare mud, and was under several cm of water. <u>Oryza</u> <u>sativa</u> (rice) contributed 15% cover, although nine other species were also

TABLE 4.13

Environmental variables recorded in ricefield and garden plots.

Plot	Altitude (m)	Plot dimensions (m)	Soil pH (rooting depth)	Soil texture and appearance	Drainage (estimated)	Description
21	-	6 x 9	7.0	-	Water at surface several cm deep	Ricefield
22	-	3 x 11	7.0	-	Water at soil surface	Ricefield
23	-	5 x 33	7.0	-	Water at soil surface	Ricefield
25	1535	10 x 17	5.7	-	Poor	Fallow ricefield just above the level of Danau di Atas
26	1535	4 x 4	5.5 (5cm)	0-30cm Loam 10YR 4/3 with stones to surface 30+cm Stony	Good	Unshaded, fallow, dry land garden near the lake outlet
27	1480	4 x 4	5.3 (5cm)	0-30cm Dark brown loam 10YR 3/2 30-60cm Transition to 60-100+cm Dark grey clay 10YR 4/2, blackened at base	Medium	Sweet potato garden

TABLE 4.14

Floristic composition of ricefield and garden plots

Collection Number	Family	Name	Percentage cover in plot 21	22	23	25	26	27
136	Caryophyllaceae	Drymaria cordata			<1		35	<1
175	Commelinaceae	Murdannia nudiflora		<1	<1		20	
141	Compositae	Ageratum conyzoides			<1		<1	3
171		Bidens pilosa		<1	<1		1	2
179		Blumea lacera					<1	<1
140		Spilanthes iabadicensis		<1				
300	Cyperaceae	Cyperus brevifolius					2	<1
178		C. cyperoides						<1
116/117		C. cf. flavidus	1		<1	4		
143		C. kyllingia	<1		<1			
157		Fimbristylis aphylla				<1		
253		F. polytrichoides		<1	<1	<1		
114		Fuirena sp.				1		
115		Lipocarpha chinensis			<1	2		
119		Scirpus juncoides	2	3	5	4		
103	Eriocaulaceae	Eriocaulon brownianum			<1			
134		E. heterolepis var. nigricans		5	<1	1		
150	Gramineae	Axonopus compressus					1	
250		Brachiaria sp.	2					
161		Digitaria violascens						10
190		Eleusine indica					2	
254		Eragrostis unioloides			<1			2
111		Hymenachne sp.			<1			
128		Isachne globosa	10	10	15	15		
110/251		Leersia hexandra		27	3	5		
118		Oryza sativa	15	20	20	10		
106/252		Panicum repens		<1	2	<1		3
112		Paspalum orbiculare			<1			
169		Pogonatherum saccharoideum			<1			
160		Sporobolus berteroanus					2	
135	Guttiferae	Hypericum japonicum		<1	<1	<1		
120	Juncaceae	Juncus prismatocarpus var. leschenaultii	1	1	1	4		
223	Leguminosae/ Papilionatae	Desmodium triflorum					1	
109	Lentibulariaceae	Utricularia bifida				<1		
198	Oxalidaceae	Oxalis corniculata		<1				
		O. corymbosa					1	
139	Polygalaceae	Polygala paniculata		<1				<1
249	Potamogetonaceae	Potamogeton oblongus	10		<1			
170/301	Rubiaceae	Borreria alata						2
129	Umbelliferae	Centella asiatica	1	<1	<1	<1		
121		Hydrocotyle sibthorpioides	<1	<1		1		
167	Urticaceae	Gonostegia hirta					<1	
104	Xyridaceae	Xyris capensis var. schoenoides		<1		<1		
298	Azollaceae	Azolla pinata				<1		
		Potato (Solanum tuberosum)					<1	
		Sweet potato (Ipomoea batatas)						60
		Cabbage (Brassica sp.)						<1

recorded. These included *Potamogeton oblongus* (10%), *Isachne globosa* (10%), *Centella asiatica* and *Hydrocotyle sibthorpioides*. Cyperaceae were represented by three species, *Scirpus juncoides*, *Cyperus* cf. *flavidus* and *C. kyllingia*, *Juncus prismatocarpus* var. *leschenaultii* was also present.

Plot 22 was also a ricefield, 3 m x 11 m, in which standing water was present. *Oryza sativa* provided 20% cover, and a further sixteen species were recorded including *Leersia hexandra*, *Isachne globosa*, *Murdannia nudiflora*, *Hydrocotyle sibthorpioides*, *Oxalis corniculata* and *Panicum repens*. Many of these taxa were present in swamp vegetation while *Polygala paniculata* which was also recorded in the plot, was often found in regrowth on dry land.

Plot 23, a ricefield with water at the surface measured 5 m x 35m. *Oryza sativa* (20% cover) was one of the twenty three species recorded in the plot. Others included *Isachne globosa* (15%), *Leersia hexandra* (3%), *Scirpus juncoides* (5%), *Ageratum conyzoides*, *Potamogeton oblongus*, *Bidens pilosa*, *Hymenachne* sp. and *Murdannia nudiflora*. Most species occurred as very small percentages of cover, and many were common also to swamp plots although some were also recorded in dry land regrowth sites.

Plot 25 was a fallow ricefield with no surface water which measured 10 m x 17 m. *Oryza sativa* made up 10% of the cover and a further seventeen species were recorded. These included *Isachne globosa* (15%), *Leersia hexandra* (5%), *Hydrocotyle sibthorpioides*, *Xyris capensis* var. *schoenoides*, *Utricularia bifida* and *Azolla pinnata*.

Plot 26 was a fallow dry land garden on which a crop of potatoes, (Solanum tuberosum) had previously been grown. Potato plants provided less than 1% cover in the plot which was now dominated by Drymaria cordata (35%) and Murdannia nudiflora (20%). Other species present included Cyperus brevifolius, Sporobolus beteroanus, Oxalis corymbosa, Bidens pilosa and Desmodium triflorum. A total of twelve species were recorded in the plot, excluding potato.

Plot 27 was a sweet potato (Ipomoea batatas) garden, and these provided 60% cover at the site. Cabbages (Brassica sp.) accounted for less than 1% cover. Eleven other species were recorded, including Digitaria violascens (10%), Panicum repens, Ageratum conyzoides, Bidens pilosa, Drymaria cordata and Polygala paniculata.

Many of the taxa found in ricefields and dry land gardens were commonly found in other non-forest vegetation types in the area. As might be expected, many of the ricefield weeds were commonly found as components of herbaceous swamp vegetation. They included Isacne globosa, Leersia hexandra, Eriocaulon brownianum and E. heterolepis var. nigricans, Xyris capensis var. schoenoides, and Utricularia bifida. Some species found at dry land sites were also occasionally found in ricefields and included Polygala paniculata, Bidens pilosa, Ageratum conyzoides and Murdannia nudiflora. However, these may have been growing in the less waterlogged parts of the fields, such as in association with the bunds. Some species found in swamp and dry land non-forest vegetation, such as *Hypericum japonicum* and *Centella asiatica* were also found in ricefields.

Similar patterns emerged with the dry land garden weeds. Many of these taxa were prevalent in the dry land regenerating vegetation. These included *Murdannia nudiflora*, *Ageratum conyzoides*, *Bidens pilosa*, *Blumea lacera* and *Digitaria violascens*. Very rarely, taxa usually common at swamp sites, such as *Panicum repens*, were found in dry land garden sites. *Axonopus compressus* was found in a dry land garden, swamp and a regrowth site, although it was not common at any of them. This species is one of a number of introduced species now found widely distributed in non-forest vegetation of the area, being of South American origin.

The ricefield and garden weed species found at these sites could be considered as the primary colonisers of highly disturbed land, although particular taxa may be restricted or found preferentially at either 'wet' or 'dry' sites. The taxa recorded do seem to support the tentative conclusions made in Section 4.6 as to the nature of first colonisers of agricultural land. Many species recorded as weeds are spread by seed rather than by rhizomes, and few seedlings of shrubs and no tree seedlings were recorded. The latter may relate to distance from seed source.

Few taxa were recorded only in field and garden plots, and many of these, although not present in the swamp or dry land regrowth plots examined, were originally collected in one or other of these vegetation types. The small number of species found only in fields and gardens in this study included Cyperus brevifolius, Fimbristylis polytrichoides, Brachiaria sp., Eragrostis unioloides, Oxalis corymbosa, Potamogeton oblongus and Azolla pinata. A more extensive study might, however, have revealed that these were not restricted to such sites. Moreover, none of these taxa have distinctive pollen which would enable them to be used as indicators of cultivation, rather than indicators of non-forest conditions. Clearly the only indicators of cultivation which can be stated with certainty are the crop plants themselves. Unfortunately, many crop plants also do not have distinctive pollen.

4.9 Other species collected in the non-forest vegetation of the Danau di Atas area

The approach used for the study of floristic composition in the non-forested areas was first to collect specimens from an area for identification purposes, and to compile a field herbarium to facilitate studies of species in plots, as described in Section 3.2b. Not all of the species collected were later recorded in the plots themselves. In addition, as almost certainly not all of the species growing in the area would be recorded in the plots, any new species observed which had not previously been recorded were also collected and identified. Details of the type of environment in which they were growing were also recorded, and the new species were added to the field herbarium. Identifications and collection locations for each of these species which were not subsequently recorded in any of the non-forest plots examined, are provided in Table 4.15. The extra

TABLE 4.15

Taxa collected in non-forest vegetation in the Danau di Atas region, not recorded in plots.

Collection Number	Family	Name	Location
131	Orchidaceae	Coelogyne sp.	Danau di Atas Swamp
132	Thelypteridaceae	? Chaistella arida	" "
149	Balsaminaceae	Impatiens javensis	" "
151	Dennstaedtiaceae subf. Lindsayoideae	Schizoloma ensifolium	" "
155	Euphorbiaceae	Glochidion sp.	Tree stump on Danau di Atas Swamp
156	Compositae	Enydra fluctuans	Danau di Atas Swamp
137	Scrophulariaceae	Lindernia anagallis	Abandoned ricefields and bunds, Danau di Atas Swamp
152	Myrtaceae	Eugenia sp.	Adjacent to Danau di Atas Swamp
153	Rubiaceae	Tarenna fragrans	" "
147	Cyperaceae	Eleocharis dulcis	Edge of lake, Danau di Atas Swamp
294	Moraceae	Ficus deltoidea var. lutescens	Edge of lake, outlet bay
295	Pandanaceae	Pandanus sp.	" "
296	Potamogetonaceae	Potamogeton malaianus	In lake, Danau di Atas
299	Cyperaceae	Cyperus javanicus	Fallow ricefield adjacent to plot 25
177	Ophioglossaceae	Botrychium ?ternatum	Low regrowth near plot 14
181	Verbenaceae	Lantana camara	" "
205	Polygonaceae	Polygonum cespitosum	" "
206	Orchidaceae	Phaius tankervilliae	" "
186	Leguminosae/ Papilionatae	Crotalaria sp.	Low regrowth near plot 15
187	Gramineae	Themeda villosa	" "
192/227	Gramineae	Oplismenus compositus	Low regrowth by stream, near plot 16
195	Acanthaceae	Gendarussa vulgaris	" "
196	Compositae	Anaphalis longifolia	" "
200	Solanaceae	Solanum melongena	" "
202	Orchidaceae	Microstylis sp.	" "
216	Orchidaceae	Microstylis sp.	Regrowth near plot 17
218	Polypodiaceae	Microsorium nigrescens	" "
219	Araceae	Homalomena cordata	" "
222	Gramineae	Setaria geniculata	Low regrowth near plot 18
226	Polypodiaceae	Pyrrosia ?winkleri	" "
235	Lycopodiaceae	Lycopodium ?casuarinoides	Regrowth near plot 19
236	Lycopodiaceae	L. clavatum	Low regrowth
237	Verbenaceae	Vitex trifolia var. ?heterophylla	High regrowth
238	Myrtaceae	Rhodomyrtus tomentosa	" "
239	Saxifragaceae	Hydrangea sp.	" "
240	Euphorbiaceae	Aleurites moluccana	" "

information provided by these collections may be of use in interpreting the ecological preferences of these taxa, and especially in the interpretation of pollen diagrams.

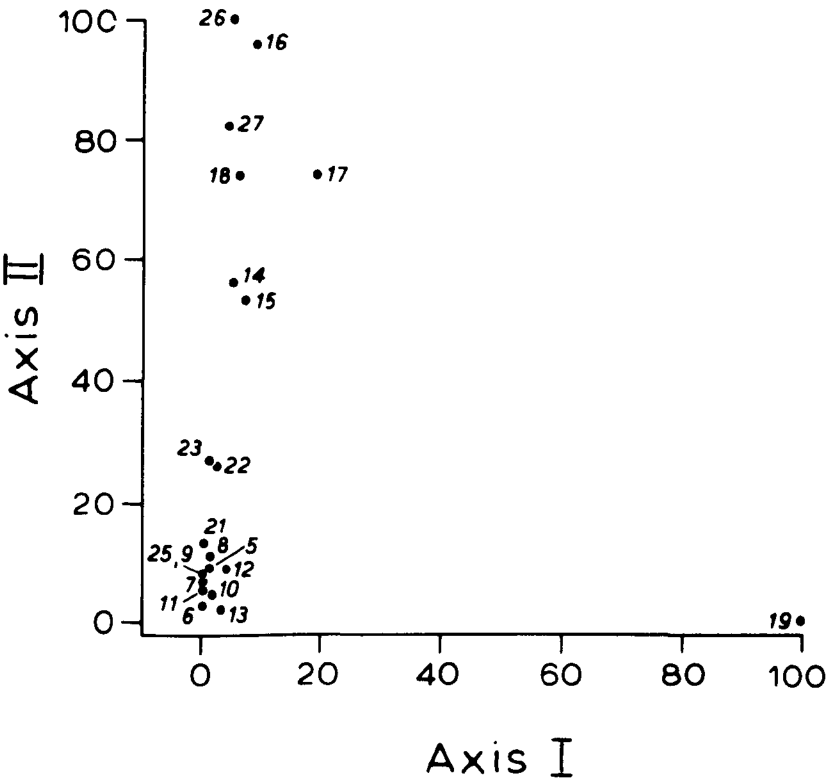
4.10 Reciprocal averaging analysis of non-forest vegetation data

The entire non-forest data set, i.e. from swamp, regrowth, ricefield and garden plots, was used with reciprocal averaging analysis to examine floristic gradients in the data. Quantitative, standardized data was the choice for the analyses.

Using the entire data set, the analysis proved to be dominated by plot 19. This took an extreme position an axis I, with a score of 100, and caused clumping together of all other sites on the axis, with scores of less than 20. Site ordination on the first two axes are shown in Fig. 4.7. Plot 19 appears to be demonstrating the effect of an outlier sample on the rest of the data i.e. this is a deviant sample of unusual composition compared with other samples. In fact plot 19 was rather different from other samples, being strongly dominated by one species which did not occur in any other plot. The effect of plot 19 on the data was so severe that the analysis was repeated, excluding this plot. The results obtained by this subsequent analysis were interpretable, and the site scores on axes I-III and species scores on axes I and II are shown in Figs 4.8 and 4.9 respectively.

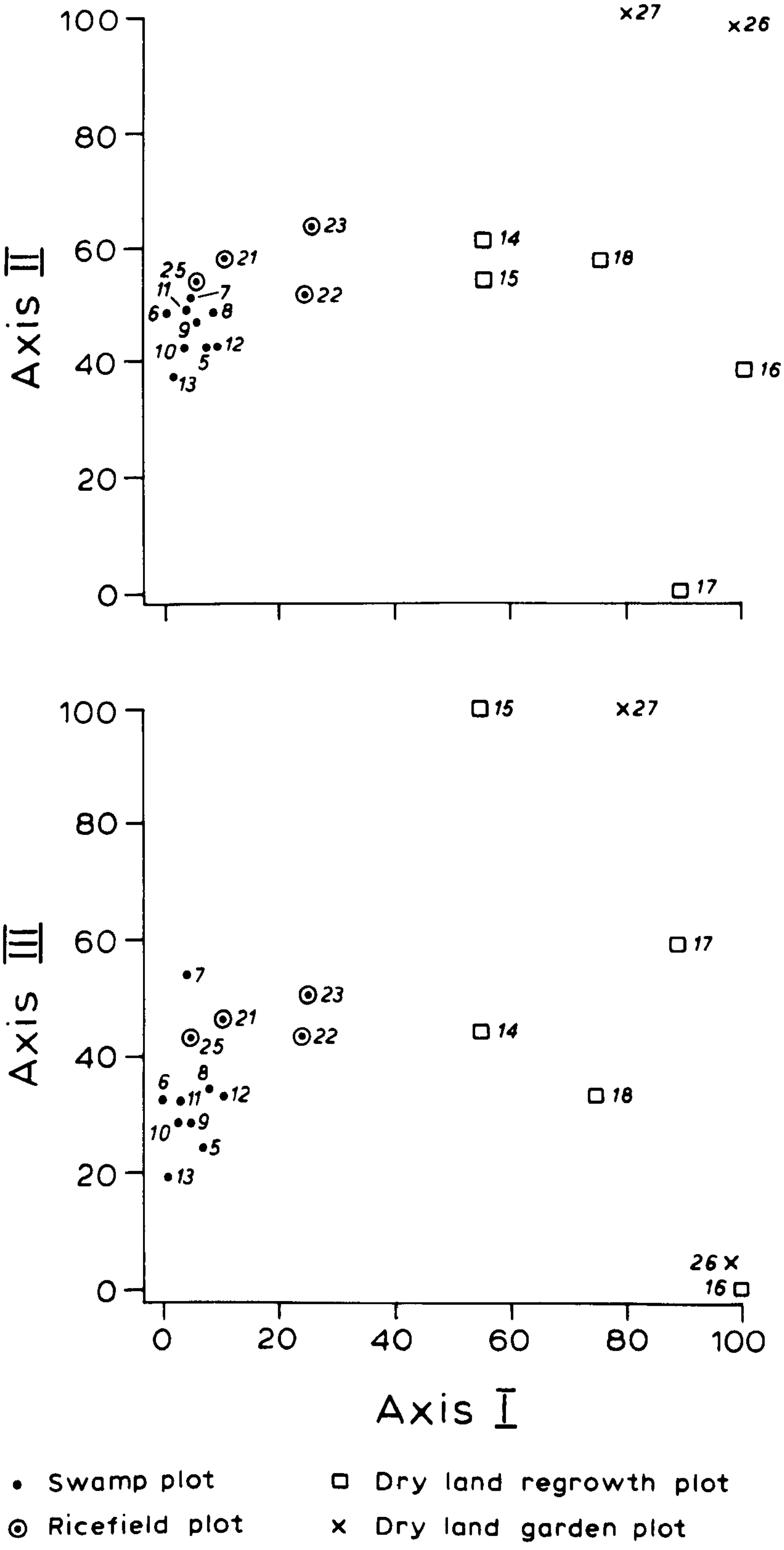
Axis I clearly separated the sites into two groups, the dry land plots, as defined by site descriptions, all scored 55 or more

Fig. 4.7
Non-forest plots, results of reciprocal averaging analysis: site ordination on axes I and II, including plot 19



Axis II
100
80
60
40
20
0
Axis I
0
20
40
60
80
100
26
16
27
18
17
14
15
23
22
21
25,9
8
5
12
7
10
11
6
13
19

Fig. 4.8
Non-forest plots, results of reciprocal averaging analysis: site ordination on axes I-III, excluding plot 19



Axis II
Axis III
Axis I
0
20
40
60
80
100
×27
×26
23
21
25
22
14
15
18
16
17
5
6
7
8
9
10
11
12
13
• Swamp plot
⊙ Ricefield plot
□ Dry land regrowth plot
× Dry land garden plot

while 'wet' sites (swamp and ricefield) scored 25 or less.

Axis II was not so easily interpretable although dry land plots were clearly separated from the others.

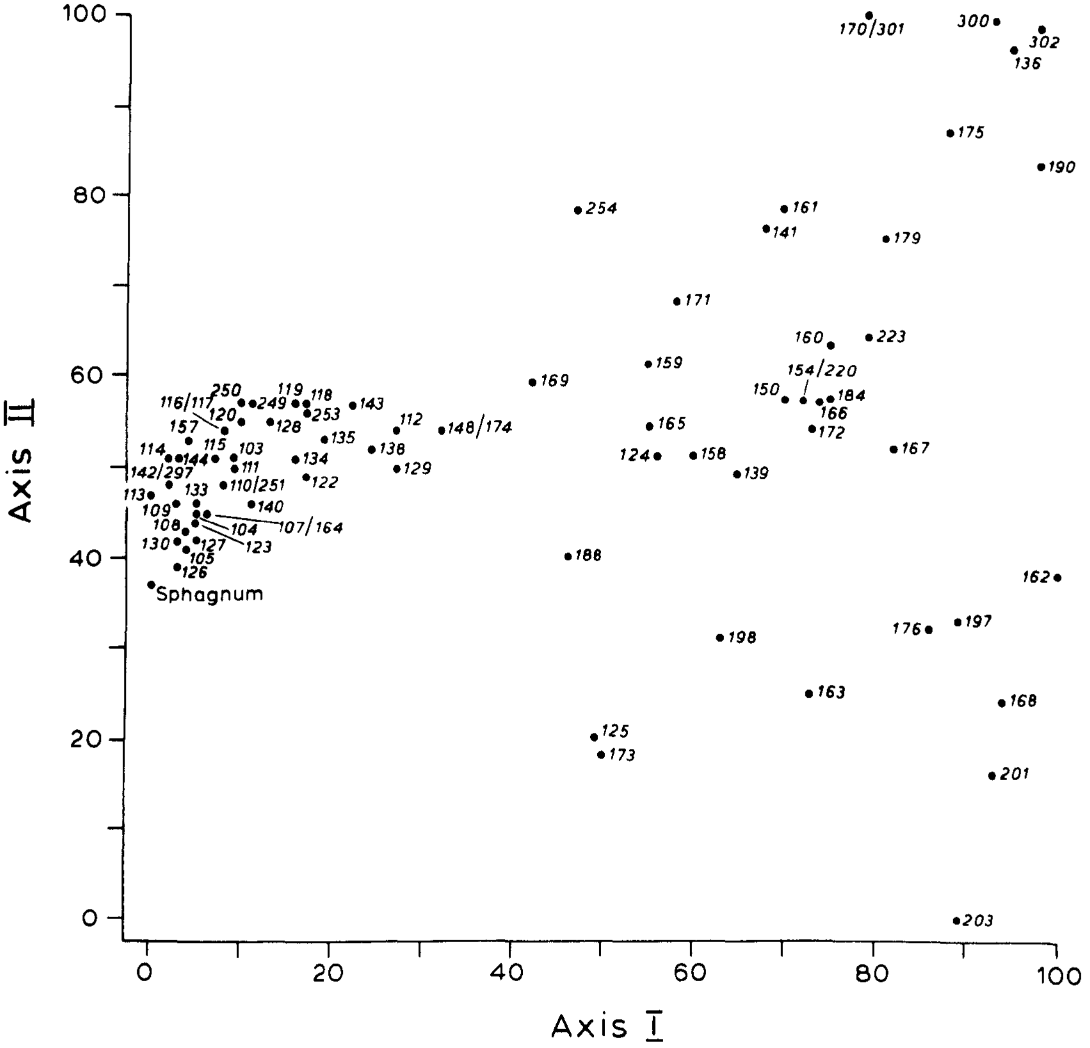
No clear pattern emerges for either axis III or axis IV (not shown).

However, using axis I and II the sites were separated into groups as shown in Fig. 4.8. Dry land gardens, dry land regrowth and 'wet' sites formed three separate groupings, while ricefield sites and swamp sites despite their close groupings were also separated to a lesser extent.

The analysis clearly shows a floristic gradient in the plots examined, and an environmental gradient is suggested by these results, for axis I. This may well be related to some factor connected with soil moisture content, perhaps to the drainage, which itself might be related to soil type, or seasonality of waterlogging.

No environmental gradient can be suggested as an explanation for axis II, which may be to a large extent dependent on axis I. However, it is interesting to note that fields and gardens, particularly dry land gardens, have a high score on this axis. The axis might therefore relate to a gradient affecting the dry land vegetation. The position of the 'wet' sites on this gradient could then be due to the chance occurrence in them of one or more of the species found in the dry land vegetation, and they may not themselves be playing a part in the analysis.

Fig. 4.9
Non-forest plots, results of reciprocal averaging analysis: species ordination on axes I and II, excluding plot 19



N.B. *104* includes *104, 106/252*

111 " *111, 121*

144 " *144, 145, 146*

157 " *157, 298*

159 " *159, 180, 182*

162 " *162, 189, 191, 193, 194, 199, 204,* sterile orchid, hirsute grass

165 includes *165, 183, 185*

170/301 " *170/301, 178,* sweet potato, cabbage

184 " *184, 224, 225*

203 " *203, 207, 208, 209, 210/288, 211, 212, 213, 214, 215, 217*

302 " *302,* potato

The species ordination on axes I and II is shown in Fig. 4.9. Numbers refer to the species collection numbers. Table 4.16 lists species scores of most species on axis I. The results do seem to confirm that the environmental gradient is connected in some way to soil moisture conditions.

4.11 Conclusions about non-forest vegetation

Large parts of the area around Danau di Atas have been strongly disturbed by human interference. A large proportion of the disturbed lands are currently under cultivation, but significant areas have been abandoned, and vegetation is regenerating on these.

On swamps the disturbance may still be continuing although this need not always take the form of cultivation. It may be as an influence on the vegetation of grazing and wallowing by domesticated animals such as water buffalo, which are utilized by the local human population as a source of meat and milk and as a work animal for pulling carts and ploughs.

Invasion of ricefields and gardens may be to a large extent accomplished by ephemeral weed species, such as some members of the Compositae (eg. *Bidens pilosa*, *Ageratum conyzoides*) and species such as *Polygala paniculata*, along with Gramineae and Cyperaceae such as *Isachne globosa*, *Eleusine indica* and *Cyperus kyllingia*. Should the garden or the field then be abandoned succession of some type may occur.

On dry land sites the ephemeral weeds may be largely replaced by more robust or perennial species which might include *Pteridium aquilinum*, *Imperata cylindrica* and *Eupatorium inulifolium*. If seedlings of shrubs and trees are established and are able to develop these will shade out many of the first colonisers and even some of the more robust species, if these are not shade tolerant. Shrubby vegetation might well include members of the Ericaceae, Rubiaceae and Myrtaceae, as observed in the Danau di Atas area. Eventually a form of secondary forest may develop, although such was not observed in the field area. *Macaranga* spp. are prominent taxa in secondary forest in South-East Asia (Whitmore, 1975).

On swampy sites the ephemeral weeds may be replaced by a diverse but low herbaceous vegetation in which Gramineae and Cyperaceae dominate. This may include species such as *Panicum repens*, *Isachne globosa*, *Leersia hexandra* and *Rhynchospora rugosa*. Other likely taxa include, in very wet places, *Machaerina* spp. and *Eleocharis* spp. Other taxa which may well appear in herbaceous swamp vegetation are *Xyris capensis* and *Utricularia bifida*. Such a Gramineae - Cyperaceae dominated swamp might eventually revert to a swamp forest, although such vegetation types no longer exist in this area. There is however convincing evidence that they have existed in the past, including woody stratigraphy and tree stumps in swamp deposits. Swamp forest types in the Kerinci area have been documented by Morley (1976).

Certain taxa may be present throughout the early regrowth stages irrespective of whether the site is a swamp or on dry land.

TABLE 4.16

Ecological preferences of taxa recorded in non-forest plots in the Danau di Atas region.

A. Species apparently preferring 'wet' land sites (swamp and ricefield)

Collection Number	Name	Species score on axis I in reciprocal averaging analysis
113	Machaerina rubiginosa	0
142	Coelachne infirma	2
114	Fuirena sp.	2
144	Carex cf. dimorpholepis	3
145	Eleocharis retroflexa	3
146	E. tetraquetra	3
130	Galium innocuum	3
126	Nephrolepis cordifolia	3
109	Utricularia bifida	3
298	Azolla pinata	4
108	Burmannia disticha	4
157	Fimbristylis aphylla	4
105	Scirpus mucronatus	4
127	Lygodium microphyllum	5
123	?Oldenlandia agrostemmoides	5
106/252	Panicum repens	5
104	Xyris capensis var. schoenoides	5
115	Lipocarpha chinensis	7
116/117	Cyperus cf. flavidus	8
110	Leersia hexandra	8
103	Eriocaulon brownianum	9
121	Hydrocotyle sibthorpioides	9
111	Hymenachne sp.	9
250	Brachiaria sp.	10
120	Juncus prismatocarpus var. leschenaultii	10
249	Potamogeton oblongus	11
140	Spilanthes iabadicensis	11

A. Species apparently preferring 'wet' land sites (swamp and ricefield) contd.

Collection Number	Name	Species score on axis I in reciprocal averaging analysis
128	Isachne globosa	13
134	Eriocaulon heterolepis var. nigricans	16
119	Scirpus juncoides	16
253	Fimbristylis polytrichoides	17
118	Oryza sativa	17
138	Laurembergia coccinea	24

B. Species apparently preferring dry land sites

Collection Number	Name	Species score on axis I in reciprocal averaging analysis
165	Crotalaria chinensis	55
159	Cymbopogon sp.	55
185	Emelia sonchifolia	55
182	Hedyotis verticillata	55
180	Basilicum polystachyon	55
183	Schizachyrium brevifolium	55
158	Pteridium aquilinum	60
161	Digitaria violascens	70
172	Erigeron sumatrensis	73
163	Imperata cylindrica	73
166	Arthraxon hispida ssp. ?langsdorfii	74
224	Borreria laevis	75
184	Chrysopogon aciculatus	75
225	Equisetum debile	75
160	Sporobolus berteroanus	75
170/301	Borreria alata	79
178	Cyperus cyperoides	79
223	Desmodium triflorum	79
179	Blumea lacera	81
167	Gonostegia hirta	82
176	Urena lobata	86
212	Carex cruciata	89
215	Dianella ensifolia	89
209	Disporum cantoniense	89
207	Elaeagnus latifolia	89
217	Ficus ribes	89
203	Humata sp	89
211	Isachne albens	89
210/288	Omalanthus populneus	89
213	Passiflora edulis	89
197	Rubus alceaefolius	89

B. Species apparently preferring dry land sites contd.

Collection Number	Name	Species score on axis I in reciprocal averaging analysis
208	Saurauia vulcani	89
214	Setaria palmifolia	89
201	Breynia microphylla	93
300	Cyperus brevifolius	93
168	Eupatorium inulifolium	94
190	Eleusine indica	98
302	Oxalis corymbosa	98
193	Amaranthus hybridus	100
204	Cassia floribunda	100
189	Cuphea balsamona	100
199	Cyclosorus sp.	100
194	Desmodium repandum	100
162	Solanum nigrum	100
191	Tithonia diversifolia	100
233	Arundina graminifolia	-
231	Eurya sp.	-
229	Rhododendron sp.	-
96/244	Rhodoleia championi	-
232	Schefflera sp.	-
234	Symplocos cochinchinensis ssp. laurina var. laurina	-
230	Vaccinium sp.	-
228	Wendlandia glabrata	-

C. Species occurring in both wet and dry land sites

Collection Number	Name	Species score on axis I in reciprocal averaging analysis
133	Lycopodium cernuum	5
107/164	Rhynchospora rugosa	6
122	Viola pilosa	17
135	Hypericum japonicum	19
143	Cyperus kyllingia	22
129	Centella asiatica	27
112	Paspalum orbiculare	27
148/174	Spiranthes sinensis	32
169	Pogonatherum saccharoideum	42
188	Plantago major	46
254	Eragrostis unioloides	47
125	Cyclosorus sp.	49
173	Melastoma affine	50
124	Dicranopteris currani	56
171	Bidens pilosa	58
198	Oxalis corniculata	63
139	Polygala paniculata	65
141	Ageratum conyzoides	68
150	Axonopus compressus	70
154/220	Fimbristylis dichotoma	72
175	Murdannia nudiflora	88
136	Drymaria cordata	95

Species having such a distribution include *Centella asiatica* and *Hypericum japonicum*.

A list of selected taxa and their apparent preferred environment, as deduced from these studies, based on field observations and reciprocal averaging analysis, is given in Table 4.16. It is not suggested that the species listed are totally restricted to these sites, but rather that they were most commonly found at them in this area of Sumatra. Further studies might lead to modifications of these conclusions.

Several points relating to Table 4.16 are worthy of note. *Pteridium aquilinum*, *Urena lobata*, *Eupatorium inulifolium* and *Dianella ensifolia* were recorded only at dry land sites in the Danau di Atas region, and were not observed on any of the swamps examined. However Morley (1976) found all of these species in swamp vegetation at Danau Padang.

Although *Lycopodium cernuum* was recorded in only one plot on the swamp, it was observed to be quite common in the dry land vegetation of the region, for example, on unshaded banks alongside roads. It has therefore been allocated to the category of taxa occurring both at wet and dry land sites.

The sequence in Table 4.16 beginning *Arundina graminifolia* (collection number 233) and ending with *Wendlandia glabrata* (collection number 228) have no species scores in the reciprocal averaging analysis as they were present only in plot 19, which was excluded from the analysis.

4.12 The altitudinal sequence of vegetation on Gunung Kerinci

The vegetation of G. Kerinci was not examined as part of this study. However, since an altitudinal sequence of modern pollen samples from the mountain was studied in order to elucidate patterns of pollen deposition with altitude, it is pertinent to consider the types of vegetation which occur on the mountain.

4.12a Sample plots examined by Dr J. R. Flenley

Dr J. R. Flenley studied the composition of three plots on the mountain in 1976. Details of the environmental variables and floristic composition of these are provided in Tables 4.17 and 4.18 respectively.

Plot 3 was situated at 2700 m a.s.l. in low forest 5-6 m tall, and basal area of species present was recorded. A species of *Myrsine* was dominant, providing 40% of the basal area of the plot, while *Symplocos* sp. and *Cyathea* sp. were also important. Other taxa recorded included *Meliosma lanceolata* and *Ardisia* sp. Poles of a Rubiaceae and *Eurya* cf. *glabra* were also common although they did not contribute much to the total basal area of the plot.

At plot 2, 3010 m a.s.l., the low forest, 2-4 m tall, was enumerated using estimates of cover. At this altitude *Myrica javanica* and *Rhododendron retusum* were both important, both providing 25% cover. Other important species included *Eurya* cf. *glabra*, *Myrsine* sp. and *Vaccinium* sp. Other taxa present

TABLE 4.17

Environmental variables recorded in the G. Kerinci plots (by Dr J.R. Flenley)

Plot	Altitude (m)	Soil pH	Soil temperature (°C)	Soil description	Slope	Description
1	3315	6.0 (0-10cm)	9.0 10cm in at base of 90cm vertical face	0-2cm Humus 2+cm Fresh ash	c. 15°	Sited at the upper limit of continuous vegetation. Vegetation height 0.5-1 m. Plot size 20m x 20m
2	3010	5.0 (0-10cm)	10.5 at 70cm depth in peat 10.2 at 20cm depth in peat	0-20cm Humus 20+cm Weathered ash	c. 10°	Vegetation 2-4m tall. *Myrica javanica* 3-4m, other species 1-3m. Plot size 30m x 4m
3	2700	5-5.5 (0-10cm)	10.7 at 70cm	0-15cm Leaf litter 15-20cm Peat or mor humus 20-45cm Loam, organic rich 45-75cm Weathered ash and abundant organic matter 75+cm Grey weathered ash	c. 5-10°	Forest 5-6m tall, ground flora of Urticaceae and ferns Plot size 30m x 4m

TABLE 4.18

Floristic composition of G. Kerinci plots 1-3 (Dr J.R. Flenley)

Collection Number	Name	Family	% Cover Plot 1	% Cover Plot 2	% basal area Plot 3
76/1	Rhododendron retusum	Ericaceae	5	25	
76/2	Vaccinium sp.		20	10	
76/3	Gaultheria punctata		5	5	
76/4	Gahnia javanica	Cyperaceae	5	5	
76/5	Senecio sp.	Compositae	+		
76/6	Carex sp.	Cyperaceae	1		
76/7	Myrica javanica	Myricaceae		25	
76/8	Eurya cf. glabra	Theaceae		15	3.0
76/9	Polygonum cf. paniculatum	Polygonaceae		2	
76/10		? Theaceae		2	
76/11	Myrsine sp.	Myrsinaceae		15	40.3
76/12	Meliosma lanceolata	Sabiaceae			7.6
76/13		Rubiaceae			1.0
76/14	Dendrophthoe sp.	Loranthaceae			*
76/15	Ardisia sp.	Myrsinaceae			0.7
76/16	Symplocos sp.	Symplocaceae			5.6
76/17	?				+
76/18	Symplocos sp.	Symplocaceae			19.7
76/19	Cyathea sp.	Cyatheaceae			19.2
76/20	Schefflera sp.	Araliaceae			+
76/21	?				2.8
	Anaphalis javanica	Compositae	+	2	
	Rubus spp.	Rosaceae		2	
	Blechnum sp.	Dennstaedtiaceae		5	
	Gleichenia sp.	Gleicheniaceae		5	
	Other ferns			5	

+ = Present
* = Present as hemiparasite

included *Gaultheria punctata*, *Gahnia javanica*, *Anaphalis javanica*, *Gleichenia* sp. and *Blechnum* sp.

The upper limit of continuous vegetation had been reached in the vicinity of plot 1, 3315 m a.s.l. The vegetation in this plot was 0.5-1 m in height, and was assessed using estimates of cover. About 40% of the plot was bare ground, with *Vaccinium* sp. (20% cover), *Rhododendron retusum*, *Gaultheria punctata* and *Gahnia javanica*. Also present were *Senecio* sp., *Carex* sp., and *Anaphalis javanica*.

4.12b The vegetation of G. Kerinci as described by Jacobs (1958)

Jacobs (1958) described the vegetation of G. Kerinci as observed during an ascent of the peak, as outlined below.

At c. 2050 m a.s.l. the vegetation is a forest in which Fagaceae are important, including species of *Lithocarpus* and *Castanopsis* along with *Schima* and *Symingtonia populnea* (R. BR. ex GRIFF.) STEEN. The forest at this altitude is however very diverse and many species are recorded. This is lower montane forest II according to the Kerinci zonation scheme used in the present study.

At 2400 m a.s.l. a girdle of *Gleichenia* spp. is encountered, which is almost impenetrable. In addition to *Gleichenia* spp. and *Dicranopteris* sp. this includes *Rubus* spp. and *Toddalia asiatica* LAMK. The upper limit of this belt is at 2800-2900 m a.s.l. Trees and shrubs present within the belt include *Lithocarpus monticola* (KING) REHD., *Meliosma* sp., *Viburnum* spp., *Litsea* cubeba PERS., Glochidion rubrum BL., Eurya decurrens DE WIT and Symplocos spp. Herbaceous taxa present include Isachne albens TRIN. and Sanicula europaea L. Loranthaceae are common and epiphytes are abundant, including Belvisia sp., Lycopodium sp. and Usnea. The origins of this belt are not understood: Jacobs (1958) found no traces of fire, which might have caused it, nor did he consider that landslides were a likely cause, because of the scale of the Gleichenia belt, and its limited altitudinal range. Both Jacobs (1958) and Morley (1976) considered that the porous, dry soil at these altitudes might have been a possible cause of the Gleichenia belt, suggesting that it is too dry to support forest. Below 2400 m the warmer climate may have enabled the forest to supersede the Gleichenia and above 2800 m the cold perhaps prevents Gleichenia from competing with the ericoid forest (Jacobs, 1958).

At the upper limit of the Gleichenia belt, at 2800-2900 m the Gleicheniaceae become lower and low trees and shrubs occur. These include Leptospermum sp., Glochidion sp., Gordonia densiflora RIDL., Symplocos aff. sessilifolia (BL.) GURKE and Rhododendron retusum (BL.) BENN. This develops into a dense 'ericoid' forest consisting mostly of Rapanea sp. (now possibly Myrsine) and Vaccinium miquelii BOERL. with these and other species which include Myrica javanica BL., Litsea cubeba, Ardisia sp., and scattered tree ferns, Cyathea sp. Herbaceous taxa include Nepenthes cf. pectinata, Senecio sumatranus MART. and Avena junghuhnii BUSE.

The ericoid forest is replaced abruptly by ericaceous shrubby vegetation at 3000 m a.s.l. Species present include *Gaultheria nummularioides* D. DON, *G. fragrantissima* WALL., *Rhododendron retusum*, *Myrica javanica*, *Eurya obovata* (BL.) KORTH var. *reticulata* (KORTH.) DE WIT, *Nertera depressa* BANKS & SOLAND, *Gentiana sumatrana* RIDL. and *Anaphalis javanica* SCH. BIP. Within the ericaceous scrub zone the vegetation gradually loses height and thins out. Various species disappear at different altitudes, for example, *Myrica javanica* and *Gaultheria nummularioides* are found to 3200 m a.s.l., while *Eurya obovata* is found to 3250 m a.s.l. Few species are found above this altitude, but include *Gaultheria fragrantissima*, *Rhododendron retusum*, *Vaccinium miquelii*, *Gahnia javanica* ZOLL. & MOR., *Carex verticillata* ZOLL. & MOR. and *Histiopteris incisa* (THUNB.) J.SM. The latter two species occur to the highest altitudes, over 3500 m a.s.l. although few specimens of any taxa exist above 3400 m a.s.l. (Jacobs, 1958).

This description is approximately in accordance with Flenley's plots. His plot 3 is apparently in the ericoid forest of Jacobs although at a slightly lower altitude. Flenley (pers. comm.) suggests that in fact the *Gleichenia* scrub and ericoid forest formed a mosaic of vegetation types at this altitude. The ericoid forest is a division of the Upper Montane Rain Forest Formation of Grubb (1974) and Whitmore (1975). Flenley's plots 2 and 1 are both in the ericaceous scrub of Jacobs; this is also a division of the Upper Montane Rain Forest Formation.

CHAPTER 5

MODERN POLLEN RAIN STUDIES

5.1 The techniques available for the study of modern pollen rain

Modern pollen rain studies are usually carried out to obtain information about relationships between the actual vegetation of an area, and the pollen it produces. Without such information the interpretation of fossil pollen diagrams may be largely guesswork. Before any interpretation of pollen deposited in sediments can be made, it is necessary to have some understanding as to the nature of pollen production, dispersal, deposition and preservation, and more specifically, how these are affected by the particular circumstances prevalent in the area of study.

Quite a considerable body of knowledge has built up in the years since von Post (1916) first introduced pollen analysis as a geological tool. Approaches to the various problems posed by the method are considered in the following sections.

A variety of collection methods may be used to study modern pollen rain, the pollen production of the contemporary vegetation. Basically they can be divided into two groups, those which employ naturally occurring pollen accumulating sediments, and those which employ artificial traps.

Mosses often occur in the form of polsters, and these and other bryophyte forms may act as efficient traps of airborne particles, including pollen and spores. By extracting these from such polsters, information about the pollen production and deposition of local plant communities can be obtained (eg. Birks, 1973; Hicks, 1977; Grabant, 1980). The major drawback with this method is that the exact time over which the pollen has been deposited is unknown, as too, is the rate of breakdown of pollen trapped within the polster. However, the method does have the advantage that only one collection has to be made, thus removing the necessity of numerous trips to a field area. If sufficient depth of the polster is removed it will represent several years accumulation, which may also be advantageous, since fluctuations in pollen production will be averaged out in the analysis. This may also be useful in tropical areas where flowering of some taxa is irregular and infrequent.

Other types of sediment may also trap pollen. Soils occasionally yield pollen (Birks, 1973), but generally the pollen in soils undergoes rapid decomposition due to high levels of oxidation and bacterial action. Other types of surface sediment may however yield large quantities of pollen; anaerobic conditions are usually prevalent at such sites. These include swamp and bog surfaces, environments which have long been recognized as being suitable for fossil pollen determination. As with moss polsters, the time of deposition, and rate of breakdown of pollen are unknown. Each of these sites receives pollen from a variety of sources, which may be both local and regional, the actual proportions of each are dependent on a number of factors.

Modern pollen rain may also be studied by employing pollen traps. A number of types have been used. These range from simple, sticky microscope slides to specially designed traps such as the aerodynamically designed trap of Tauber (1967a) or traps with water overflow facilities capable of being left unattended in the field for considerable periods (Flenley, 1973). Advantages of using these types of pollen traps are that absolute values of pollen deposition per unit time can be calculated. They can also be placed at different heights in vegetation stands in order to study pollen transport through different parts of the vegetation. This would not normally be possible using naturally occurring pollen traps, although the rich growths of epiphytic mosses which occur in parts of the tropical forests could perhaps be used in a similar fashion and might yield interesting results. One potential problem with the use of artificial traps is that they may act differently on pollen and spores than do natural deposition processes, and therefore deposition in them may not be comparable with deposition in a natural site.

5.2 Studies of modern pollen characteristics

5.2a Relative pollen production, dispersal, deposition and preservation

All taxa do not produce identical amounts of pollen, nor does the pollen production by different taxa relate to factors such as size. Pollen production by different species may however be broadly related to their pollination mechanisms. Wind pollinated, or anemophilous plants tend to produce large amounts of pollen whereas insect pollinated (entomophilous) plants tend to produce small amounts. The latter is particularly often sticky or spiny. Some plants have very specific pollination mechanisms, for example, species of the genus Ficus have enclosed inflorescences in which pollination is brought about by a parasitic wasp. The pollen of Ficus is not commonly found in sediments, and where it does occur may be a result of the breakdown of inflorescences which have fallen from parent trees (Morley, 1976). Pollination mechanisms may therefore affect the representation of pollen in sediments.

Pohl (1937) estimated actual pollen production in grains/m^2 of stand for a variety of North European tree species. From these he calculated values for the relative production of pollen by these taxa. Although the results obtained were not directly applicable to fossil pollen studies, they were at least an aid in interpretation and did demonstrate the large pollen production of anemophilous taxa compared with entomophilous ones.

Pollen grains are affected differentially by dispersal mechanisms, depending on their size, weight and other attributes such as possession of air sacs. Some types of pollen are sticky or spiny and form clumps which are not dispersed far. Examples of extreme clumping are found in the pollen of Orchidaceae and Asclepiadaceae which consequently do not disperse widely and are rarely found in fossil sediments. The source at which pollen enters the dispersal system is also important as it determines subsequent dispersal patterns. Clearly, pollen produced at canopy height stands a greater chance of wide dispersal than of identical pollen produced at ground level.

Approaches to the study of pollen dispersal have included both theoretical, and field studies. A major contribution to the understanding of pollen dispersal in temperate areas was provided by Tauber (1965). He produced a composite model for pollen dispersal and deposition. This was based on the theoretical behaviour of small particles carried in the atmosphere as formulated by workers such as Sutton (1932, 1947), and was tested by extensive field studies using pollen traps. The model proposed three major components of aerial pollen transport. The canopy component comprised those grains picked up and transported above the tree canopy, the trunk space component was made up of pollen grains picked up and carried by wind within the trunk space, and the rainout component comprised that pollen washed out of the atmosphere by contact with raindrops. Tauber's field results (1967a, 1977) certainly appeared largely to support his proposed model. The model also predicted that the contribution of the three components would vary at different depositional sites (Tauber, 1965). Small sites such as small bogs or lakes within forested areas would have a more important trunk space component than large sites (eg. larger lakes or open deposition sites within forested areas) which would conversely show greater representation of the canopy component. Tauber (1967b) also recognized that pollen taxa would be differentially filtered if the air carrying them was to pass through dense vegetation, such as a thicket surrounding a small depositional site. This filtration would come about by the impaction of grains against twigs and trunks and would affect the composition of the resultant pollen spectrum. However, unless a depositional site was actually densely vegetated, this would be of significance largely to the composition of the trunk space component, and therefore would be of importance only at sites where this component was itself the major contributor to the total pollen spectrum. It would therefore be most significant at small depositional sites. Andersen (1974) found that high winds in spring and summer transported pollen grains rapidly, and reduced the differential filtration effects of large and small pollen grains.

Tauber's model of pollen transfer was developed within a forested area in the North Temperate zone and it was not originally known how applicable the model would be in a tropical environment, where, for example, air movement within the trunk space is often small (Richards, 1952; Muller, 1965). However, more recent evidence (Flenley, 1973) suggests that the pollen rain in tropical regions is of the same nature as in temperate regions, except that the components have different relative importance.

Tauber (1965, 1967a) also recognized the reflotation of pollen, due to the washing of leaves and branches by, for example, autumn storms. This led to increased deposition of pollen in traps at those times of year. However, such reflotation would not be of consequence in fossil pollen studies, where such events are smoothed out in the pollen record, although it is important to recognize them if pollen traps are being used to study pollen production of a vegetation type. Leaf litter deposition in autumn in seasonal climates may also produce pollen maxima since pollen adheres to the leaf surfaces (Kryzwinsky, 1977).

Pollen dispersal studies have also been carried out on specific taxa, for example, Pinus pollen dispersal from a plantation was studied by Turner (1964) in a temperate region, and Morley (1976) in a tropical lower montane situation. Pollen concentrations fell rapidly with distance in both studies however Morley (1976) concluded that pollen dispersion in the tropical example was considerably less than in the temperate one. Conant (1978) examined the dispersal of isotopically labelled spores of the tree fern Cyathea arborea away from the parent plant. He found a rapid decline in spore concentration with distance but was able to recognize two types of transport. These were poorly dispersed whole sporangia, travelling less than 7.5m, and more widely dispersed individual spores.

Aquatic dispersal has been studied far less than aerial dispersal, and is the only medium of pollen dispersal in relatively few, aquatic, plant taxa (Proctor and Yeo, 1973). However, other pollen may be transported by water after being deposited actually on a water surface, or being washed into it by surface run off, or bank erosion, from other sites. Inflowing streams may contribute a large proportion of the deposited pollen in open water lake sediments (Peck, 1973) although at some sites they may be of little or no importance.

Studies of pollen production in mountainous areas have demonstrated a tendancy for pollen to be dispersed in an uphill direction (Rudolf and Firbas, 1926; Flenley, 1973; Salgado-Labouriau, 1979). Where vegetation is sparse and produces little pollen the effect of this pollen dispersal from other vegetation types may be particularly noticeable, especially where only relative pollen values are available. Flenley (1973) suggested that wind regimes in mountains may be an important factor in uphill transport of pollen, up-valley winds being prevalent during the day when most pollen is released, and down-valley winds being prevalent at night when pollen content of the air is normally low. While pollen is often transported uphill on mountains from its source, movement downhill is much less common.

Other factors which have been investigated include pollen incorporation and mixing in sediments, and preservation. Studies of pollen incorporation on a bog surface using marked grains showed that pollen at a sediment surface could be moved down into the sediment, by water, although distances involved were small (Rowley and Rowley, 1956). In lake sediments reworking and resuspension may occur several times before the sediments are buried deeply enough not to be resuspended (Davis, 1968) and once deposited may be mixed vertically by the activities of burrowing animals. Davis (1974) showed that the latter could move pollen as much as 15 cm, but usually the distance was much less than this. In anaerobic lakes there may be little or no bottom fauna and this mixing may not occur. The results of these studies do suggest that fossil pollen spectra may be very much an average of a number of years deposition.

Pollen types differ in their resistance to corrosion which may be caused by oxidation, high temperatures, mechanical forces or bacterial decay. For example, pteridophyte spores are often quite resistant while pollen of some taxa, such as members of the Lauraceae, rapidly decay under oxidizing conditions. Resistance may be related to the sporopollenin content of the grain (eg. Havinga, 1967), greater sporopollenin content conferring greater resistance. Differential preservation may account for the virtual absence of some taxa, such as Lauraceae, from fossil and even modern pollen spectra, which can present problems in interpretation.

5.2b Pollen - vegetation relationships

The studies previously described have largely been involved in the formulation of general models for pollen production, dispersal and incorporation, which provide a basis for the understanding of fossil pollen assemblages. However, other approaches have also been used to study modern pollen rain, and most of these involve comparing the present vegetation with the pollen rain it produces. Early approaches included that of Davis and Goodlett (1960) and Davis (1963) who calculated R-values on the basis of the species representation in the surrounding vegetation compared with representation in the pollen assemblages from surface samples of ponds. These conversion factors were then applied to fossil pollen spectra, to aid interpretation. However, they had to be used with caution as a number of assumptions were made in the calculation of these. Furthermore, subsequent studies revealed that pollen production by a species is not constant and can vary with environmental conditions and even with the abundance of the particular species within the community (Janssen, 1967).

Relationships between distinct vegetation types and pollen in moss polsters or surface sediments have been studied by a large number of workers (eg. Hicks, 1977; Salgado-Labouriau, 1979; Grabant, 1980). Results of such studies rarely show a straightforward relationship between vegetation and its pollen rain, due to the complexity of the situation as was outlined in the previous section. A background effect of regional pollen, or pollen of taxa not recorded in the vegetation is usually present (Grabant, 1980). Caratini et al. (1973) showed for a South Indian mangrove that nearly 25% of the pollen in surface samples was derived from vegetation outside the mangrove, and highest values of this allochthonous pollen were in samples taken from wide channels. In this case transport of pollen by water was particularly important. Although pollen dispersal and deposition patterns complicate relationships between vegetation and pollen rain, these do emerge (eg. Rymer, 1973; Tinsley and Smith 1974; Salgado-Labouriau, 1979; Bradshaw, 1981; Heide and Bradshaw, 1982). Certain taxa may also emerge as markers in the pollen spectrum, strongly indicating the presence of a particular vegetation type (Salgado-Labouriau, 1979). All of such information aids in the interpretation of fossil assemblages.

Relationships between vegetation and pollen rain may be difficult to quantify and a number of workers have aimed at developing robust statistical techniques to serve this purpose. Such quantification of relationships also reduces subjectivity. Because of the complex nature of the data most approaches involve the use of multivariate statistics (eg. Kershaw, 1973; O'Sullivan and Riley, 1974; Birks et al., 1975; Caseldine and Gordon, 1978). Situations in which the techniques have successfully been applied have usually had fairly distinct vegetation types, and it has been possible to distinguish vegetation types in terms of pollen spectra (eg. O'Sullivan and Riley, 1974; Caseldine and Gordon, 1978). However, problems may arise from the data itself both due to its variability, and due to other factors such as species with low or no pollen representation, which cause 'blind spots' in the analysis (Birks, 1973). Having quantified vegetation - pollen relationships there is still the possibility that past vegetation types do not always have a modern analogue, which may reduce the success with which the information can be applied in interpreting fossil assemblages.

In tropical rainforest the problems associated with the study of vegetation - pollen relationships may be greater than in temperate regions, where much of the work has been carried out. The richness of the flora, lack of dominance of particular species and complexity of forest structure present difficulties in quantifying vegetation, while difficulties in identification of much of the pollen to specific level present problems to acquisition of pollen data. Often vegetation changes in the tropics are very gradual which makes recognition of distinct vegetation types difficult. However, Kershaw (1973) applied numerical analysis to data from a North Queensland rain forest and found quite good correlations between the floristic vectors and those from pollen data. However, he had simplified his rain forest vegetation data by including only the larger trees. As vegetation does change with altitude, and distinct vegetation types are often more easily recognizable at high altitudes, so studies of vegetation pollen relationships in the tropics have also been concentrated in high montane areas (eg. Hamilton, 1972; Salgado-Labouriau, 1979). This study aims to demonstrate vegetation- pollen relationships in a tropical lower montane region.

5.3 The aims of the present study

Modern pollen rain studies were carried out in the Danau di Atas region for several reasons.

i) To elucidate the nature and magnitude of pollen rain components within forested areas, and to clarify any vegetation-pollen relationships among the arboreal taxa involved.

ii) To elucidate pollen deposition patterns in a variety of non-forest environments, including swamps, in order to assess the nature and magnitude of local pollen production and regional pollen deposition at such sites. In addition it was hoped that pollen spectra characteristic of open conditions would become apparent, which might be of use in interpreting fossil pollen diagrams.

iii) To study pollen rain variations with altitude on Gunung Kerinci as these were potentially important for the interpretation of fossil pollen diagrams, if depression of vegetation during the Late Quaternary had occurred in this area.

In order to carry out these studies, moss polsters and surface samples were collected from a variety of locations in the area. Pollen rain in forested areas was studied using moss polsters collected from plots 1-4, 20 and 24. Deposition patterns in non-forest were studied using moss polsters and surface samples from swamp sites (plots 5-13) and regrowth sites (plots 14-19). However, two of the samples from regrowth sites (plots 14 and 15) contained no pollen. The study of pollen rain variations with altitude was facilitated by the availability of eleven surface samples collected from Gunung Kerinci by Dr J. R. Flenley, from altitudes ranging from 1935 m to 3315 m a.s.l. These samples were of particular interest as the pollen rain from lower altitudes in the area (1230 m - 2190 m a.s.l.) had already been examined by Morley (1976), the combined studies therefore encompass a considerable altitudinal range. It was not within the realms of this study to set up a pollen trapping programme in the field since only one field trip to the area was envisaged. Therefore the studies of modern pollen rain are based only on relative pollen values in surface samples. A pollen trapping programme would however have had some advantages since it would have provided estimates of absolute pollen deposition values and these would have permitted more accurate elucidation of the vegetation-pollen relationships, and of the nature of the pollen rain components.

Collection and preparation of moss polsters and other surface samples was as described in Chapter 3 and Appendix 2.

Fig. 5.1 shows the pollen assemblages recorded in all surface samples from the Danau di Atas region, while Fig. 5.4 shows pollen assemblages from the G. Kerinci samples; the pollen sum is Total Dry Land Pollen (TDLP). In both diagrams the palynomorph taxa are arranged broadly according to life form and habitat. Brackets are used to indicate those having source taxa with a variety of life forms or habitat preferences. Dry land pollen taxa are arranged to the left of the pteridophyte spores.

Summary diagrams are provided in two forms. Figs 5.2 and 5.6 show the composition of the arboreal pollen sum in terms of altitudinal forest types. Definition of arboreal pollen and allocation of pollen taxa to groups sometimes presented difficulties. Some pollen types have a number of possible sources which may be arboreal or non-arboreal, or which may occur in a wide range of altitudinal forest types. The allocation of pollen taxa to the various altitudinal forest categories was made on the basis of several sources of information. Clearly the vegetation studies carried out in the Danau di Atas area, and those from G. Kerinci described in Chapter 4 provided much information as to the altitudinal preferences of source taxa. However these studies were not entirely comprehensive, so further information about source taxa was drawn from sources including Morley (1976) which includes studies of vegetation in the Kerinci area, Flora Malesiana and Flora of Java (Backer and Bakhuizen van den Brink, 1963-1967). Where source taxa are found in a wide range of altitudinal forest types the pollen taxon has been placed in the category 'common to all lower montane forest types', even if the sources may occur also in vegetation at higher or lower altitudes. Generally, pollen taxa of more restricted range have been allocated to the category which most probably includes their source, although it is possible that occasionally their source may lie within a different altitudinal forest group. Particular problems were encountered in allocation of taxa to the categories 'ericoid forest and *Gleichenia* scrub' and 'ericaceous scrub'. *Myrsine* comp. and *Vaccinium* comp. were allocated to the former category on the basis of the abundance of *Vaccinium* sp. (*V. miquelii*) and *Myrsine* sp. in this vegetation on G. Kerinci (Section 4.12). However *Vaccinium* spp. also occur in other vegetation types, and *Myrsine affinis* was also present in swamp forest in the Kerinci area (Morley, 1976). *Myrica* comp. and *Rhododendron* comp. were allocated to the 'ericaceous scrub' category, again because the nominate taxa are prominent in this vegetation on G. Kerinci. However, *Rhododendron* spp. do occur at lower altitudes in a variety of habitats and therefore other sources for this pollen are possible. *Myrica* comp. may be derived from *Myrica javanica* or *Myrica esculenta* and while the former is prominent at high altitudes the latter occurs at lower altitudes and may be found in well drained situations and in light forest (Backer, 1954). Allocation of pollen taxa to these two higher altitudinal forest groupings is therefore more tentative than for other categories. Appendix 6 shows the actual allocation of taxa to the altitudinal forest groups.

Figs 5.3 and 5.7 are summary diagrams in which the total pollen, excluding aquatics, unknown and unidentifiable grains is shown in terms of most likely source habitat. This pollen sum has been termed the Dry Land Pollen or DLP to distinguish it from TDLP. Allocation of pollen taxa to categories was again based on the ecological preferences of source taxa as determined by the present vegetation studies (Chapter 4) and information from the available literature. Again some problems arose in the allocation of pollen taxa to categories, some had such a wide range of possible sources that they had to be allocated to the category 'various'. Gramineae and Cyperaceae were allocated to the non-forest and swamp category although they do occur less commonly in other habitats such as forest.

5.4 Pollen rain within the forests of the Danau di Atas region

5.4a Results

Results of pollen analysis of moss polsters from plots 1-4, 20 and 24 are shown in Fig. 5.1 where the pollen sum is Total Dry Land Pollen. Details of the pollen rain recorded in the six forest plots are given below. For comparison of pollen production with representation of source taxa the percentage of Total Arboreal Pollen of the pollen taxon can be compared with the percentage basal area of probable source taxa in the plot, for trees of 30 cm girth and greater. Values of these for selected pollen taxa are provided in Table 5.1. Forest taxa are considered as having probably been represented in the pollen rain if they produce pollen of one of the types identified in the surface sample. Other sources of pollen such as small shrubs, ground flora, climbers and epiphytes cannot be compared with pollen production in this way since they were not included in the enumerations of forest plots. However, these contribute a relatively small amount to the total pollen spectrum, as demonstrated in Table 5.2, which shows the nature of the components of the pollen rain in terms of arboreal, non-arboreal and unclassified origin. Arboreal taxa have also been tentatively divided into those types having their origin from species which occur predominantly in the canopy, and those which are more often understory trees. It should also be noted that source taxa of the pollen recorded in a plot do not necessarily occur in that plot, and they may be present in the surrounding forest. Because of the floristically diverse nature of these forests it is a little more difficult to relate pollen production to source taxa than would be the case in more uniform vegetation stands such as those in temperate regions.

The pollen sample from plot 1 was dominated by Macaranga comp., with significant amounts of Lithocarpus/Castanopsis comp., Quercus comp. and Myrtaceae. A number of other taxa were present in small amounts and included Altingia comp., Symplocos comp., Myrsine comp. and Lauraceae. In addition pteridophyte spores contributed the equivalent of about 14% TDLP and sources of these probably included both terrestrial and epiphytic taxa, plus the tree fern Cyathea (Fig. 5.1).

Of the twenty species of arboreal taxa recorded at the site, thirteen species, which in total contributed more than 70% of the basal area of the plot, were probably represented in the pollen rain. Those taxa not apparently represented in the pollen rain included two uncollected and therefore unidentified species, along with Prunus arborea, Claoxylon longifolium, Turpinia sphaerocarpa, Ardisia sp. and Flacourtia rukam.

At this site, most of the pollen, over 92% TDLP was most likely of arboreal origin (Table 5.2). However, a large part of the arboreal pollen may have been derived from understory rather than canopy taxa. The bulk of this was composed of Macaranga comp., itself derived most probably from species of Macaranga. These are typically pioneer trees, and they often colonise gaps which form within forests (Whitmore, 1975). Morley (1976) considered that Macaranga spp. were often highly over-represented in the pollen sum. The high values of Macaranga comp. recorded at this site may be an indication of over-representation, as the basal area of probable source taxa is small (2.9% basal area versus 49.1% Total Arboreal Pollen, Table 5.1). However, the possibility of a source outside the perimeter of the plot or from trees having a girth of less than 30 cm cannot be ruled out. Also of note is the very low representation of Lauraceae pollen (less than 1%), whereas source taxa comprise over 34% of the basal area of the plot. This may be due largely to poor pollen preservation in this family.

The pollen assemblage obtained from plot 2 was quite diverse, but was dominated by Lithocarpus/Castanopsis comp. and Quercus comp. The large number of other pollen taxa recorded as low percentages included Adinandra comp., Altingia comp., Longetia, Elaeocarpus comp. and Lauraceae. Pteridophyte spores, recorded outside the pollen sum, accounted for the equivalent of c. 23% TDLP and were of variable source (Fig. 5.1).

Of the sixteen tree species recorded in this plot, nine were represented in the pollen assemblage, and had accounted for over 90% of the basal area. Taxa which were not apparently represented in the pollen assemblage were *Styrax paralleloneurum*, *Weinmannia blumei*, *Vernonia arborea*, *Tetractomia obovata*, *Tarenna fragrans* and *Fagraea* sp. A large proportion of the pollen rain, about 77% TDLP was of arboreal origin. Pollen unclassified as to origin made up a further 19% and that of non-arboreal source the remaining 4%. Most of the arboreal pollen was derived from canopy rather than understory taxa (Table 5.2).

Comparison of selected pollen taxa and probable source for plot 2 (Table 5.1) showed Lauraceae, uncommon in the plot, to be represented by small but significant amounts of pollen. *Lithocarpus*/*Castanopsis* comp. and *Quercus* comp. were important both at the site and in the pollen assemblage. Also notable was the relatively low pollen percentage of Myrtaceae recorded (3.9% Total Arboreal Pollen) compared with the large basal area (37.1%) of this family recorded in the plot.

Lithocarpus/*Castanopsis* comp. was one of the dominant taxa recorded in the pollen assemblage from plot 3, while *Memecylon* comp. and Myrtaceae also contributed significantly to the pollen sum. Other pollen taxa recorded included *Adinandra* comp., *Quercus* comp., *Schima*, *Macaranga* comp. and Meliaceae/Sapotaceae comp. Pteridophytes contributed the equivalent of 25% TDLP and included Cyathea comp., Gleichenia comp. and Asplenium comp. (Fig. 5.1).

Of the thirty six tree taxa recorded in the plot, eighteen were apparently represented in the pollen assemblage, and had contributed over 70% of the basal area. Taxa not represented in the pollen assemblage included two uncollected and therefore unidentified species, nine members of the family Lauraceae, Drypetes sp., Garcinia lateriflora, Ternstroemia patens, Alangium rotundifolium, Timonius cf. sericeus, Gynotroches axillaris and Olea javanica. Over 80% TDLP was most likely from an arboreal source, and most of this was derived from the canopy rather than the understory (Table 5.2). Non-arboreal taxa contributed only 6% TDLP, the remainder being unclassified as to source.

Comparison of selected pollen taxa and probable source taxa for plot 3 shows some quite interesting results (Table 5.1). Lauraceae, which contributed 12.7% of the basal area of the plot were absent in the pollen assemblage. Lithocarpus/Castanopsis comp. was common in the pollen assemblage, and possible source taxa were equally well represented in the plot. Schima, which was important in the plot (22% basal area) appears to have been somewhat under-represented in the pollen spectrum (5.7% Total Arboreal Pollen). Conversely Macaranga comp. appears to be over-represented in the pollen assemblage (7.7% Total Arboreal Pollen) when compared with its basal area in the plot (0.5%).

Plot 4 yielded a quite diverse pollen assemblage (Fig. 5.1), dominated by Lithocarpus/Castanopsis comp. and Quercus comp. Also recorded were Dacrycarpus, Engelhardtia comp., Symingtonia, Symplocos comp. and Myrtaceae, plus many other taxa. Pteridophyte spores, recorded outside the pollen sum, contributed the equivalent of about 21% TDLP of which Cyathea comp. made up almost half.

In the plot itself thirty one tree taxa were recorded, of which nineteen, contributing c. 68% of the basal area, were represented in the pollen assemblage obtained. Those species not apparently represented in the pollen assemblage were Weinmannia blumei, Platea excelsa, Tetractomia obovata, T. holtumi, Garcinia lateriflora, Ternstroemia patens, Schefflera sp., Carallia brachiata, Goniothalamus sp., Rhodoleia championi and an uncollected, unidentified specimen. Arboreal taxa contributed over 70% TDLP, a further 8% being of non-arboreal source and the remainder being of unclassified origin. Most of the arboreal pollen was again derived from the canopy (Table 5.2).

Fagaceae (Lithocarpus/Castanopsis comp. and Quercus comp.) were well represented in both the vegetation of plot 4 and in the pollen assemblage, the same was also true for the Myrtaceae, and Elaeocarpus comp. Symingtonia was well represented in the plot (9.6% basal area) but appeared to be under-represented in the pollen spectrum (1.4% Total Arboreal Pollen). This same pattern was found for the Lauraceae and Schima (Table 5.1).

The pollen assemblage obtained from plot 20 was quite mixed and included common Engelhardtia comp. Lithocarpus/Castanopsis comp., *Dodonaea* and *Wendlandia* comp. Other taxa recorded included *Quercus* comp., Myrtaceae, *Elaeocarpus* comp. and *Tarenna fragrans*. Pteridophyte spores were relatively abundant, contributing the equivalent of c. 40% TDLP, and included *Cyathea* comp., *Asplenium* comp. and *Lindsaya* sim. (Fig. 5.1).

Of the eleven species recorded in the plot, six were represented in the pollen assemblage and had accounted for over 50% of the basal area. Taxa not represented in the pollen assemblage were *Weinmannia blumei*, *Cinnamomum* sp., *Symingtonia populnea*, *Rhodoleia championi* and *Schefflera* sp. About 74% of the pollen recorded in the sample was most likely derived from an arboreal source, a further 8% being of non-arboreal source and the remainder being unclassified as to origin. Canopy taxa probably accounted for about 45% TDLP with understory taxa contributing about 29% (Table 5.2).

Comparison of the basal area of species with pollen representation shows *Dacrycarpus* pollen to be very under-represented in the pollen rain in this plot (Table 5.1). This is not as expected since in studies elsewhere (Morley, 1982) this taxon was consistently over-represented. *Lithocarpus*/*Castanopsis* comp. is well represented in the pollen assemblage from the plot, and the basal area of probable source taxa is of comparable magnitude.

The pollen assemblage obtained from plot 24 was dominated by *Quercus* comp. and *Elaeocarpus* comp. with small amounts of *Lithocarpus*/*Castanopsis* comp., *Medinilla* comp. and Myrtaceae. A number of other taxa recorded included Dacrycarpus, Ilex cymosa, Macaranga comp., Styrax and Symplocos comp. Pteridophyte spores contributed the equivalent of c. 26% TDLP and were quite diverse, including Cyathea comp., Davallia sim. and Gleichenia comp.

Sixteen of the thirty tree species recorded in the plot, which contributed over 50% of the basal area, were represented in the pollen assemblage. Those taxa not represented in the assemblage were Turpinia sphaercarpa, Weinmannia blumei, Garcinia lateriflora, Symingtonia populnea, Cryptocarya sp., Cinnamomum sp., Cratoxylon arborescens, Glochidion sp. and Mischocarpus sundaicus. Terminalia sp. and Pternandra sp. were possibly represented in the pollen assemblage, having pollen of a Melastomataceous type. Almost 85% TDLP was likely to have been derived from an arboreal source, 4% being of non-arboreal origin and the remainder from unclassified source. Canopy components contributed the bulk of the arboreal pollen (Table 5.2).

Fagaceae were well represented in the pollen assemblages and in plot 24 itself (Table 5.1). Schima, which contributed over 18% of the basal area of the plot, was poorly represented in the pollen assemblage (0.4% Total Arboreal Pollen). Conversely, Elaeocarpus comp. was a major contributor to the pollen assemblage (31% Total Arboreal Pollen) yet source taxa in the plot contributed only 3.3% of the basal area.

5.4b Discussion

There were sometimes problems in allocating a structural source to each pollen taxon, particularly where a taxon had a number of possible source taxa, which on occasions could include more than one life form. Despite these limitations some conclusions can be drawn. As can be seen from Table 5.2, the bulk of the pollen deposited in moss polsters in these forest sites was derived from an arboreal source (72-92.5%). Ground and low vegetation components contributed relatively little pollen (3.8%). Pollen of unclassified origin (4.5-20%) may include elements from either or both of these sources. Further examination of the arboreal components of the pollen rain show them to have been composed predominantly of pollen from canopy taxa at most sites (45 - 75.5%), while pollen derived from understory elements was of much lesser importance, except in plot 1 where it was 47%. These findings tend to confirm those of Morley (1976) and Kershaw and Hyland (1975) that the canopy is the major source of arboreal pollen deposited in a tropical forest environment. Of interest, is the finding that even within the forest, under quite dense vegetation, pollen from the canopy still predominated in pollen assemblages. The understory trees contributed quite large amounts of pollen at some, but not all, sites. This is not surprising since samples for analysis were collected within the forest vegetation. In these circumstances understory components might be expected to contribute a greater proportion of the arboreal pollen than they would at a deposition site outside the forest.

Pteridophyte spores recorded in the assemblages (equivalent to 14-40% TDLP) probably represent deposition of spores produced mainly within the plots themselves. The presence of Cyathea

TABLE 5.1

Pollen representation as percentage total arboreal pollen, and percentage basal area of probable source taxa, for selected pollen taxa only, for forest plots.

Pollen Type	Plot 1		Plot 2		Plot 3		Plot 4		Plot 20		Plot 24	
	A	B	A	B	A	B	A	B	A	B	A	B
Dacrycarpus	-	-	-	-	-	0.4	-	0.9	21.1	0.4	0.7	1.1
Adinandra comp.	-	-	2.3	2.6	-	1.6	-	3.8	-	0.4	-	-
Ilex cymosa	1.1	0.4	-	0.4	5.3	0.4	-	0.5	-	1.3	-	1.9
Lithocarpus/*Castanopsis* comp.	27.1	11.7	12.9	38.0	23.6	28.5	21.2	30.7	22.7	16.5	5.9	9.1
Quercus comp.	-	13.9	25.6	29.4	-	3.3	9.2	31.6	-	5.5	13.2	36.4
Schima	-	0.4	-	-	22.0	5.7	5.1	0.5	-	0.4	18.3	0.4
Styrax	-	-	0.7	-	-	-	-	0.5	-	-	2.7	0.8
Symingtonia	-	-	-	-	-	0.4	9.6	1.4	9.0	-	1.3	-
Symplocos comp.	1.5	1.1	1.9	0.4	0.8	0.4	0.5	0.5	-	0.8	0.8	0.8
Elaeocarpus comp.	2.4	0.7	-	2.2	4.5	2.0	9.1	7.1	-	3.8	3.3	31.1
Lauraceae	34.3	0.7	0.3	4.8	12.7	-	2.7	0.5	1.2	-	0.6	-
Linociera comp.	-	-	10.7	0.4	-	-	-	-	-	3.4	-	0.8
Macaranga comp. (all types)	2.9	49.1	-	2.2	0.5	7.7	-	5.7	-	0.4	3.2	1.5
Medinilla comp.	-	0.4	-	0.4	1.0	2.4	-	1.4	-	-	-	4.9
Meliaceae/Sapotaceae comp.	-	-	-	-	0.9	0.8	-	-	-	-	-	-
Myrtaceae (all types)	2.8	16.4	37.1	3.9	14.7	18.7	10.9	8.0	2.2	9.3	3.3	2.7
Tarenna fragrans	-	-	1.4	-	-	-	-	-	7.4	0.8	-	0.4

A = Percentage basal area of probable source taxa
B = Percentage of Total Arboreal Pollen (to 1 decimal place)

TABLE 5.2

Representation (%) of pollen from various structural components of forest, for samples from forest plots.

Pollen sum = Total Dry Land Pollen

Plot	Arboreal:			Non-arboreal	Unclassified as to origin
	Canopy	Understory	Total		
1	45.5	47.0	92.5	3.0	4.5
2	73.0	4.0	77.0	4.0	19.0
3	65.5	15.0	80.5	6.0	13.5
4	63.0	9.0	72.0	8.0	20.0
20	45.0	29.0	74.0	8.0	18.0
24	75.5	9.0	84.5	4.0	11.5

comp. is notable, this was probably derived from Cyathea spp., tree ferns commonly observed in the understory of the forests and occasionally of considerable stature. Other sources of pteridophyte spores within the forests included terrestrial, epiphytic and climbing taxa. Some spores may also have been contributed from a source outside the forest, via raindrops, although such a source seems unlikely to be of great significance in view of potentially high local production.

The composition of the arboreal pollen sum in terms of altitudinal forest types for the six forest samples examined is shown in Fig. 5.2. All plots except plot 20 theoretically lay within the lower montane forest II. As was therefore expected the bulk of the arboreal pollen at all sites was derived from taxa distributed throughout the lower montane forest, with smaller contributions from taxa having more restricted altitudinal ranges. A small percentage of pollen from taxa more or less confined to sub-montane forest (i.e. below 1400 m) was found at some sites. This may represent uphill transport of pollen from slightly lower altitudes, or may be derived from individuals of these taxa occurring, uncommonly, above their normal altitudinal limits. Also of interest was the presence of pollen from taxa commonest in the ericoid forest and Gleichenia scrub belt, and very rarely, ericaceous scrub. As explained in Section 5.3, the most likely source of this pollen was from taxa, notably Vaccinium and Myrsine, growing in habitats other than those indicated.

The composition of the pollen sum (DLP) in terms of source habitats, is shown in Fig. 5.3, for the six forest plots. The bulk of the pollen at all sites was derived from a forest source (49-91%). Taxa having a possible forest, secondary forest or non - forest source were also represented at all sites, but were particularly significant in plot 1, which was one of the more disturbed sites. Pollen taxa having a non-forest source, or a non-forest or swamp source occurred only in very small amounts in the forest samples examined.

Representation of selected pollen taxa in the pollen assemblages compared with their probable source taxa in the vegetation is shown in Table 5.1. For some pollen taxa, such as Symplocos comp., and Meliaceae/Sapotaceae comp., representation in the pollen spectrum (as % Total Arboreal Pollen) closely corresponded with their representation in the plot (as % basal area). A number of taxa appeared to be generally under-represented in the pollen assemblages. These included Schima, Symingtonia, Lauraceae and Tarenna fragrans. Conversely taxa which tended to be over-represented were Quercus comp., Macaranga comp. and Adinandra comp. These sometimes occurred in pollen assemblages even when not recorded within a plot itself. Representation of a number of pollen taxa was variable, these being both under and over-represented in different locations. These included Myrtaceae, Lithocarpus/Castanopsis comp. and Elaeocarpus comp. However, despite these variations, it seems likely that overall, the pollen representation of Lithocarpus/Castanopsis comp. and Myrtaceae does reflect their status in the vegetation as a whole.

Elaeocarpus comp. tends overall, to be over-represented in the pollen assemblages. *Dacrycarpus* was not well represented in the pollen spectra at these sites, although elsewhere (Morley, 1976, 1982) it was shown to be consistently over-represented.

The absence of pollen of certain taxa in pollen assemblages from the forest plots, despite the presence of source taxa, is also of interest. Taxa occurring in plots which were never represented in pollen assemblages included *Prunus arborea*, *Turpinia sphaerocarpa*, *Flacourtia rukam*, *Alangium rotundifolium*, *Gynotroches axillaris*, *Olea javanica*, *Garcinia lateriflora*, *Goniothalamus* sp. and *Rhodoleia championi*. This non-representation of taxa in the pollen record may result in blind spots in interpretation of fossil pollen diagrams, if such deposition patterns have also occurred in the past, and has long been recognized as a potential problem (eg. Birks, 1973). Non-representation of taxa in the pollen spectrum may be a result of one or more of several factors. These include: low pollen production by the taxon, poor pollen preservation (eg. in Lauraceae), irregular or uncommon flowering, unusual pollination mechanisms (eg. *Ficus*) and chance dispersal. The difficulties associated with distinguishing taxa having the same type of pollen may also result in apparent non-representation of taxa in the pollen spectrum. In this study this problem was encountered where a number of taxa produced grains of the same type, and especially with tricolporate, more or less psilate, more or less spherical grains of 10-15μm size. Often these could not be identified to a specific or generic level.

5.5 Pollen rain at non-forest sites in the Danau di Atas region

Results of the pollen analysis of moss polsters and surface samples from plots 5-19 are shown in Fig. 5.1, as percentages of Total Dry Land Pollen. For plots 14 and 15 no pollen was recovered from the surface samples collected. Details of the pollen rain at all other plots are described in the following sections. Summary diagrams, as described in Section 5.3 are also provided (Figs 5.2 and 5.3).

In order to consider the nature of regional and local deposition at each site, the pollen taxa recovered in a sample were allocated to one of four source area categories, and the proportional representation of these was then calculated for each plot (Table 5.3). The source area categories used were regional, intermediate, on-site and unclassified. These are discussed in greater detail in the following sections.

5.5a Pollen deposition in regrowth sites

A single moss polster collected from plot 16 yielded a fairly diverse pollen assemblage (Fig. 5.1). About 27% of the Total Dry Land Pollen was of regional arboreal origin, (Table 5.3) and included *Dacrydium*, *Altingia* comp., *Lithocarpus*/*Castanopsis* comp., *Quercus* comp. and *Symingtonia*. Compositae types (Tubuliflorae) contributed more than 32% TDLP and most of this was probably of very local origin since the plot was itself dominated by this family. Although Cyperaceae were not recorded in plot 16, and Gramineae were present only in small quantities, pollen of these two taxa was well represented in the assemblage by values of 17% and 6.5% TDLP respectively. This possibly reflects relatively high pollen production and dispersal of these anemophilous taxa. Other pollen taxa recorded for which source taxa were present within the plot were *Plantago major*, *Polygala* comp., and Urticaceae/Moraceae, the latter perhaps derived in this case from *Gonostegia hirta* or some other urticaceous herb.

Pteridophyte spores, recorded outside the pollen sum, were very common, and included *Cyathea* comp., *Gleichenia* comp., *Pteridium* and *Cyclosorus* comp. 1. Although possible source taxa for these were not common within plot 16, they were often widespread in the regrowth vegetation of this area. As might be expected, a number of taxa recorded at plot 16 were not represented in the pollen assemblage obtained from it. These included *Rubus alceaefolius*, *Cuphea balsamona* and *Urena lobata*.

The bulked moss polsters collected from plot 17 yielded a pollen assemblage of apparently low diversity. The regional component recorded at this site was also low, about 5% TDLP (Table 5.3). It was comprised *Pinus*, *Lithocarpus*/*Castanopsis* comp., *Quercus* comp. and *Elaeocarpus* comp. The most likely source of *Pinus* pollen was one of the small plantations in the area. Pollen of Compositae (Tubuliflorae) was abundant, totalling over 77% TDLP (Fig. 5.1) and was probably from a local source; the plot itself had 35% cover of *Eupatorium inulifolium*. Gramineae were poorly represented in the pollen assemblage (2.5% TDLP) despite their dominance in the plot itself. Conversely the Cyperaceae which provided only 1% cover at the site, were better represented in the pollen assemblage (4.5% TDLP). Polygala comp. and Urticaceae/Moraceae were also recorded in the pollen assemblage and had possible source taxa within the plot.

Pteridophyte spores were fairly common in the pollen assemblage, and included Selaginella, Filices undifferentiated, Lycopodium cernuum and Gleichenia comp. The most likely source of most of these spores was the regenerating vegetation surrounding the plot, although some may have had their source within the plot itself. A number of taxa present in plot 17 were not represented in the pollen assemblage. These included Melastoma affine, Centella asiatica, Murdannia nudiflora and Pteridium aquilinum.

The bulked moss polsters collected at plot 18 yielded a fairly diverse pollen assemblage (Fig. 5.1). Regional elements, including Lithocarpus/Castanopsis comp., Quercus comp. and Elaeocarpus comp. contributed 19% TDLP. The vegetation of the plot was dominated by Gramineae, which was reflected by the presence of 28% TDLP of Gramineae in the pollen assemblage. Cyperaceae, which provided 16% cover in the plot were also well represented in the pollen assemblage (18.5% TDLP). Polygala comp., Compositae (Tubuliflorae) and Urticaceae/Moraceae were recorded in the pollen assemblage and had possible source taxa within the plot. Pteridophyte spores were abundant in the assemblage and included Lindsaya sim., Filices undifferentiated, Dicranopteris comp., Gleichenia comp. and Cyclosorus comp. 1. Taxa occurring in the plot which were not represented in the pollen assemblage included Desmodium triflorum, Centella asiatica, Rubus alceaefolius and Murdannia nudiflora.

The bulked moss polsters from plot 19 yielded a fairly diverse pollen assemblage with a large regional component (52.5% TDLP, Table 5.3). This included *Dacrydium*, *Altingia* comp., *Engelhardtia* comp., *Lithocarpus*/*Castanopsis* comp., *Quercus* comp., and *Schima*. The plot itself was dominated by *Rhodoleia championi*, although this was not represented in the pollen assemblage. A number of the pollen taxa recorded did however have potential source taxa at the site, these included *Wendlandia* comp., *Melastoma* comp. and *Rhododendron* comp. in addition to Gramineae. Pteridophyte spores were very abundant in the assemblage and many taxa were represented. They included *Microsorium* comp., *Cyathea* comp., *Davallia* sim. and *Lycopodium cernuum*, with very large quantities of Filices undifferentiated, *Dicranopteris* comp., *Gleichenia* comp. and *Pteridium*. Among the taxa not represented in the pollen assemblage but present in the plot were *Eurya* sp., *Vaccinium* sp. and *Schefflera* sp.

5.5b Pollen deposition in swamp sites

The composite surface sample collected from plot 5 revealed a moderately diverse pollen assemblage (Fig. 5.1) with a regional component of 10.5% TDLP (Table 5.3). This included *Engelhardtia* comp., *Lithocarpus*/*Castanopsis* comp., *Quercus* comp. and *Elaeocarpus* comp. Over 82% TDLP had a possible source occurring within the plot itself. Gramineae and Cyperaceae (52% and 28% TDLP respectively) provided the bulk of this component, reflecting their dominance in the plot, although the actual source of these may have included a wider area. *Xyris*, *Eriocaulon* and Compositae (Tubuliflorae) also contributed to the pollen assemblage and had possible source taxa within the plot. A number a taxa including *Utricularia bifida*, *Burmannia disticha* and *Viola pilosa* were not represented in the pollen assemblage although they occurred in the plot. Pteridophyte spores were recorded in the assemblage although these were not so abundant as in the regrowth plots described in the previous section. They included Filices undifferentiated, *Lycopodium cernuum*, *L. clavatum* comp., *Pteridium* and *Gleichenia* comp. Since pteridophytes were not particularly common in the plot or in the swamp vegetation as a whole, it seems likely that at least some of the pteridophyte spores were derived from the dry land areas peripheral to the swamp.

The composite surface sample from plot 6 revealed a pollen deposition pattern similar to that at plot 5, with a regional component of comparable magnitude (13.5% TDLP, Table 5.3). The pollen assemblage was again dominated by pollen of Cyperaceae (27%) and Gramineae (43%), reflecting the predominance of these taxa in the plot. *Xyris*, *Eriocaulon* and *Utricularia* were also represented in the pollen and had source taxa in the plot. Pteridophyte spores, though present, were not abundant, and included *Lycopodium cernuum*, *L. clavatum* comp. and *Pteridium*.

Although the vegetation of plot 7 was composed of members of only three families (Cyperaceae, Gramineae and Juncaceae), the pollen assemblage recorded was quite diverse (Fig. 5.1). About 28% TDLP was derived from regional elements (Table 5.3) such as

Dacrycarpus, *Lithocarpus*/*Castanopsis* comp., *Quercus* comp. and *Symingtonia*. Gramineae contributed 47% TDLP and Cyperaceae 14% TDLP to form the on-site component of 61% TDLP. Much of the remaining pollen was contributed by components of the swamp vegetation such as *Burmannia*, *Xyris* and *Impatiens*, although these did not actually occur in the plot. Pteridophyte spores were recorded in the assemblage in small quantities. They included *Humata* sim., *Lycopodium cernuum* and Filices undifferentiated.

The composite surface sample from plot 8 yielded a moderately diverse pollen assemblage with a regional component of 21% TDLP (Table 5.3). This included *Dacrycarpus*, *Lithocarpus*/*Castanopsis* comp., *Quercus* comp., and *Evodia* comp. The plot was dominated by Gramineae with Cyperaceae and together these accounted for 94% cover. This is reflected to a large extent in the pollen spectrum, the two families together accounting for over 60% TDLP. However, while the Cyperaceae provided only 12% cover they contributed 29% TDLP (Table 5.4) and they thus appear to be over-represented compared with the Gramineae. *Xyris*, *Utricularia* and *Laurembergia* comp. were also represented in the pollen assemblage and had possible source taxa within the plot. Pteridophyte spores were quite abundant in the pollen assemblage. They included *Microlepia* sim., *Humata* sim., *Lycopodium cernuum* and Filices undifferentiated. However, no pteridophytes were recorded in the plot so the source of these spores must have been elsewhere on the swamp and surrounding dry land areas.

The plot 9 pollen assemblage contained 20% TDLP derived from a regional source (Table 5.3). This included *Dacrycarpus*, Dacrydium, Engelhardtia comp., Lithocarpus/Castanopsis comp., Quercus comp. and Macaranga comp. Gramineae contributed about 74% cover in the plot, and 33% TDLP while Cyperaceae (18% cover) contributed 31% TDLP (Table 5.4). Xyris, Hydrocotyle comp., Laurembergia comp., Eriocaulon and Compositae (Tubuliflorae) were also represented in the pollen assemblage (Fig. 5.1) and had possible source taxa within the plot. Again pteridophyte spores were abundant in the assemblage, and they included Lycopodium cernuum (equivalent to 105% TDLP) and Filices undifferentiated. Although L. cernuum was growing in the plot, the large amount of spores recorded may have been derived from both within the plot and from plants growing in surrounding areas.

The pollen assemblage from plot 10 was moderately diverse (Fig. 5.1) and had a regional component of 11% (Table 5.3). This included Altingia comp., Lithocarpus/Castanopsis comp., Quercus comp., Schima and Myrsine comp. The dense vegetation of the plot itself included over 80% cover provided by Gramineae, reflected as 51% TDLP. Cyperaceae provided over 30% cover and 23% TDLP (Table 5.4). Other taxa recorded in the pollen assemblage, and having possible source taxa in the plot, were Xyris, Hydrocotyle comp. and Compositae (Tubuliflorae). A number of taxa were present in the plot but not recorded in the pollen assemblage. They included Burmannia disticha, Viola pilosa, Galium innocuum and Hypericum japonicum. Pteridophyte spores were moderately abundant and included Cyathea comp., Filices undifferentiated, Lycopodium cernuum, Cyclosorus comp. 1 and Pteridium. Of these, only Cyclosorus comp. 1 had a possible source within the plot.

The contribution of regionally derived pollen to the assemblage from plot 11 was relatively large (26% TDLP). It included *Dacrycarpus*, *Dacrydium*, *Lithocarpus*/*Castanopsis* comp., *Quercus* comp., *Celtis* comp. and *Elaeocarpus* comp. Gramineae contributed only 23% TDLP although they provided 82% cover in the plot. Cyperaceae appear to have been relatively over-represented contributing 31% TDLP but only 11% of the cover at the site (Table 5.4). *Eriocaulon* and *Xyris* were both represented both in the plot and in the pollen assemblage. Pteridophyte spores were moderately abundant in the record, and included Filices undifferentiated, *Lycopodium cernuum*, *L. clavatum* comp. and *Gleichenia* comp., although no pteridophytes were recorded in the plot.

The composite surface sample from plot 12 contained a moderately diverse pollen assemblage with a regional component of 11% TDLP (Table 5.3). This included *Dacrycarpus*, *Lithocarpus*/*Castanopsis* comp., *Quercus* comp., *Schima* and *Macaranga* comp. Although Gramineae dominated in the plot (86% cover) they were represented in the pollen assemblage by only 37% TDLP. Conversely, Cyperaceae, which provided 4% cover in the plot contributed 39% TDLP (Table 5.4). *Xyris*, *Hydrocotyle* comp. and *Melastoma* comp. were represented in the pollen assemblage and had possible source taxa within the plot. Pteridophyte spores were fairly common in the assemblage. They included Filices undifferentiated, *Lycopodium cernuum*, *L. clavatum* comp., *Pteridium* and *Cyclosorus* comp. 1, although no pteridophytes occurred in the plot itself.

TABLE 5.3

Representation (%) of pollen derived from different sources for samples from non-forest plots

Pollen sum = Total Dry Land Pollen

Plot	Regional	Intermediate	On-site	Unclassified as to origin
Regrowth sites				
16	27.0	22.0	46.0	5.0
17	5.0	0.0	88.0	7.0
18	19.0	2.0	68.5	10.5
19	52.5	13.0	17.0	17.5
Swamp sites				
5	10.5	4.5	82.5	2.5
6	13.5	8.5	75.0	3.0
7	28.0	6.0	61.0	5.0
8	21.0	11.5	64.0	3.5
9	20.0	5.0	73.0	2.0
10	11.0	5.5	82.0	1.5
11	26.0	8.0	57.5	8.5
12	11.0	6.5	78.5	4.0
13	27.0	18.0	50.0	5.0

TABLE 5.4

Representation of Gramineae and Cyperaceae in the vegetation and pollen assemblages of non-forest plots in the Danau di Atas region.

Values are calculated to the nearest 1%

Plot	Gramineae % cover	 % TDLP	Cyperaceae % cover	 % TDLP
Regrowth sites				
16	3	7	0	17
17	43	3	1	5
18	89	28	17	19
19	1	9	0	5
Swamp sites				
5	83	52	8	28
6	51	43	38	27
7	73	47	34	14
8	82	33	12	29
9	74	33	18	31
10	83	51	32	23
11	82	23	11	31
12	86	37	4	39
13	31	23	13	23

A moderately diverse pollen assemblage was recovered from the bulked moss polster from plot 13 (Fig. 5.1). This included a relatively large regional component (27%) with taxa such as *Altingia* comp., *Engelhardtia* comp., *Lithocarpus*/*Castanopsis* comp., *Quercus* comp., *Linociera* comp. and *Trema* comp. represented. Both the Cyperaceae and the Gramineae contributed significantly to the total pollen sum. *Xyris* was represented in the pollen assemblage and was present also within the plot. Pteridophyte spores were very common and these included *Asplenium* comp., Filices undifferentiated, *Lycopodium* *cernuum* and *Gleichenia* comp.

5.5c Discussion

Pollen deposition in non-forest plots can be considered in terms of source area. Most non-forest samples examined yielded a diverse pollen assemblage in which distinct pollen rain components could be observed.

All sites yielded a regional component of arboreal pollen which was probably derived from forest or forest remnants (Table 5.3). Neither of these vegetation types was observed in the immediate vicinity of the non-forest plots from which the pollen samples were collected. However, forest and forest remnants were present about 1 km away from the regrowth plots (16-19) and somewhat further away (3-4 km) from the swamp plots (5-13) (Fig 4.1). For this reason it was considered justifiable to refer to this pollen component as a regional component for which transport over considerable distances prior to deposition had possibly occurred.

The magnitude of this component was from as little as 5% TDLP (plot 17) to 52.5% TDLP (Plot 19). For most sites, however, the values were between 10% and 28% TDLP. A montane forest source for this pollen component was suggested by the diversity and nature of the taxa represented. These included pollen of the Fagaceae (*Lithocarpus*/*Castanopsis* comp. and *Quercus* comp.) which was recorded in all of the non-forest pollen assemblages. Amounts of pollen recorded, although generally small in percentage terms, reflected the abundance of this family in the forests of the area (Sections 4.2 and 4.4). Other pollen taxa commonly recorded were *Altingia* comp., *Engelhardtia* comp., *Elaeocarpus* comp., *Myrsine* comp., *Macaranga* comp., Myrtaceae and *Trema* comp. Less common, although still recorded at several non-forest sites were *Dacrydium*, *Dacrycarpus*, *Medinilla* comp. and *Celtis* comp. *Schima* and *Symingtonia* were recorded rather uncommonly despite their importance in the forests of the area. However these both appear to be under-represented in the pollen rain (Table 5.1). Myrtaceae pollen was included as part of the regional component although some members of the family were recorded in non-forest vegetation (eg. *Rhodomyrtus tomentosa* was recorded in regenerating vegetation). Most species were however forest trees. *Pinus* pollen recorded at five non-forest sites was probably derived from one of the small plantations of *P. merkussii* growing in the area.

The 'on site' component of the pollen rain comprised all pollen which could, though in reality may not actually, have been derived from taxa growing within the 4m x 4m sample plot. The values presented (Table 5.3) are therefore the maximum values possible for extremely local pollen production, with pollen being deposited within a few metres of its source. Since the component includes pollen of taxa which were recorded in the plots but which probably occurred also in the surrounding vegetation, the actual values of such extremely local pollen production are probably lower than the maximum values suggested. The values of the on-site component ranged from 17% to 88% TDLP but most were within the range 50-80% TDLP. Even accepting that not all of this pollen in reality had its source in the plot, it is still likely to have been of fairly local origin and demonstrates the importance of local pollen production and deposition in these open, non-forest sites. Major contributors to the on-site component of the swamp plots were Gramineae and Cyperaceae, which were both abundant in the vegetation. Pollen of these families was also quite important at the regrowth sites, where they were not usually so dominant in the vegetation. Compositae (Tubuliflorae) pollen was also very important in three of the four regrowth sites, reflecting the importance of this family in the vegetation, and particularly of Eupatorium inulifolium. Whether this type of pollen was also more resistant to decay under oxidizing conditions was not known, but would account for the high levels of Compositae pollen at these sites, which provided less than ideal conditions for pollen preservation.

The 'intermediate' component included pollen derived from taxa not growing within the plots themselves, but which were known to be present in the surrounding vegetation. Hence, while some of the pollen may have been of very local origin, some might also have been derived from more distant sources. For example, pollen Rhododendron comp. and Vaccinium comp. recorded at some swamp sites was considered to have been of intermediate source, since possible source taxa grew in the regrowth vegetation. An alternative, less likely, source of this pollen might have been from the montane forests themselves, and in this case the pollen could be considered as part of the regional component. However, much of the intermediate pollen component recorded at the non-forest sites is probably of fairly local origin. The magnitude of this component was normally fairly low, 4-18% TDLP, although extreme values of 0% and 22% were recorded.

The final component of the pollen rain recognized was that of unclassified source. This category included pollen of form taxa, unidentified grains and grains of unknown ecological affinity. It ranged from 1.5-17.5% TDLP but was usually less than 10% TDLP.

The composition of the arboreal pollen sum at the non-forest sites in terms of altitudinal forest types is shown in Fig. 5.2. All plots lay within the range of altitudes associated with lower montane forest I. Although the arboreal pollen totals were small in these assemblages, the results are broadly similar to those from the forest plots. The pollen assemblages for all non-forest plots were dominated by pollen derived from taxa distributed throughout the lower montane forest, with smaller contributions from taxa with more restricted altitudinal ranges. The apparently significant amounts contributed by the 'ericoid forest and Gleichenia scrub' and 'ericaceous scrub' components might possibly be due to long distance dispersal from higher altitudes. However a more probable source is from taxa such as Vaccinium and Rhododendron growing in habitats other than those indicated i.e. in the forest or regrowth vegetation of the more immediate area. It is also of interest that the contribution of the 'more or less confined to sub-montane forest' component was greatest at the swamp sites. Possibly this was due to long distance dispersal of pollen from lower altitude forests lying to the west of the area. If so, it demonstrates the differences in pollen deposition within a closed (forest) and open (swamp) environment for well dispersed pollen.

The composition of the pollen sum (DLP) in terms of source habitats is shown in Fig. 5.3. For the regrowth sites the importance of the different components varied quite considerably. At plot 16, taxa having a forest or a 'forest, secondary forest or non-forest' source contributed almost 70% DLP. At plot 17 these two sources contributed even more of the DLP although at this site taxa having a 'forest, secondary forest or non-forest' source were dominant. This plot was quite shrubby. At the fairly open, grazed, plot 18, taxa having a non-forest or swamp source were very important, reflecting to some extent the open, herbaceous nature of the vegetation. Taxa having a forest source were particularly important at plot 19, a very shrubby plot, and here the representation of taxa having a non-forest or swamp source was low.

For the swamp plots, the contributions of the various sources were much less variable. At these sites the bulk of the DLP was contributed by taxa having a non-forest or swamp source. Taxa having only a swamp source contributed a small amount of pollen at each plot while those having a forest or a 'forest, secondary forest or non-forest' source were also represented at all sites.

It is interesting to note the changes in the composition of the pollen rain in terms of source habitat components at the different types of site examined (Fig. 5.3). These changes can be attributed largely to the different nature of local pollen production, since this seems to contribute the bulk of the pollen at most sites, even in forested areas.

Non-representation of some taxa in the pollen record occurred with non-forest assemblages, as it had in forest assemblages, and the reasons for non-representation were presumably the same (Section 5.4b). Certain taxa which exhibited this phenomenon were *Viola pilosa*, *Centella asiatica*, *Hypericum japonicum*, *Urena lobata*, *Murdannia nudiflora* and *Desmodium triflorum*, although in some of these cases the non-representation may have been apparent rather than real, relating to identification problems rather than pollen production and dispersal.

Some taxa seemed to be fairly well represented in the pollen spectrum when compared with percentage cover values of source taxa. These included *Polygala* comp., *Hydrocotyle* comp., *Xyris* and *Eriocaulon*.

Pollen of Gramineae and Cyperaceae was recorded at all non-forest sites, but was particularly abundant at the swamp sites. The high representation of these two families was much as expected in view of their anemophilous nature. One interesting pattern which did emerge from these studies, was that the Cyperaceae were more prone to over-representation in pollen assemblages than were the Gramineae, at least in the plots examined. Percentage cover values, and % TDLP values for Gramineae and Cyperaceae in the non-forest plots are shown in Table 5.4. To what extent these apparent relationships applied in the past is, however, unknown.

Pteridophyte spores were not included in the pollen rain components as they were counted outside the pollen sum. Inclusion of pteridophyte spores in the pollen sum may make the interpretation of pollen spectra more difficult since spore totals often fluctuate widely between samples and are often very high. Reasons for this may include copious spore production in many species, effective dispersal and resistance to decay, once deposition has occurred. Pteridophyte spores were present in all of the non-forest samples examined which yielded palynomorphs, and they were often extremely abundant (eg. at plot 19). Often the source of the spores recorded in a sample could not be identified as being from within the plot, and even where no pteridophytes occurred in a plot the spore recovery was still high. Most spores deposited within plots were probably of 'intermediate' source, as defined for pollen previously, being derived from a few metres to perhaps several hundred metres away from the sampling site, most however being derived fairly locally.

Fig. 5.1
Modern pollen rain for plots in the Danau di Atas region

Fig. 5.2
Summary pollen diagram for plots in the Danau di Atas region showing the composition of the arboreal pollen in terms of altitudinal forest types

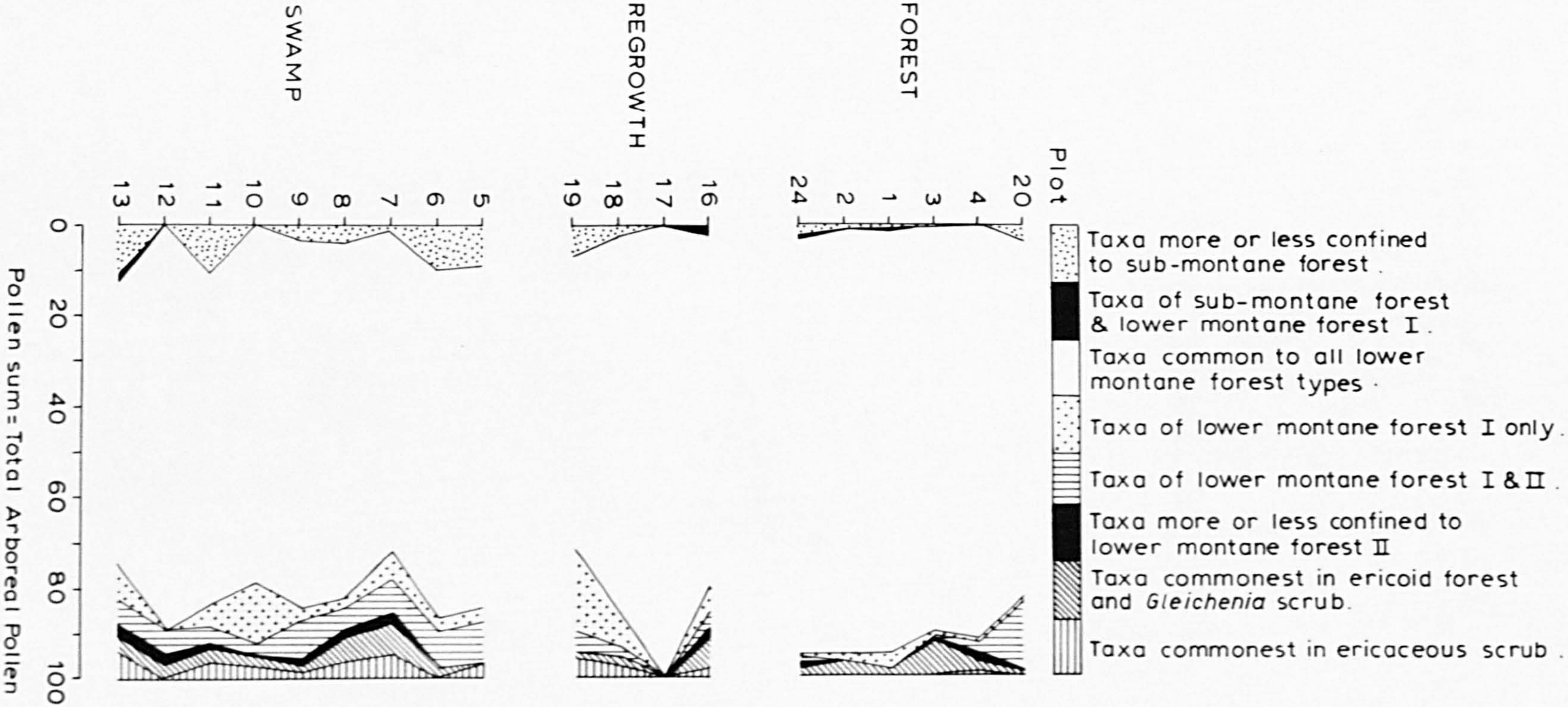
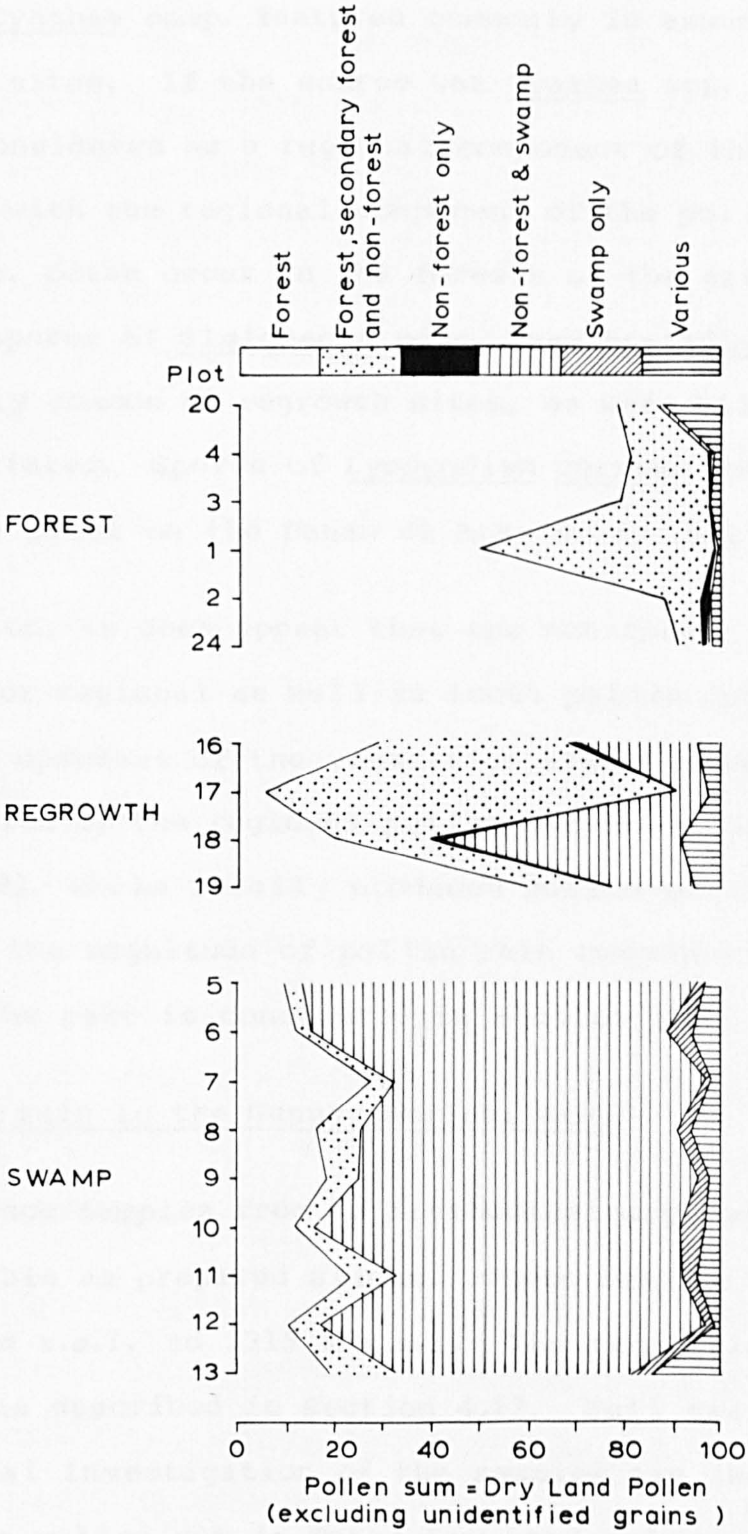

Plot
FOREST
20
4
3
1
2
24
REGROWTH
16
17
18
19
SWAMP
5
6
7
8
9
10
11
12
13
0
20
40
60
80
100
Pollen sum = Total Arboreal Pollen
Taxa more or less confined to sub-montane forest.
Taxa of sub-montane forest & lower montane forest I.
Taxa common to all lower montane forest types.
Taxa of lower montane forest I only.
Taxa of lower montane forest I & II.
Taxa more or less confined to lower montane forest II
Taxa commonest in ericoid forest and *Gleichenia* scrub.
Taxa commonest in ericaceous scrub.

Fig. 5.3
Summary pollen diagram for plots in the Danau di Atas region showing the composition of the dry land pollen in terms of source habitats


Plot
Forest
Forest, secondary forest and non-forest
Non-forest only
Non-forest & swamp
Swamp only
Various
FOREST
20
4
3
1
2
24
REGROWTH
16
17
18
19
SWAMP
5
6
7
8
9
10
11
12
13
0
20
40
60
80
100
Pollen sum = Dry Land Pollen
(excluding unidentified grains)

Spores of *Cyathea* comp. featured commonly in assemblages from non-forest sites. If the source was *Cyathea* spp. then these could be considered as a regional component of the spore rain, comparable with the regional component of the pollen rain, since *Cyathea* spp. often occur in the forests of the area. As expected, spores of *Gleichenia* comp. and *Pteridium* were particularly common at regrowth sites, as were Filices undifferentiated. Spores of *Lycopodium cernuum* were particularly abundant in plots on the Danau di Atas Swamp (plots 5-12).

In conclusion, it does appear that the non-forest sites act as a catchment for regional as well as local pollen deposition. Despite the openness of the vegetation around these sites the representation of the regional pollen component was generally low (10-27% TDLP), while locally produced pollen was abundant (50-80% TDLP). How the magnitude of pollen rain components may have varied in the past is considered in Section 5.7.

5.6 Pollen rain in the Gunung Kerinci area

Eleven surface samples from an altitudinal sequence on G. Kerinci were available as prepared slides. These samples covered the range 1935 m a.s.l. to 3315 m a.s.l. The vegetation sequence on G. Kerinci is described in Section 4.12. Full results of the palynological investigation of the samples are shown in Fig. 5.4, in which the pollen sum is Total Dry Land Pollen. Fig. 5.5 shows pollen curves for selected taxa, as percentage Total Arboreal Pollen, and includes data from a further eight samples from the area studied by Morley (1976). Two summary diagrams are also provided. Fig. 5.6 shows the composition of the arboreal pollen sum in terms of altitudinal forest types. Fig. 5.7 shows the dry land pollen sum in terms of most likely source habitats. Both summary diagrams also include Morley's data; the original pollen counts having been used for the calculation of all three figures. Details of the G. Kerinci samples studied are presented in the following section.

5.6a Pollen deposition in the G.Kerinci samples

The pollen assemblage obtained at 1935 m a.s.l. was dominated by pollen of *Symingtonia* (29% TDLP) although pollen of *Lithocarpus*/*Castanopsis* comp., and *Quercus* comp. was also common. Significant amounts of *Adinandra* comp., *Engelhardtia* comp., *Ilex* comp., *Macaranga* comp. and Myrtaceae type 1 were also recorded. Very little pollen of non-arboreal taxa occurred, but did include very small quantities of Compositae type 2 (Tubuliflorae), Cyperaceae and Gramineae. Pteridophyte spores occurred in relatively small amounts and included *Asplenium* comp. small, Dennstaedtiaceae comp., and Filices undifferentiated.

At an altitude of 2085 m a.s.l. the pollen assemblage included a number of common taxa, such as *Lithocarpus*/*Castanopsis* comp., *Quercus* comp., *Schima*, *Symingtonia*, *Symplocos* comp. and Myrtaceae type 1. Smaller amounts of *Adinandra* comp., *Altingia* comp., *Engelhardtia* comp., *Macaranga* comp., *Psychotria* comp., *Trema* comp. and *Schefflera* comp. 2 were also recorded. Pteridophyte spores were abundant and included *Asplenium* comp. small, Dennstaedtiaceae comp., Filices undifferentiated and *Gleichenia* comp.

The pollen assemblage obtained at 2240 m a.s.l. was dominated by Ilex comp. (35% TDLP) and Symingtonia (19% TDLP). Other taxa recorded included Engelhardtia comp., Ilex cymosa, Lithocarpus/Castanopsis comp., Quercus comp., Macaranga comp., Myrtaceae and Trema comp. Non-arboreal taxa were uncommon, but included Compositae type 5 (Tubiliflorae) and Gramineae. Pteridophyte spores were moderately abundant and included Asplenium comp. small, Cyathea comp. striate, Filices undifferentiated and Gleichenia comp.

The pollen assemblage recorded at 2395 m a.s.l. was dominated by Engelhardtia comp. (41% TDLP). Also present in significant amounts were Vaccinium comp., Lithocarpus/Castanopsis comp., Quercus comp., Symingtonia, Myrtaceae type 1 and Schefflera comp. 2. Pteridophyte spores were moderately abundant and included Cyathea comp. striate, Filices undifferentiated and Gleichenia comp.

At an altitude of 2545 m a.s.l. the pollen assemblage was dominated by Lithocarpus/Castanopsis comp. (60% TDLP). Other taxa recorded in small amounts included Quercus comp., Macaranga comp. and Vaccinium comp. The form taxon, tricolporate, more or less psilate, 12-15μm, accounted for 21% TDLP although source taxa were undefined. Pteridophyte spores occurred in small amounts and included Filices undifferentiated and Gleichenia comp.

The pollen assemblage obtained from 2700 m a.s.l. was dominated by Myrsine comp. (38% TDLP). Other numerically important taxa were Ardisia comp. and Symplocos sessilifolia sim.. Taxa recorded in smaller amounts included Lithocarpus/Castanopsis comp., Quercus comp., Trema comp., Myrica comp. and Macaranga comp. Pteridophyte spores were moderately abundant and were dominated by Gleichenia comp. (38%).

At an altitude of 2855 m a.s.l. the pollen assemblage was dominated by Ardisia comp. (32% TDLP) and Myrsine comp. (52% TDLP). Taxa such as Lithocarpus/Castanopsis comp. and Quercus comp. were present in very small amounts while some other taxa, such as Symplocos sessilifolia sim. and Myrica comp. were represented by small but significant amounts of pollen. Pteridophyte spores were poorly represented.

Ardisia comp. and Myrsine comp. remained well represented at 3010 m a.s.l., although the sample was dominated by Myrica comp. (51% TDLP). Rhododendron comp. and Vaccinium comp. also featured in this sample. Non-arboreal taxa and pteridophytes were present in small amounts, and Lycopodium cernuum was moderately common.

The pollen assemblage from 3070 m a.s.l. was dominated by Myrica comp. (87% TDLP). Other taxa occurring in small amounts included Quercus comp., Myrsine comp., Trema comp. and Rhododendron comp. Pteridophyte spores were uncommon.

The pollen assemblage from 3175 m a.s.l. contained abundant Myrica comp. (32% TDLP) while a number of other taxa were numerically important. These included Ardisia comp., Macaranga

Fig. 5.4
Modern pollen rain from G. Kerinci

comp., *Myrsine* comp. and *Rhododendron* comp. Other taxa recorded included *Altingia* comp., *Lithocarpus*/*Castanopsis* comp., *Quercus* comp. and *Trema* comp. Pteridophyte spores remained relatively uncommon and included Filices undifferentiated and *Lycopodium cernuum*. *Gentiana* pollen was also recovered.

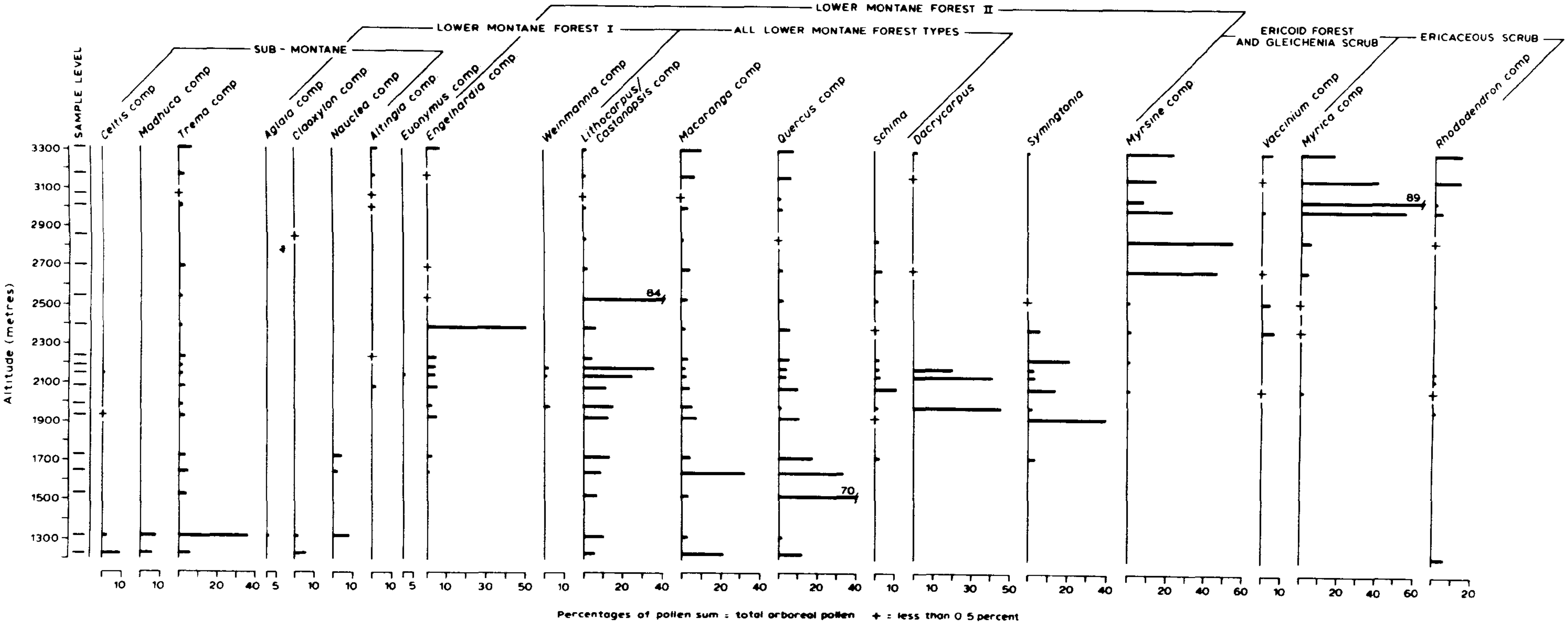
A relatively mixed assemblage was recorded from 3315 m a.s.l., the highest sample examined. This included common *Myrsine* comp. (19% TDLP), *Myrica* comp. (14% TDLP) and moderate amounts of *Rhododendron* comp., *Vaccinium* comp., *Trema* comp., *Macaranga* comp., *Quercus* comp. and *Engelhardtia* comp. Other taxa recorded included *Dacrycarpus*, *Altingia* comp., *Lithocarpus*/*Castanopsis* comp., Compositae (Tubuliflorae), Cyperaceae and *Gentiana*. Pteridophyte spores remained relatively uncommon.

5.6b Discussion

Major changes in the pollen assemblages occur with altitude, and comparison of these with the present vegetation shows that the two are closely related. The lower altitude samples, from 1935 m to 2545 m a.s.l. were dominated by the pollen of lower montane forest elements, which were themselves common up to c. 2400 m a.s.l. This pollen included *Lithocarpus*/*Castanopsis* comp., *Engelhardtia* comp., *Quercus* comp. and Myrtaceae. These pollen types were infrequent in samples from above 2545 m a.s.l., with the exception of the highest sample, 3315 m a.s.l.

Even within the lower montane forest there were some differences in pollen deposition, as shown in Fig. 5.5. This shows the pollen curves of selected taxa expressed in terms of Total

Fig. 5.5
Modern pollen rain from the G. Kerinci area, showing selected arboreal taxa only, and incorporating the results of Morley (1976)


LOWER MONTANE FOREST II
LOWER MONTANE FOREST I
ALL LOWER MONTANE FOREST TYPES
SUB - MONTANE
ERICOID FOREST AND GLEICHENIA SCRUB
ERICACEOUS SCRUB
SAMPLE LEVEL
Altitude (metres)
Celtis comp
Madhuca comp
Trema comp
Aglaia comp
Claoxylon comp
Nauclea comp
Altingia comp
Euonymus comp
Engelhardia comp
Weinmannia comp
Lithocarpus/ Castanopsis comp
Macaranga comp
Quercus comp
Schima
Dacrycarpus
Symingtonia
Myrsine comp
Vaccinium comp
Myrica comp
Rhododendron comp
3300
3100
2900
2700
2500
2300
2100
1900
1700
1500
1300
84
70
89
Percentages of pollen sum = total arboreal pollen
+ = less than 0.5 percent

Arboreal Pollen, and includes data from sites studied by Morley (1976).

Taxa such as *Celtis* comp., *Madhuca* comp. and *Trema* comp. which are derived from taxa more or less confined to sub-montane forest tended to be represented in the pollen rain only at the low altitude sites, 1230 m and 1320 m a.s.l. *Trema* comp. was found in smaller amounts at most sites irrespective of altitude, which seems to confirm that it is transported uphill rather easily.

Pollen taxa such as *Aglaia* comp., *Claoxylon* comp. and *Nauclea* comp., which have their source in sub-montane forest and lower montane forest I were not particularly well represented in pollen assemblages. Even so, they still tended to be found in the lower altitude samples especially from below c. 1400 m a.s.l.

Altingia comp. and *Euonymus* comp. were likewise not well represented in the pollen assemblages. *Altingia* comp. was represented in some samples from high altitudes, presumably a result of uphill transport since the sources of this pollen occur in lower montane forest I.

Weinmannia comp. and *Engelhardtia* comp. were found predominantly in assemblages from 1650 m to 2395 m a.s.l. This corresponds closely with the altitudinal range of the source taxa which occur in lower montane forest I and II.

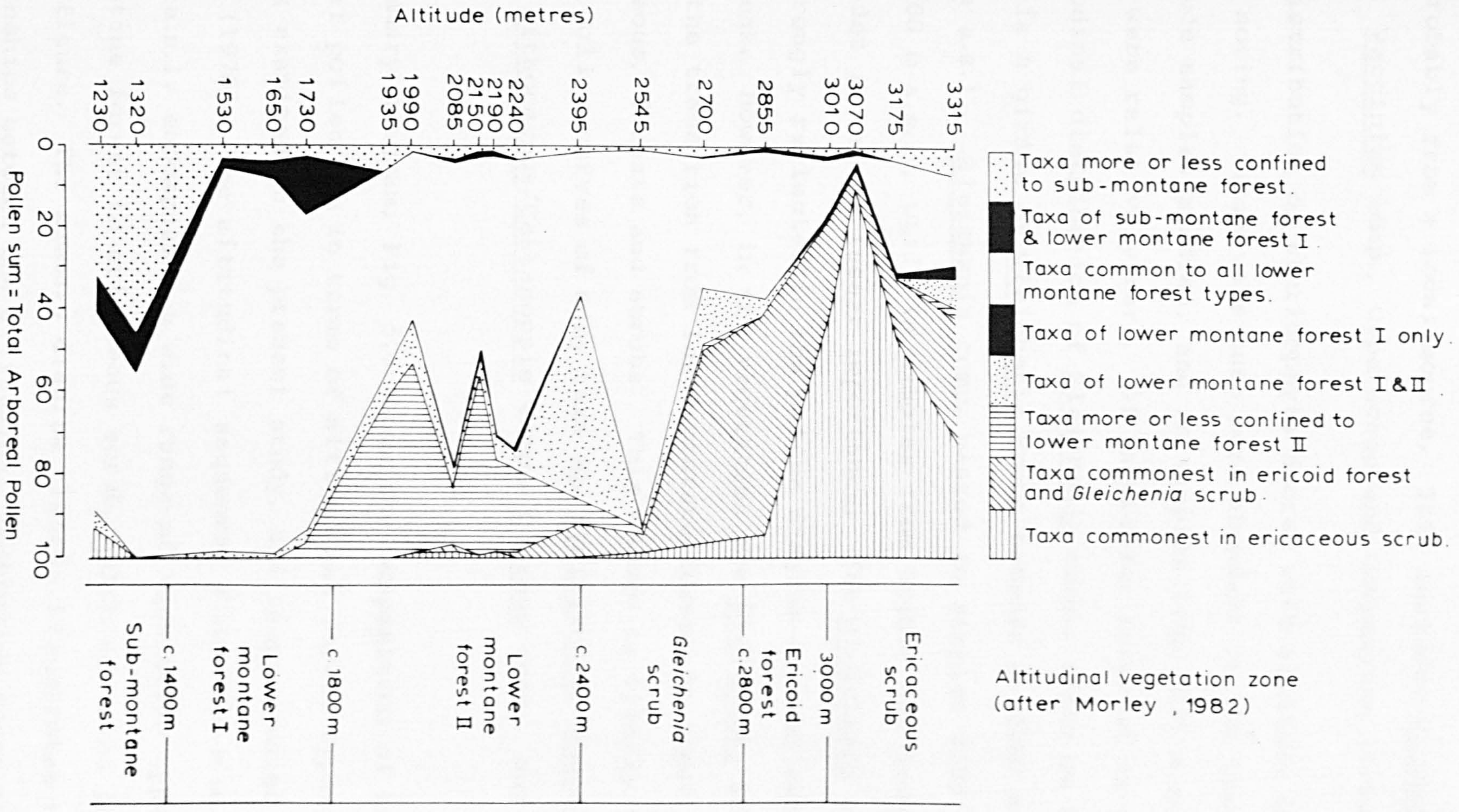
Dacrycarpus and *Symingtonia* pollen was found predominantly in assemblages from lower montane forest II which is where the source taxa occur. *Dacrycarpus* was common in pollen assemblages from 1990 m to 2190 m a.s.l. while *Symingtonia* was common from 1935 m to 2395 m a.s.l. Both occurred rarely in samples from other altitudes.

From 2700 m to 3175 m a.s.l. the pollen assemblages (Fig. 5.4) were dominated by pollen of *Ardisia* comp., *Myrsine* comp. and *Myrica* comp. with, occasionally, *Rhododendron* comp. The source of most of this pollen was the ericaceous forest and scrub which presently occurs above 2800 m a.s.l. on the mountain. *Myrsine* comp. and *Ardisia* comp. were fairly common in all of the samples 2700 m to 3175 m a.s.l., although *Myrsine* comp. peaked in samples 2700 m to 3010 m a.s.l. *Myrsine* comp. is derived mainly from the genus *Myrsine* (some *Rapanea* spp. are now *Myrsine* spp.). This is common in the vegetation of G. Kerinci between the altitudes of c. 2700 m and c. 3000 m (Section 4.12). Elsewhere *Myrsine* is also found widely distributed in elfin and mossy forests in Java, between 1800 m and 3000 m a.s.l., according to van Steenis (1972).

Myrica comp. peaked in samples from 3010 m to 3175 m a.s.l. *Myrica javanica* is the most likely source of this pollen and was recorded in Kerinci plot 2 at 3010 m a.s.l. (Section 4.12a). Morley (1976) also describes this species as occurring on G. Kerinci between 3000 m and 3100 m a.s.l., while Jacobs (1958) found it to occur to a maximum altitude of 3200 m a.s.l. on the mountain. *Rhododendron* comp. pollen also increased in abundance in the samples from 3010 m a.s.l. and above. This may have been derived to a large extent from *Rhododendron retusum*, a species which was common in Kerinci plot 2 (3010 m a.s.l.) and at higher altitudes, almost to the altitudinal limit of vegetation (Section 4.12). The Gentiana pollen recorded at 3315 m and 3175 m a.s.l. was probably derived from G. sumatrana, as this occurs on the mountain above 3000 m a.s.l. according to Jacobs (1958). It seems, therefore, that even within the ericoid forest and ericaceous scrub zones, the pollen rain reflects the vegetation to a considerable extent.

The sample from 3315 m illustrates the effect of pollen deposition in more open conditions. The vegetation at this altitude is not continuous, and in Kerinci plot 1 (Section 4.12a) about 40% of the area was bare ground. The sample from this altitude contained relatively high percentages of pollen derived from the vegetation of lower altitudes, which had been transported uphill. The predominance of uphill movement in mountainous areas has long been recognized and described (eg. Rudolf and Firbas, 1926; Flenley, 1973). That it was particularly noticeable in the sample from 3315 m may have been related to relatively low local pollen production. Elsewhere, other workers such as Salgado-Labouriau (1979) have recognized that where local pollen production is low, such as on sparsely vegetated high mountains, the relative importance of imported pollen is increased. The sudden increase in the quantities of montane forest elements represented in sample 3315 m might well be an indication of low local pollen production, although this cannot be confirmed since no absolute pollen data is available. Some of the pollen recorded in the assemblage of sample 3315 m

Fig. 5.6
Summary pollen diagram for the G. Kerinci area showing the composition of the arboreal pollen in terms of altitudinal forest types

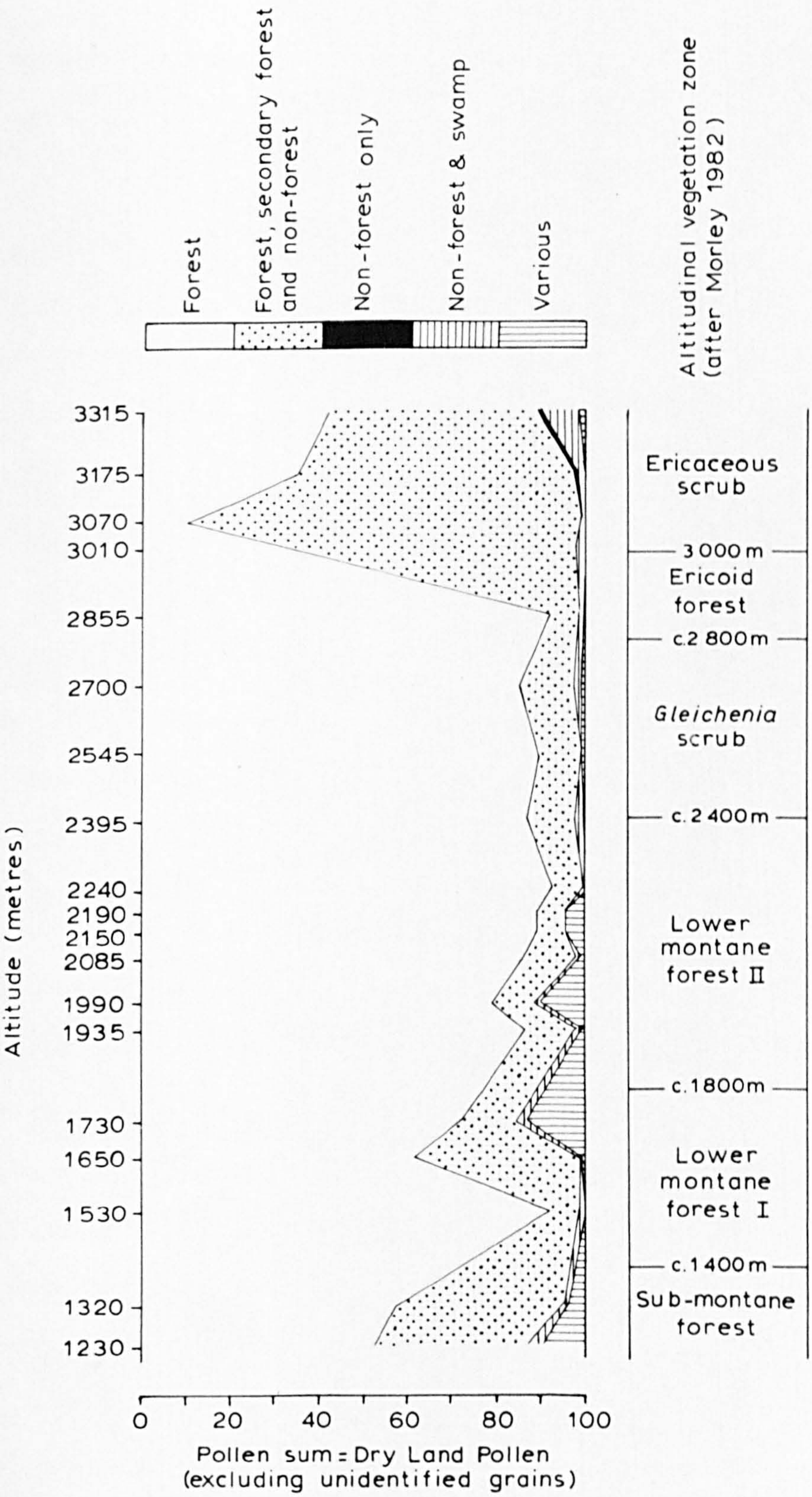

Altitude (metres)
1230
1320
1530
1650
1730
1935
1990
2085
2150
2190
2240
2395
2545
2700
2855
3010
3070
3175
3315
0
20
40
60
80
100
Pollen sum = Total Arboreal Pollen
Taxa more or less confined to sub-montane forest.
Taxa of sub-montane forest & lower montane forest I.
Taxa common to all lower montane forest types.
Taxa of lower montane forest I only.
Taxa of lower montane forest I & II
Taxa more or less confined to lower montane forest II
Taxa commonest in ericoid forest and *Gleichenia* scrub.
Taxa commonest in ericaceous scrub.
Sub-montane forest
c. 1400m
Lower montane forest I
c. 1800m
Lower montane forest II
c. 2400m
Gleichenia scrub
c. 2800m
Ericoid forest
3000 m
Ericaceous scrub
Altitudinal vegetation zone (after Morley, 1982)

was probably from a local source. This included *Rhododendron* comp., *Vaccinium* comp., Cyperaceae and Compositae (Tubuliflorae).

The distribution of pteridophyte spores with altitude is also worth noting. These were much more abundant in the lower altitude samples studied, and in samples from 2855 m a.s.l. and above were relatively rare. Of particular interest is the altitudinal distribution of *Gleichenia* comp., since on G. Kerinci there is a girdle of *Gleichenia* scrub between c. 2400 m and c. 2800 m a.s.l.. *Gleichenia* comp. peaked in samples 2395 m, 2545 m and 2700 m a.s.l., while in samples from higher and lower altitudes it was of lesser importance. The *Gleichenia* girdle is not strongly reflected in the pollen diagram as such except by this peak. However, in the vegetation the *Gleichenia* scrub zone marks the transition from lower montane forest to upper montane, ericaceous, forests and scrubs. This change is clearly visible in the pollen curves of many taxa eg. *Symingtonia*, *Engelhardtia* comp., *Lithocarpus*/*Castanopsis* comp., *Quercus* comp. and *Myrsine* comp.

The summary diagram, Fig. 5.6 shows the composition of the arboreal pollen sum in terms of altitudinal forest types, for the samples examined in the present study, and those studied by Morley (1976). The altitudinal sequence, from 1230 m a.s.l. to 3315 m a.s.l. encompasses a wide range of vegetation types, from sub-montane forest to ericaceous scrub, which are also indicated on the figure. The summary diagram clearly illustrates the relationships between the altitudinal vegetation zones and the pollen rain. Where pollen taxa can be allocated to a specific

Fig. 5.7
Summary pollen diagram for the G. Kerinci area showing the composition of the dry land pollen in terms of source habitats


Forest
Forest, secondary forest and non-forest
Non-forest only
Non-forest & swamp
Various
Altitudinal vegetation zone (after Morley 1982)
Altitude (metres)
3315
3175
3070
3010
2855
2700
2545
2395
2240
2190
2150
2085
1990
1935
1730
1650
1530
1320
1230
0
20
40
60
80
100
Pollen sum = Dry Land Pollen (excluding unidentified grains)
Ericaceous scrub
3000 m
Ericoid forest
c.2800 m
Gleichenia scrub
c.2400 m
Lower montane forest II
c.1800 m
Lower montane forest I
c.1400 m
Sub-montane forest

altitudinal forest type, then most of the pollen is normally deposited within the altitudinal range of the forest type. Where movement out of the source area occurs, the movement is predominantly uphill. There are some exceptions to this, notably a downhill tail of ericaceous scrub pollen. However this movement of pollen downhill may be apparent rather than real, due in major part to problems in allocating pollen taxa to the altitudinal categories. The peak of 'ericaceous scrub' pollen at 1230 m is due to the presence of Rhododendron comp. in the pollen assemblage. In this case the source of the pollen is likely to have been Rhododendron sp. growing in other habitats, possibly swamps, rather than in the ericaceous scrub zone. This example illustrates one type of problem experienced in pollen analysis in the montane tropics, caused by the wide range of habitats which may be occupied by source taxa of a single pollen type.

Also of interest in the summary diagram (Fig. 5.6) is the occurrence, at almost all altitudes, of small amounts of pollen derived from taxa more or less confined to sub-montane forest. Much of this pollen is comprised Trema comp. This taxon appears to be extremely well dispersed and other studies (Morley, 1976) have also shown that it is capable of being transported long distances. The implications of this are that small percentages of Trema comp. in a pollen assemblage do not indicate that its source was growing in proximity to the sampling site.

The summary diagram, Fig. 5.7, shows the composition of the dry land pollen sum in terms of source habitats. As might be expected, pollen derived from forest dominates at all sites below 2855 m a.s.l. At 3010 m a.s.l. and above taxa having a forest, secondary forest or non-forest source increase in importance, due to the inclusion of *Myrica* comp., *Rhododendron* comp. and *Vaccinium* comp. in this category. Pollen from non-forest or swamp also increases in importance in the sample from 3315 m a.s.l. reflecting the more open conditions at this altitude, and the importance of Cyperaceae (*Carex* sp.) in the vegetation.

5.7 Conclusions about the modern pollen rain in the Danau di Atas region, and on G. Kerinci

The present studies reveal a number of the characteristics of the pollen rain in the Danau di Atas region and on G. Kerinci. These are summarized in the following section.

In these areas, at deposition sites entirely within the forest, the bulk of the deposited pollen is derived from arboreal taxa, and further, much of this is from higher trees, notably those forming the canopy. Small trees and low growth forms contribute relatively little pollen. This is in agreement with the findings of Morley (1976) and Kershaw and Hyland (1975). Within the forests much of the pollen deposited, even from arboreal taxa, appears to have a local source, and therefore represents the surrounding vegetation reasonably well. However non-representation and under-representation of some taxa is always a problem. Where forest pollen is deposited in a site outside the forested area the contribution of canopy taxa is even more important relative to that from the understory and low growth forms.

At non-forest deposition sites a high proportion of the pollen is very local in origin and comprises in large part non-arboreal taxa. However, at all sites there is a significant regional pollen component, derived from arboreal taxa, despite the extensive forest clearance which has occurred and the quite large distances (up to 4 km) from some of the deposition sites to the remaining areas of forest. The regional component recorded at these sites, with few exceptions, makes up 10-27% TDLP. At these sites a third pollen component can also be recognized, having a source intermediate between local and regional.

On G. Kerinci, a high mountain having several altitudinal vegetation zones, pollen deposited at different altitudes shows a close relationship with the surrounding vegetation, demonstrating that the altitudinal vegetation types on such a peak do have reasonably characteristic pollen spectra. The bulk of the pollen produced by a particular vegetation type appears to be deposited within the altitudinal range of that type. Some movement of pollen away from source areas does however occur, and this is predominantly an uphill movement.

Since these studies were carried out to aid the interpretation of fossil spectra from two swamp sites in the area, and particularly the Danau di Atas Swamp site, it is worth considering further the present sources of pollen at such a site, and how these might have varied in the past.

The Danau di Atas Swamp lies adjacent to the large lake of the same name. At some point in the past it may itself have been a body of open water, more or less continuous with the main lake. However it seems unlikely that the circulation of water in the main lake would be strongly linked with that in the area now occupied by the swamp, due to the sheltered nature of the latter and the relatively small area of contact between the two. The present junction of the swamp and the lake is of short length relative to the length of the swamp, and the latter is surrounded by dry land for most of its perimeter (Fig. 4.6). These surrounding dry land areas take the form of low, undulating land, separating the swamp from the lake on the west and from lower lying areas of cultivated land to the east. A small stream appears to flow into the northern end of the swamp, but disappears below the surface, at least at the drier times of the year. The source of this stream is also very local, being in the low undulating area described previously.

The present pollen deposition at the Danau di Atas Swamp has been studied using the series of surface samples from plots 5-12. At these sites a large percentage of the pollen appears to be derived from local, non-arboreal vegetation, with some having an intermediate source but there are also significant amounts of regional pollen. The latter is mainly derived from canopy trees but clearly not all taxa currently found in the forests are represented in this. At the present time much of the pollen deposited on the swamp surface is probably contributed by aerial deposition with perhaps some washed from the surrounding areas by surface runoff, although these areas are of limited extent. The stream is unlikely to contribute to the surface pollen spectra except perhaps at the wettest times of year when the water table is higher and some water may flow across the surface of the swamp. Even so the stream is local in origin and thus its contained pollen and spores may be similar in nature to those in the surface runoff.

Aerial deposition is the only source of regional pollen. This may be deposited directly onto the swamp surface, or may be deposited onto the surrounding areas and be washed in by the stream or surface runoff. The present sources of this regional arboreal pollen could lie in any of the remaining forested areas. These include the extensive areas to the west of Danau di Atas, and on the flanks of G. Talang. There are also areas to the south-east and north-east of the lake and remnants on the ridges to the east of Danau di Baruh. Many of these lie at higher altitudes than the swamp with the exception of areas to the west. The extent to which uphill wind movements may affect pollen deposition is difficult to determine. It might be of a different order from that on G. Kerinci since the topography is less steep. However, if there is any tendency for pollen to be moved uphill then this is likely to be from the lower lying forested areas to the west of the lake. This was also the predominant direction of winds during the time that field work was carried out.

Formerly the forest cover in the Danau di Atas area was probably more extensive than at present. If the Danau di Atas Swamp remained unforested at this time then deposition of pollen components may have been similar to that of today. However, arboreal taxa would have contributed more pollen than at present if forests occurred in closer proximity to the swamp. In fact, with forest occurring adjacent to the swamp then much of the arboreal pollen deposited may have had a fairly local source rather than a regional one. However, it is still likely that a significant percentage of the arboreal pollen deposited at the site would be regional in origin. The better representation of arboreal taxa in the pollen spectrum would also provide a better picture of the composition of the forest as a whole than is provided by modern surface samples from the swamp, although some taxa would still be subject to non-representation, thus continuing to provide some problems for interpretation.

Occurrence of swamp forest vegetation at the swamp site might lead to some reduction in the importance of the regional component of the pollen rain, through filtration effects. Even so the local arboreal pollen is likely to be well represented in the pollen assemblages. Non-arboreal taxa tend to contribute little to the pollen assemblages from forested areas at present and might be similarly affected if swamp forest occupied the site.

The presence of open water at the Danau di Atas Swamp site may also have affected pollen deposition patterns. The contribution by inflowing streams might be of increased importance, although if the topography of the area has remained fairly similar to the present then these would also have a local source.

The significance of uphill movement of pollen in the past is difficult to ascertain, particularly if wind systems may have been affected by changing climate. However it is likely that most pollen deposited in the past would be derived from the vegetation of the surrounding areas.

The present pollen deposition patterns at the Telago Swamp were not studied. However this site is landlocked, with a single small, probably intermittent, inflow stream from the local area. Pollen deposition at this site is therefore likely to be predominantly aerial, with perhaps some pollen washed in by surface runoff from surrounding slopes. Patterns of pollen deposition at the site in the past were probably similar.

CHAPTER 6

STRATIGRAPHY AND POLLEN ANALYSIS OF THE DANAU DI ATAS CORE

6.1 Collection of the Core

The Danau di Atas core was collected in two sections from an area of the Danau di Atas Swamp at 1535 m a.s.l., which was thought to hold deep sediments. The Danau di Atas Swamp is itself a side arm of the lake of the same name, and is about 800 m long and 200 m wide (see Plate 11). The immediately surrounding area consists of low deforested hummocky land. A sketch map of the swamp, which shows the location of the coring site was provided in Chapter 4 (Fig. 4.6). I am indebted to Dr J.R. Flenley, who undertook the actual collection of the core.

Initial sampling, in 1976, provided a core 6.5 m in length. A Russian sampler was used to obtain the section from 0 to 5.75 m, using one hole rather than the preferred two. This was due to the presence of large amounts of wood in the sediment, which caused problems from the start of coring. At 5.75 m an auger had to be used as wood prevented further use of the Russian sampler. Sediment was collected by this method from 5.75 m to 6.5 m, although some contamination may have occurred at these depths due to the use of the auger. Use of the auger showed at least 10 m depth of sediment at the site.

Subsequently, in July 1977, a further core was taken at the same spot, as measured in from the swamp edge and ricefield bunds. Dr Flenley suggests that the maximum possible horizontal distance between the two sampling sites was 10 m. The second section of core was collected using a Hiller sampler, with one hole only, and the top 5 m of sediment was ignored. Sediment was collected from 5 m to 16.5 m which was not thought to be the base of the sediment.

On each occasion the whole sections of core were transported in plastic drain piping to the Hull laboratory, where they were stored at c. 5°C until they could be analysed. The two core sections have been treated as one core, with an overlapping section , for the purposes of this study.

The problems encountered in the extraction of the core were such that a borehole transect at the swamp site was not constructed.

6.2 Stratigraphy of the core

The stratigraphic characteristics of the Danau di Atas (DDA) core sections were not, unfortunately, recorded in the field. However, the core was examined in the laboratory, and the lithological characters observed are shown in Table 6.1. There are no stratigraphic indications that the overlap sections are not from sediments of similar age.

The percentage weight loss on ignition was calculated for a number of depths throughout the core, as described in Section 3.4. This gives an indication of the relative changes in the organic carbon content of the sediment. The results obtained are shown in Fig. 6.2. Values for percentage weight loss on ignition decline gradually from 80-90% at the surface of the core to 70-80% at 12.20 m. Below this depth the values decline quite

TABLE 6.1

The stratigraphy of the Danau di Atas core

Depth (m)	Description
0 -1.2	Very fibrous vegetation mat, containing many roots
1.2-2.0	Coarse, herbaceous, detritus mud, containing large amounts of leaves and roots, but not woody
2.0-2.5	Coarse herbaceous, detritus mud, with large detritus fragments, but fewer fragments from 2.3-2.5m
2.5-3.0	Coarse, herbaceous, detritus mud
3.0-3.5	Very woody, coarse detritus mud
3.5-4.0	Very woody, coarse detritus mud, with some very large wood fragments
4.0-5.5	Coarse, very woody, detritus mud
5.5-6.5	Coarse detritus mud with many large woody fragments
5.0-11.0	Coarse, woody, detritus mud. Detritus slightly finer between 9.0 and 10.0m
11.0-12.0	Coarse, herbaceous, detritus mud with a few woody fragments
12.0-13.9	Coarse, herbaceous, detritus mud. Some small woody fragments at c.13.0m. Decreased amounts of detritus below 13.5m
13.9-14.5	Fine detritus mud with small amounts of silt
14.5-16.5	Fine detritus mud with silt

rapidly until c. 14.10 m. Thereafter the values are generally in the range 45-55%. These changes relate broadly to other changes in the lithology of the core as described in Table 6.1. In particular, the lowest values of percentage weight loss on ignition, and therefore the lowest organic carbon content are found at the base of the core, below c. 14.00 m. In this section the deposit contains silt as well as organic material.

6.3 Radiocarbon dating of the core

All samples for ^{14}C dating were taken directly from the core. For each determination a section 10 cm in length was selected for analysis. The ^{14}C dates obtained are listed in Table 6.2. All dates quoted in connection with the DDA core and the Telago core are uncorrected radiocarbon years before 1950. Initially two samples, from 13.15-13.25 m and 15.60-15.70 m were sent to Geochron Laboratories for analysis. The larger than normal counting error in these samples was attributed by Geochron to the limited size of the sample. Further samples were analysed at the NERC laboratory of the Scottish Universities Research and Reactor Centre, who did not suggest any problems in dating due to limited sample size. However, the basal age of the initial series of five samples which they analysed (SRR - 1350) showed an apparent marked discrepancy with the Geochron values. Consequently, a sample from an intermediate depth was sent for rechecking. The result (SRR - 1487) confirmed an apparent inversion in the ages of samples between 13.15 m and 14.25 m (Table 6.2). Two further samples were also analysed, giving a total of ten ^{14}C dates on

TABLE 6.2

Radiocarbon dates obtained for the Danau di Atas core

Sample no.	Sample depth (m)	Age (^{14}C years B.P.)	δ^{13}C
SRR-1900	1.30-1.40	4520 ± 50	-27.3‰
SRR-1346	2.60-2.70	6850 ± 60	-27.0‰
SRR-1347	5.25-5.35	11710 ± 110	-26.7‰
SRR-1348	7.80-7.90	13160 ± 170	-26.5‰
SRR-1349	10.55-10.65	16930 ± 170	-26.5‰
GX-4915	13.15-13.25	23250 +1220 -1060	Not available
SRR-1487	13.75-13.85	21180 +580 -540	-24.2‰
SRR-1350	14.15-14.25	18250 ± 290	-24.6‰
SRR-1901	14.60-14.70	22370 ± 320	-25.3‰
GX-4916	15.60-15.70	31450 +2990 -2180	Not available

the 16.5 m sequence.

The inversion of dates between 13.15 m and 14.25 m is of interest. There are a number of possible explanations for this. One possibility is that the inversion is not real, being due instead to sample error. However, the number of samples involved, and absence of such problems elsewhere in the sequence, suggests that this is not the case. A more likely explanation is that some time after c. 18250 years B.P., redeposition of older deposits has occurred in the sequence. Redeposition may have taken the form of slumping of a mass of material from elsewhere in the depositional basin. Such an event could easily be precipitated by tectonic activity. However, the ordered age sequence of the reversal, 23250 + 1220-1060 at 13.15-13.25 m, 21180 + 580-540 at 13.75-13.85 m and 18250 ± 290 at 14.15-14.25 m suggests the possibility of a more ordered redeposition of the sediments. This might have occurred if some of the deposits in the basin had been exposed by a lowering of lake level, with subsequent erosion and redeposition in the basin of the marginal deposits, with the youngest being affected first. Changes in lake level might be a result of changes in climate, but equally, at this site, could be due to tectonic or volcano-tectonic events, or changes in geomorphology. There is some evidence, provided by terraces around the shores of Danau di Atas, of lake levels 9 m higher than present, possibly related to the capture of the lake by the R. Gumanti (Verstappen, 1973) as described earlier, in Section 2.2. It is possible to envisage an event of this kind leading to a fall in lake level with subsequent erosion and redeposition of marginal sediments. There is no direct evidence, however, to favour any one of these particular explanations of the date inversion in this sequence.

Maloney (1984a) suggests that 'dead' carbon, having no ^{14}C, emitted during volcanic eruptions can account for inverted ^{14}C dates in volcanically active areas, since it is taken up by plants, giving old ages when their remains are dated. However, this explanation is not considered to be a likely cause of the inverted dates in this sequence. The reasons for this are that the sediments contain no volcanic ash which would indicate volcanic activity during this period, and because evidence from sediment accumulation rates and pollen influx (see later this Section and Sections 6.6 and 6.7) supports the idea of redeposition as discussed above.

Accumulation rates for the sediments can be calculated from the ^{14}C dates, and are necessary for calculation of pollen influx values. A diagram showing age with depth of sediments for the DDA core is presented in Fig. 6.1. From this it can be seen that accumulation rates have not been constant for the entire duration of sediment deposition at the site, although some very lengthy periods of apparently fairly constant accumulation rates have occurred (see also Table 6.3).

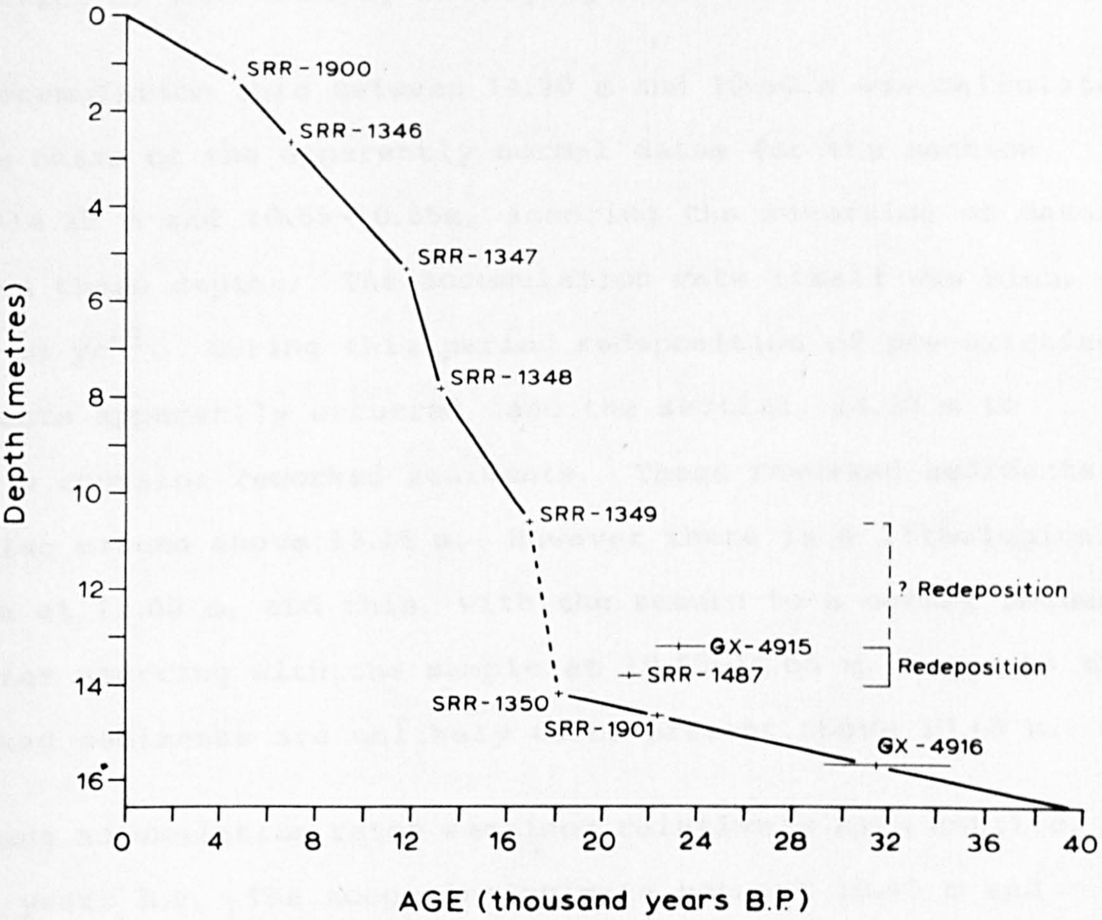
From 15.65 m to 14.20 m (c. 31450 to c. 18250 years B.P.) the sediment accumulation rate was 0.110 mm yr^{-1}. Extrapolating this rate to the base of the core at 16.50 m, a basal age for the core of 39188 years B.P. is obtained. This relatively slow

TABLE 6.3

Sediment accumulation rates for the Danau di Atas core.

Depth (m)	Accumulation rate (mm yr^{-1})
0.00 -1.35	0.299
1.35 -5.30	0.550
5.30 -7.85	1.759
7.85 -10.60	0.729
10.60-14.20	2.727
14.20-15.65	0.110

Fig. 6.1
Age-depth details for the DDA core



Horizontal bar shows error on date (1σ)

accumulation rate may be due in part to post-depositional compaction of sediments by overlying material.

The accumulation rate between 14.20 m and 10.60 m was calculated on the basis of the apparently normal dates for the section 14.15-14.25 m and 10.55-10.65m, ignoring the inversion of dates between these depths. The accumulation rate itself was high, 2.727 mm yr^{-1}. During this period redeposition of pre-existing sediments apparently occurred, and the section 14.20 m to 13.15 m contains reworked sediments. These reworked sediments may also extend above 13.15 m. However there is a lithological change at 11.00 m, and this, with the return to a normal sequence of dates starting with the sample at 10.55-10.65 m, suggests that reworked sediments are unlikely to be present above 10.65 m.

Sediment accumulation rates remained relatively high until c. 11710 years B.P. The accumulation rate between 10.60 m and 7.85 m (c. 16930 to c. 13160 years B.P.) was 0.729 mm yr^{-1}, and between 7.85 m and 5.30 m (c. 13160 to c. 11710 years B.P.) was 1.759 mm yr^{-1}.

The accumulation rate over the top section of the core decreased. Between 5.30 m and 1.35 m (c. 11710 to c. 4520 years B.P.) the rate was 0.550 mm yr^{-1}. However if this rate is extrapolated to the present day then a further c. 1 m of deposit would be expected at the surface. The accumulation rate over the last 1.35 m had therefore decreased still further, or else erosion or human interference has reduced the level of the swamp surface. Man may indeed have affected the present development of the swamp surface by interfering with the vegetation such as by planting rice, or allowing domestic animals such as water buffalo onto the swamp. He may even have removed material, such as wood, from the superficial deposits as was observed on swamps elsewhere (Section 2.1). However, the change in lithology at 1.20 m depth (Table 6.1) indicates that a change in accumulation rate is not unlikely. Assuming this to be the case, then the rate of sediment accumulation between 1.35 m and 0 m (c. 4520 years B.P. to presumed present) is 0.299 mm yr^{-1}.

6.4 Pollen analysis of the core

6.4a Introduction

A total of 36 samples from the core were analysed palynologically. They comprised 13 from the upper section , including the topmost sample, 0-0.01 m, and 23 from the lower section . The sample interval was thus approximately 0.5 m. Preparation and counting of samples was as described in Chapter 3 and Appendix 2.

Figure 6.2 shows the values for all taxa identified from the core as a percentage of Total Dry Land Pollen (TDLP). A total of 143 distinct palynomorph types were identified although a number of types remained unidentifiable or unclassifiable. Fig. 6.2 also shows the lithology, ^{14}C dates and percentage weight loss on ignition as determined for the core. The arrangement of palynomorph taxa in the diagram is as described previously (Section 5.3).

Two summary diagrams are also provided. Fig. 6.3 shows the composition of the arboreal pollen sum in terms of altitudinal forest types. Fig. 6.4 shows the dry land pollen sum in terms of source habitats. Both types of summary diagram were defined in Section 5.3.

6.4b Zonation of the pollen diagram

Since the main aim of pollen diagrams is to document vegetation change through time, it is normally found convenient to zone them, as this is one way of aiding interpretation. A pollen zone is usually a part of a pollen diagram with internal constancy, and was defined by Gordon and Birks (1972) as "a body of sediment with a consistent and homogenous fossil pollen and spore content that is distinguished from adjacent sediment bodies by the differences in the kind and frequencies of its contained pollen grains and spores". However, it is also possible to zone pollen diagrams such that zones describe sections in which change is taking place.

Zones may be placed by the observer, although if data is large and complex it may be difficult to interpret a diagram consistently and thus there may be difficulties in placing zones. Zones placed by the observer may also be subjective in that they tend not to be placed on the basis of all pollen types equally but only on the basis of the most abundant. As it is also difficult for consistent and comparable results to be produced by different analysts, numerical techniques have also been developed for the zonation of pollen diagrams. Approaches to the problem include the stratigraphical approaches of Gordon and Birks (1972) using constrained agglomerative and constrained divisive procedures, and P.C.A. and non-metric multidimensional scaling techniques (Birks, 1974). The POLZON programme uses three separate analyses to suggest the most appropriate zonation for a data set, based on separating the data into zones of internal constancy. The analyses are a constrained agglomerative procedure, CONSLINK, and two constrained divisive procedures, each using a different measure of variance, SPLITINF and SPLITSQ. SPLITINF divides the data on the basis of its total information content while SPLITSQ divides the data on the basis of sum of squared deviations (Gordon and Birks, 1972). POLZON is a commonly used zoning technique, and the method was selected for use with the Danau di Atas pollen data. The programme was first however, modified by Dr K. Richards at Hull University in order to accommodate the large data set involved.

Four varied data sets were used with the POLZON analysis, to test the effect on zonation of excluding certain aspects of the data which are known to be highly variable, such as spores. In two of the data sets, very rare palynomorphs, not occurring as greater than 0.5% TDLP in any sample, were also excluded. The four data sets on which analysis was carried out were:

i) All dry land and aquatic pollen, excluding spores and unknown grains.

ii) Dry land pollen only, excluding unknown grains.

iii) All pollen and spores occurring as greater than 0.5% TDLP in any sample.

iv) Dry land pollen only, occurring as greater than 0.5% TDLP in any sample.

For the purposes of this analysis the two core sections were treated as one, and samples from overlapping sections were arranged for the analysis according to depth.

Results produced by the POLZON analysis were very disappointing, and did not fulfil their intended purpose, namely to be useful as an aid in interpretation. The results of the analysis are provided in Appendix 7, and only a brief discussion of the results and problems with the analysis will be outlined below. The results of POLZON were not subsequently used to zone the DDA data set.

The extreme variability inherent in the DDA data set appears to have been the main problem for pollen zonation using POLZON, and particular problems were encountered for samples between 2.20 m and 5.60 m. Although the POLZON analysis consistently suggested a zone boundary between the surface sample 0 m, and 0.55 m, and also one between 3.20 m and 3.70 m, the fluctuations in pollen frequencies between samples over the section 2.20 m to 5.60 m resulted in zone boundaries being suggested for points between whole series of adjacent samples. Hence, the extreme variability of the upper section dominated the analysis, and very few main zone boundaries were suggested for the lower section of the diagram. This problem occurred with all data sets analysed. The section of overlap between the two cores caused less of a problem, although a possible boundary was suggested in the analysis between samples 5.60 m and 5.70 m.

Some of the sample variability observed may relate to the rich and varied species composition of the montane tropical vegetation itself. If many species act independently of each other, and react at different rates to environmental change, then it is easy to envisage a situation where zonation of pollen diagrams is of limited use in ecological terms. In fact, even where such diagrams are zoned the pollen curves will also act independently so that while pollen frequencies for some taxa may be fairly constant within a zone, important changes may occur in the pollen curves of other taxa within the same zone. There is perhaps, therefore, some justification for interpreting pollen curves individually, rather than dividing the whole data set into zones. However, such an approach could be a very difficult and time consuming method of interpreting large data sets.

A zonation has been produced for the DDA data set. This is largely for convenience of description and in no way is it meant to suggest that these zones are necessarily of regional importance, since they are based only on changes in this data set. The zones were established on the basis of observable changes in the proportions of all pollen and spore taxa. To reduce subjectivity each pollen or spore curve was considered individually, and points where changes occurred between samples were recorded. The changes at each level were totalled, and zone boundaries were placed at the levels which showed maxima (or peaks) in the numbers of changes. The pollen zones are described in detail in the following section.

6.5 Description of the pollen zones

Seven pollen zones were established on the data set, one of these was divided into two subzones

Zone DDA-I, 16.50 m to 13.15 m

This zone is taken as extending from the base of the core, to some point between the samples at 13.60 m and 13.10 m. The upper boundary is placed at 13.15 m since this marks the minimum upper limit of the reworked sequence.

A date of 31450 + 2990-2180 years B.P. was obtained for the lower part of the section at 15.60 m - 15.70 m. A date of 22370 ± 320 years B.P. was obtained for 14.60 m -14.70 m while 14.15 m - 14.25 m provided a date of 18250 ± 290 years B.P. Above this level the zone lies within the reversed sequence of ^{14}C dates described in Section 6.3 and is thought to include considerable proportions of reworked material, and therefore is likely to contain redeposited pollen. The reworking is thought to postdate c. 18250 years B.P. The basal age of the zone could be considerably older than 31450 years B.P. as described in Section 6.3 and could possibly be as old as 39000 years B.P.

Lower montane forest elements dominate the arboreal pollen component in the zone (Fig. 6.3), while taxa more or less confined to lower montane forest II are present in low percentages. About 60-75% of the Dry Land Pollen is contributed by forest sources (Fig. 6.4), while non-forest and swamp sources contribute around 20% to the total. Much of the latter may in fact have a hydrophytic source.

The zone is characterized by moderate to low percentages of gymnosperm pollen, including *Dacrycarpus* (up to 7% TDLP), *Dacrydium* (3-11%) and smaller percentages of *Pinus* and *Podocarpus* (Fig. 6.2). Moderate amounts of pollen from lower montane forest taxa such as *Lithocarpus*/*Castanopsis* comp. (7-14%) and *Quercus* comp. (5-13%) also occurs. Numerous other arboreal taxa are represented by small percentages of pollen. These include *Adinandra* comp., *Altingia* comp., *Symingtonia*, *Ilex* comp., Araliaceae comp. and *Medinilla* comp. *Symplocos* comp., *Linociera* comp. and *Macaranga* comp. are recorded sporadically in the zone while *Tarenna fragrans* occurs only in samples from 14.10 m to 15.25 m. *Rhododendron* comp. and *Vaccinium* comp. are both represented in the zone; *Rhododendron* comp. occurring more frequently towards the top of the zone. *Psychotria* comp. also occurs consistently in the zone in small amounts.

Taxa which can have a swamp forest or a dry land source are also represented in the zone. They include *Ilex cymosa*, *Elaeocarpus* comp., *Myrsine* comp. and occasional *Glochidion* comp., all of which are represented by small percentages of TDLP. Several types of Myrtaceae are recorded and are quite abundant overall. Some of this pollen may have been derived from swamp taxa, although a dry land source probably contributed the bulk of this pollen, Myrtaceae being a common component of lower montane forests (Chapter 4), with some species eg. *Leptospermum* sp. occurring throughout much of the upper montane forest (Section 4.12).

The non-arboreal element of the pollen sum in this zone is represented by a number of taxa. Cyperaceae percentages are generally fairly high, but variable, frequently comprising over 10% TDLP, but ranging from 2-20%. The Gramineae are also represented by moderate amounts of pollen, particularly in the upper part of the zone where they contribute up to 13% TDLP. Other taxa recorded include Laurembergia comp. and Pandanus, which occur sporadically, while Eriocaulon (1-2% TDLP) is consistently present. Impatiens is common at the top of the zone, in the section which includes redeposited material.

Aquatic taxa are poorly represented in the zone by rare Typha comp. Pteridophyte spores are however quite varied and abundant. They include small percentages of Cyathea comp. and Davallia sim., and common Filices undifferentiated (up to the equivalent of 74% TDLP). Lycopodium cernuum (2-34%) is moderately common in this zone but is absent or uncommon in younger samples. Nephrolepis comp., Pteris comp. and Pteridium are also present.

Zone DDA-II, 13.15 m to 7.40 m
Subzone IIA, 13.15 m to 9.90 m
Subzone IIB, 9.90 m to 7.40 m

This zone is taken as extending from 13.15 m to a point between samples 7.60 m and 7.10 m; this upper boundary has been placed at 7.40 m. Some minor changes in pollen frequency within the zone have been used to delimit two subzones, the boundary being placed between the samples at 9.60 m and 10.20 m, at 9.90 m.

A date of 16930 ± 170 years B.P. was obtained for the section

10.55 m - 10.65m, and one of 13160 ± 170 years B.P. was obtained at 7.80 m - 7.90 m, just below the top of the zone. The basal part of the zone may include some redeposited material, as an extension of the redeposited section at the top of DDA-I, and is not older than 18250 years B.P.

The arboreal pollen is dominated by elements common to all lower montane forest types, although taxa more or less confined to lower montane forest II form a significant proportion of the total (Fig. 6.3). Taxa which are commonest in the ericoid forest and *Gleichenia* scrub are also a significant element of the arboreal component in this zone. About 70-80% of the Dry Land Pollen is derived from forest taxa (Fig. 6.4) while pollen from non-forest and swamp sources is less abundant than in zone DDA-I. There is also a slight increase in taxa which may have either a forest, secondary forest or non-forest source.

The zone is characterized by an abundance of gymnosperm pollen, and *Dacrycarpus* (4-18% TDLP) shows a particularly marked increase in abundance compared with zone DDA-I. Both *Dacrydium* (2-13%) and *Podocarpus* (0-3%) also exhibit slightly increased frequencies. *Pinus* is recorded only in subzone IIB (Fig. 6.2).

Lithocarpus/*Castanopsis* comp. (4-10%) and *Quercus* comp. (3-6%) are moderately abundant in the zone but show decreased percentages from zone DDA-I. Other taxa recorded, in small amounts, include *Adinandra* comp., *Altingia* comp., *Symingtonia*, *Engelhardtia* comp., *Ilex* comp., and Araliaceae comp. Taxa such as *Symplocos* comp., *Wendlandia* comp., *Celtis* comp., *Linociera* comp., *Macaranga* comp., *Mallotus* comp., *Trema* comp., *Myrica* comp. and *Lonicera* are also recorded, but are present only sporadically within the zone. *Psychotria* comp. and *Elaegnus* comp. occur rarely.

Taxa which may have both dry land or swamp forest sources are again well represented in the zone and include *Elaeocarpus* comp., *Ilex cymosa* and *Myrsine* comp. Myrtaceae are also abundant, values being similar to those recorded in DDA-I. Both *Rhododendron* comp. and *Melastoma* comp. are consistently present throughout the zone.

Non-arboreal taxa recorded include Cyperaceae (3-14%) and Gramineae (2-8%), both of which are slightly less common than previously, *Laurembergia* comp., *Xyris*, *Pandanus* and *Eriocaulon*. Aquatic taxa are represented by variable amounts of *Potamogeton* and *Typha* comp. Pteridophyte spores are quite abundant in the zone but considerably less so than in DDA-I. They include *Asplenium* comp., *Cyathea* comp., *Davallia* sim., Dennstaedtiaceae comp., Filices undifferentiated, *Dicranopteris* comp. and *Pteridium*. *Lycopodium cernuum* is rare in this zone.

The division of DDA-II into subzones IIA and IIB is made on the basis of frequency changes for a number of taxa. Values of *Medinilla* comp. increase through subzone IIA reaching 6% TDLP but decline in subzone IIB to 1-2% TDLP. *Myrsine* comp. exhibits a similar pattern reaching values of 10% TDLP in subzone IIA but declining to 0-4% TDLP in subzone IIB. *Impatiens* and *Gentiana* are recorded only at the base of subzone IIA, as is *Selaginella* planata comp. Pollen of Vaccinium comp. steadily increases in frequency to the top of subzone IIA where values of 4-6% TDLP are recorded. It declines at the base of subzone IIB but increases again towards the top of the subzone. Pinus pollen is recorded only in subzone IIB, while Meliaceae/Sapotaceae comp. and Symplocos sessilifolia sim. occur sporadically in subzone IIB only.

Zone DDA-III, 7.40 m to 5.40 m

This zone extends from 7.40 m to a point between samples 5.20 m and 5.60 m, placed at the midpoint 5.40 m. No ^{14}C dates were available from samples within the zone although a date of 13160 ± 170 years B.P. was obtained from 7.80-7.90 m in zone DDA-II, and a date of 11710 ± 110 years B.P. was provided by the section 5.25 - 5.35 m, just above the zone boundary.

The arboreal pollen is increasingly dominated by taxa common to all lower montane forest types through the zone, and conversely the importance of taxa more or less confined to lower montane forest II declines within the zone. Taxa commonest in ericoid forest and Gleichenia scrub are also less common than formerly (Fig. 6.3). About 60-80% DLP is derived from forest (Fig. 6.4) with a further 3-20% from non-forest and swamp. Taxa which may have a source in forest, secondary forest or non-forest still contribute small amounts of pollen.

Within the zone the gymnosperms decline in importance. Dacrycarpus values fall from 10-20% TDLP to less than 7%, while

Dacrydium decreases from values of up to 15% TDLP to 1-5%. *Pinus* is absent from the zone, while *Podocarpus* is rare (Fig. 6.2).

Percentages of both *Lithocarpus*/*Castanopsis* comp. and *Quercus* comp. increase slightly in this zone, compared with DDA-II, as does *Altingia* comp. *Symingtonia*, *Engelhardtia* comp., *Symplocos* comp., *Ilex* comp., *Macaranga* comp., *Ardisia* comp., *Vaccinium* comp., *Rhododendron* comp. and *Melastoma* comp. are all present throughout the zone in small amounts. *Adinandra* comp., Meliaceae/Sapotaceae comp. and Loranthaceae occur sporadically, while *Trema* comp., *Strobilanthes*, *Myrica* comp. and Melastomataceae comp. occur rarely. *Medinilla* comp. is present in variable amounts throughout the zone, and percentages show an increase over those in zone DDA-IIB.

Taxa which may have a dry land or swamp forest source are present in small amounts. They include *Elaeocarpus* comp., *Ilex* *cymosa* and *Myrsine* comp. *Glochidion* comp. occurs only rarely. Myrtaceae remain abundant in the zone, although it is likely that the bulk of this pollen is actually derived from dry land rather than swamp forest sources.

Cyperaceae values are generally fairly low, but do start to increase towards the top of the zone. Gramineae values (1-10% TDLP) are variable. Other non-arboreal swamp taxa represented are *Eriocaulon* and *Xyris*, both of which are present in small amounts. Urticaceae/Moraceae of various types are present as low frequencies while Indeterminate type 18 is consistently present as 1-4% TDLP. Aquatic taxa are represented by both *Potamogeton* and *Typha* comp. *Potamogeton* peaks at the base of the zone where it contributes the equivalent of over 50% TDLP. However it is absent from the top part of the zone. *Typha* comp. occurs in small amounts throughout the zone. All aquatic taxa are absent from the overlying zones.

Pteridophyte spores are relatively low in abundance in this zone compared with zones DDA-I and DDA-II. They include *Asplenium* comp., *Davallia* sim., Dennstaedtiaceae comp. and rare *Crypsinus* comp., *Cyathea* comp., *Pteridium* and *Nephrolepis* comp. Filices undifferentiated are less common than in previous zones but are still quite abundant in some samples. *Lycopodium cernuum*, *L. clavatum* comp. and *L. phlegmaria* comp. are all recorded rarely.

Zone DDA-IV, 5.40 m to 3.40 m

This zone extends from 5.40 m to a point between samples 3.20 m and 3.70 m, taken at 3.40 m. A ^{14}C date of 11710 ± 110 years B.P. was obtained for 5.25-5.35 m. The age of the upper zone boundary can only be estimated, using the age-depth graph provided in Fig. 6.1. This suggests an age for the upper zone boundary of c. 8200 years B.P.

Arboreal pollen in this zone is dominated by elements common to all lower montane types (75-95%). Pollen from taxa restricted to lower montane forest I or II contributes only a few percent of the total (Fig. 6.3). Pollen from taxa commonest in ericoid forest and *Gleichenia* scrub is of variable importance (0-16%). Some of the variability between samples in this zone may actually relate to the relatively low total pollen counts in two of the samples.

Although pollen from forest taxa contributes significantly to the dry land pollen sum in the lower part of the zone (Fig. 6.4), it falls to below 45% DLP in the uppermost two samples, associated with a large increase in the non-forest and swamp component. Although this component also increases in importance in the sample at 5.20 m, in this case it may be a function of the low pollen count. However, the increase in the top two samples is far less likely to be such an anomaly, since the count was of normal size in one of the samples involved.

Zone DDA-IV (Fig. 6.2) is characterized by very low percentages of gymnosperm pollen, comprising up to 5% *Dacrydium*, with rare *Podocarpus*. *Dacrycarpus* and *Pinus* do not occur in the zone. *Lithocarpus*/*Castanopsis* comp. exhibits slightly increased frequencies in the zone, while *Quercus* comp. values are variable and little different from those in zone DDA-III. *Adinandra* comp., *Altingia* comp., *Ilex* comp. and *Medinilla* comp. all occur fairly consistently, but in small amounts. *Engelhardtia* comp., *Symingtonia*, *Melastoma* comp. and *Vaccinium* comp. occur sporadically while *Symplocos* comp., *Macaranga* comp., *Trema* comp., *Myrica* comp. and *Rhododendron* comp. occur only rarely. Loranthaceae are absent from the zone.

Taxa which may have a dry land or swamp forest source are represented by variable amounts of *Elaeocarpus* comp. (1-9%) and *Myrsine* comp. (0-10%), along with sporadic occurrences of *Ilex cymosa*. Myrtaceae are overall less abundant than in previous zones, but still remain common.

Variable percentages of Cyperaceae and Gramineae are recorded. Gramineae comprise 55% TDLP in one sample, but values are otherwise low, and Cyperaceae (up to 40% TDLP) are also abundant in some samples. The high percentages of Cyperaceae ought however be viewed with some caution in this zone as they occur only in the two samples where the total pollen count was unusually low. *Nepenthes*, *Impatiens*, *Eriocaulon* and *Pandanus* are recorded rarely in the zone, while Urticaceae/Moraceae of various types are recorded in most samples.

No aquatic pollen is recorded in the zone, and pteridophyte values are generally quite low. They include *Selaginella planata* comp., *Davallia* sim., Filices undifferentiated, *Lycopodium cernuum*, *L. clavatum* comp., *Pteridium* and *Pteris* comp.

Zone DDA-V, 3.40 m to 1.90 m

This zone extends from 3.40 m to a point between 1.60 m and 2.20 m, taken at 1.90 m. A single ^{14}C date of 6850 ± 60 years B.P. was obtained for a sample from 2.60 - 2.70 m. The age of the upper and lower zone boundaries can only be estimated, using Fig. 6.1. This suggests an age for the lower zone boundary of c. 8200 years B.P. and for the upper zone boundary of c. 5400 years B.P.

Lower montane forest elements dominate the arboreal pollen of the zone, while pollen of taxa restricted to lower montane forest I increases in abundance, reaching values of 10% (Fig. 6.3). The contribution of forest pollen to the dry land pollen sum is variable, ranging from 56-87% (Fig. 6.4), the bulk of the rest being contributed by non-forest and swamp taxa. Pollen which may have a source in forest, secondary forest or non-forest contributes variable but small amounts to the pollen sum.

The zone (Fig. 6.2) is characterized by the absence of gymnosperm pollen, increasing values of Altingia comp. and decreased values of Lithocarpus/Castanopsis comp. (8-9% TDLP). Quercus comp. is of variable abundance (4-14%) while Engelhardtia comp. and Symingtonia are consistently present throughout the zone in low frequencies. Also present in small amounts are Ardisia comp., which is not present in zones DDA-IV or DDA-VI, Symplocos comp., Celtis comp., Claoxylon comp., Ilex comp., Macaranga comp., Medinilla comp., Loranthaceae, Myrica comp. and Vaccinium comp. The latter occurs in much lower percentages than in earlier zones. Linociera comp. is consistently present in low percentages in this zone, whereas in previous zones it occurred only sporadically. Trema comp., Schefflera aromatica sim. and Rhododendron comp. occur only rarely in this zone.

Taxa having a possible arboreal swamp forest or dry land source include Ilex cymosa, which shows an increase towards the top of the zone to 4% TDLP, rare Myrsine comp. and Glochidion comp. Elaeocarpus comp. (1-6%) is common while Myrtaceae are abundant in the zone. Most of the Myrtaceae pollen is of type 1, which accounts for up to 50% TDLP, Myrtaceae type 2 is not recorded in the zone. Such high Myrtaceae values might indicate a swamp forest source for some of this pollen.

Cyperaceae values are variable, up to 29% TDLP, but Gramineae values are low (2-5%). Pandanus and Urticaceae/Moraceae types are also recorded in the zone, but Indeterminate type 18, and aquatic pollen are absent.

Pteridophyte spore values remain relatively low. They include rare Selaginella planata comp., S. semicaudata sim., Cyathea comp., Dennstaedtiaceae comp., Lycopodium cernuum, L. phlegmaria comp., Dicranopteris comp., Gleichenia comp. and Cyclosorus comps 1 and 2. Filices undifferentiated occur in low percentages except at 2.20 m where they contribute the equivalent of 20% TDLP. Filices undifferentiated areolate are also common in this sample.

Zone DDA-VI, 1.90 m to 0.20 m

This zone is taken as extending from 1.90 m to a point between the samples at 0 m and 0.55 m, and placed for convenience at 0.20 m. A ^{14}C date of 4520 ± 50 years B.P. was obtained for the section 1.30 - 1.40 m. Ages of the zone boundaries can only be estimated, using Fig. 6.1. This suggests an age of c. 5400 years B.P. for the lower zone boundary. The major changes in pollen assemblages which occur between the samples 0.55 m and 0 m cannot be assigned a specific date, but appear, from Fig. 6.1 to have occurred at some time after c. 1800 years B.P., which is the estimated age of the sample from 0.55 m.

Lower montane forest elements dominate the arboreal component of the zone, with pollen of taxa restricted to lower montane forest I contributing about 6% of the Total Arboreal Pollen (Fig. 6.3). Pollen from taxa more or less confined to sub-montane forest reach a peak of almost 8% in the zone.

Pollen derived from forest taxa contributes about 80-85% of the DLP in the zone. The non-forest and swamp component contributes relatively little, about 7-10%. There is also a slight increase in the zone of pollen taxa which may have a forest, secondary forest or non-forest source (Fig. 6.4).

The zone (Fig. 6.2) is characterized by the virtual absence of gymnosperm pollen, only rare *Dacrydium* and *Podocarpus* being recorded. *Lithocarpus*/*Castanopsis* comp. (9-18% TDLP) increases in importance in the zone, and *Altingia* comp. remains moderately common (4-5%). *Engelhardtia* comp., *Symingtonia*, *Symplocos* comp., *Vernonia arborea* sim., *Linociera* comp., *Macaranga* comp. and *Medinilla* comp. occur throughout the zone as small percentages of TDLP. Of these, *Medinilla* comp. (5-7%) shows slightly increased frequencies in the zone. *Antidesma* comp. (up to 2%) is consistently present. Other taxa recorded include *Adinandra* comp., *Celtis* comp., *Evodia* comp., *Fagraea* comp., *Ilex* comp., *Trema* comp., Araliaceae comp., Santalaceae comp. Gesneriaceae comp., *Melastoma* comp., *Myrica* comp., *Rhododendron* comp., *Vaccinium* comp. and *Viburnum* comp.

Taxa which may have either a dry land or swamp forest source are represented by *Ilex cymosa*, which peaks at the base of the zone before declining, *Elaeocarpus* comp., *Myrsine* comp. and *Glochidion* comp. Elaeocarpus comp. is less common than in zone DDA-V. Myrtaceae types 1 and 4 are abundant, both exhibit increased frequencies towards the top of the zone.

Cyperaceae are present throughout the zone but frequencies are relatively low (4-6%) as are values of Gramineae (up to 3%). Monocotyledon undifferentiated and Eriocaulon occur rarely, while small amounts of Urticaceae/Moraceae occur throughout the zone.

Pteridophyte spores are moderately abundant and include rare Selaginella planata comp., Selaginella comp., Pteridium, Pyrossia sim. and Cyclosorus comp. 2 along with low percentages of Cyathea comp., Humata sim., Davallia sim. and Dennstaedtiaceae comp. Filices undifferentiated increase in abundance in the zone, to the equivalent of 29-32% TDLP. Lycopodium cernuum is consistently present in the zone while L. phlegmaria comp. and Gleichenia comp. occur occasionally. Both Nephrolepis comp. and Sphenomeris comp. are moderately common.

Zone DDA-VII, 0.20 m to 0 m

This zone comprises one sample only, the surface sample of the core from 0 - 0.01 m depth. The age of the sample is presumed to be contemporary.

The arboreal component of the pollen assemblage is dominated by pollen from taxa common to all lower montane forest types (65%) with small percentages from taxa restricted to lower montane forest I, lower montane forest I and II, and lower montane forest II (Fig. 6.3). Forest pollen contributes only 7% DLP, the bulk

Fig. 6.2
Pollen diagram for DDA

Fig. 6.3
Summary pollen diagram for DDA showing the composition of the arboreal pollen in terms of altitudinal forest types

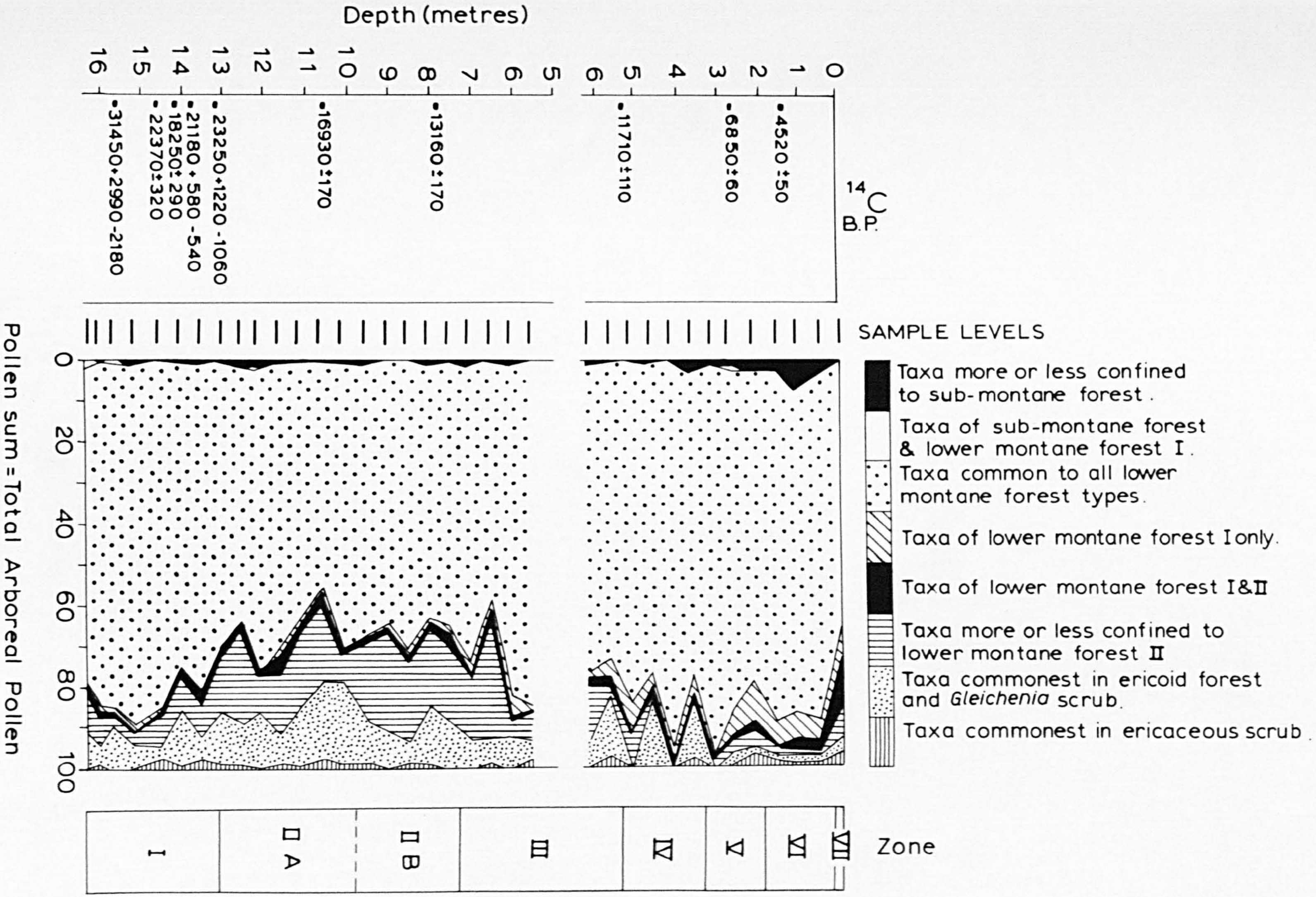
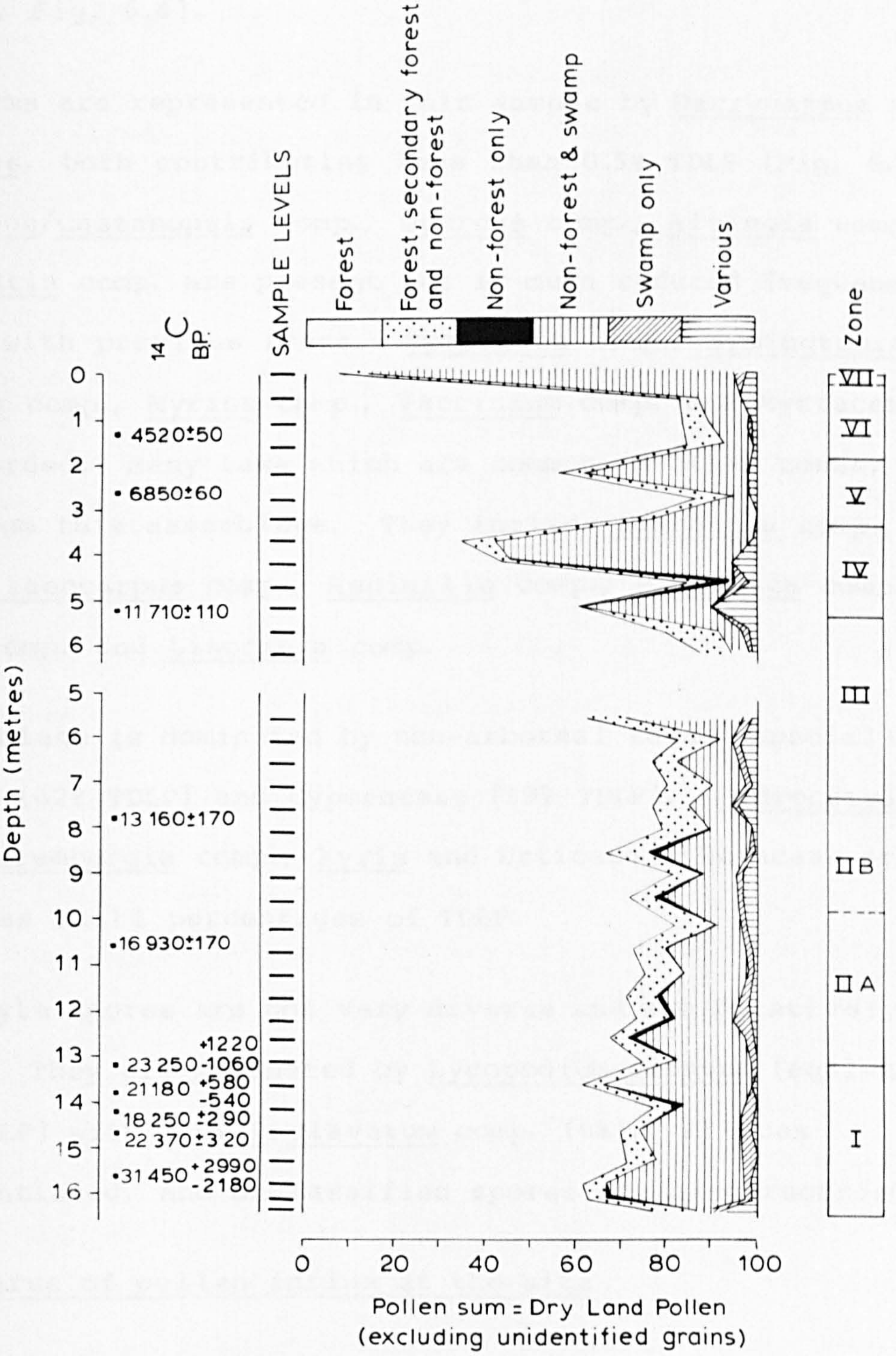

Depth (metres)
16 15 14 13 12 11 10 9 8 7 6 5
6 5 4 3 2 1 0
^{14}C B.P.
31450+2990-2180
22370±320
18250±290
21180+580-540
23250+1220-1060
16930±170
13160±170
11710±110
6850±60
4520±50
SAMPLE LEVELS
Pollen sum = Total Arboreal Pollen
0
20
40
60
80
100
Taxa more or less confined to sub-montane forest.
Taxa of sub-montane forest & lower montane forest I.
Taxa common to all lower montane forest types.
Taxa of lower montane forest I only.
Taxa of lower montane forest I&II
Taxa more or less confined to lower montane forest II
Taxa commonest in ericoid forest and *Gleichenia* scrub.
Taxa commonest in ericaceous scrub.
I
II A
II B
III
IV
V
VI
VII
Zone

Fig. 6.4
Summary pollen diagram for DDA showing the composition of the dry land pollen in terms of source habitats


Depth (metres)
14C BP
4520±50
6850±60
11 710±110
13 160±170
16 930±170
23 250 +1220 -1060
21180 +580 -540
18 250 ±290
22 370 ±320
31 450 +2990 -2180
SAMPLE LEVELS
Forest
Forest, secondary forest and non-forest
Non-forest only
Non-forest & swamp
Swamp only
Various
Zone
VII
VI
V
IV
III
II B
II A
I
0
1
2
3
4
5
6
5
6
7
8
9
10
11
12
13
14
15
16
0
20
40
60
80
100
Pollen sum = Dry Land Pollen
(excluding unidentified grains)

of the latter is made up by the non-forest and swamp component (85% DLP, Fig. 6.4).

Gymnosperms are represented in this sample by Dacrycarpus and Podocarpus, both contributing less than 0.5% TDLP (Fig. 6.2). Lithocarpus/Castanopsis comp., Quercus comp., Altingia comp. and Engelhardtia comp. are present but in much reduced frequencies compared with previous zones. Symplocos comp., Symingtonia, Melastoma comp., Myrica comp., Vaccinium comp. and Myrtaceae are also recorded. Many taxa which are common in other zones, are absent from this assemblage. They include Adinandra comp., Ilex cymosa, Elaeocarpus comp., Medinilla comp., Macaranga comp., Myrsine comp. and Linociera comp.

The assemblage is dominated by non-arboreal taxa, especially Gramineae (62% TDLP) and Cyperaceae (19% TDLP). Hydrocotyle comp., Laurembergia comp., Xyris and Urticaceae/Moraceae are also recorded as small percentages of TDLP.

Pteridophyte spores are not very diverse and are relatively uncommon. They are dominated by Lycopodium cernuum (equivalent to 30% TDLP) with some L. clavatum comp. (6%). Filices undifferentiated, and unclassified spores are also recorded.

6.6 Patterns of pollen influx at the site

Pollen influx was calculated for selected taxa and pollen groups only, for the entire DDA core. The methods for actual calculation of pollen influx are detailed in Appendix 3. Accumulation rates used in the calculations are those listed in

Table 6.3. Details of amounts of the exotic marker (Lycopodium clavatum) added to samples, and actual counts are also provided in Appendix 3. Descriptions of pollen influx patterns at the site are provided in the following Sections. In these sections age estimates are included for depths at which changes in influx occur. These age estimates have been extracted from the age-depth information for the core provided in Fig. 6.1. This assumes a constant accumulation rate between dated levels, which in reality is not always the case, therefore the dates shown are only tentative.

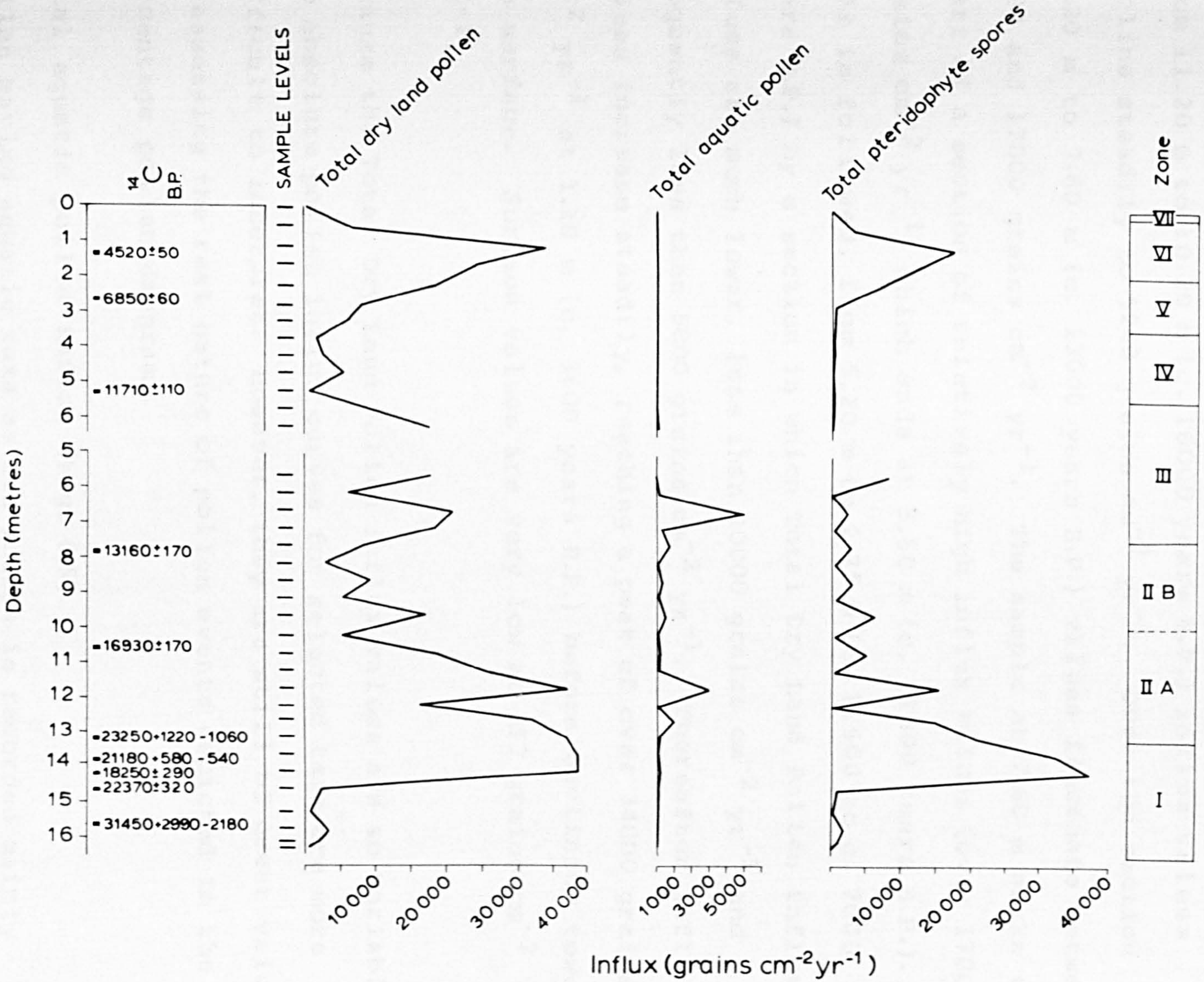
Absolute pollen frequency (also known as pollen concentration) expressed as grains g^{-1} sediment was also calculated for total dry land pollen; the method is also shown in Appendix 3.

6.6a Influx of major palynomorph groups

Total Dry Land Pollen influx (Fig. 6.5).
The Total Dry Land Pollen influx was very variable over the core section, ranging from 430 to 38500 grains cm^{-2} yr^{-1}. However, some patterns do emerge.

For the section 16.30 m to 14.60 m influx values are extremely low, the highest value being 3040 grains cm^{-2} yr^{-1}. This section covers a period from prior to c. 31450 years B.P. to c. 22370 years B.P. At some point between 14.60 m and 14.10 m influx values increase markedly. This point might well coincide with the deposition of older sediments within the core, an event starting after c. 18250 years B.P. at, or just above, the dated 14.15-14.25m section. Influx values in the section 14.10 m to

Fig. 6.5
DDA: Pollen influx curves for major palynomorph groups


14C B.P.
SAMPLE LEVELS
Total dry land pollen
Total aquatic pollen
Total pteridophyte spores
Zone
Depth (metres)
0
1
2
3
4
5
6
5
6
7
8
9
10
11
12
13
14
15
16
4520±50
6850±60
11710±110
13160±170
16930±170
23250+1220-1060
21180+580-540
18250±290
22370±320
31450+2990-2180
10000
20000
30000
40000
1000
3000
5000
10000
20000
30000
40000
Influx (grains cm-2yr-1)
VII
VI
V
IV
III
II B
II A
I

11.20 m (c. 17100 years B.P.) rise to over 38000 grains cm^{-2} yr^{-1} and are generally over 25000 grains cm^{-2} yr^{-1}.

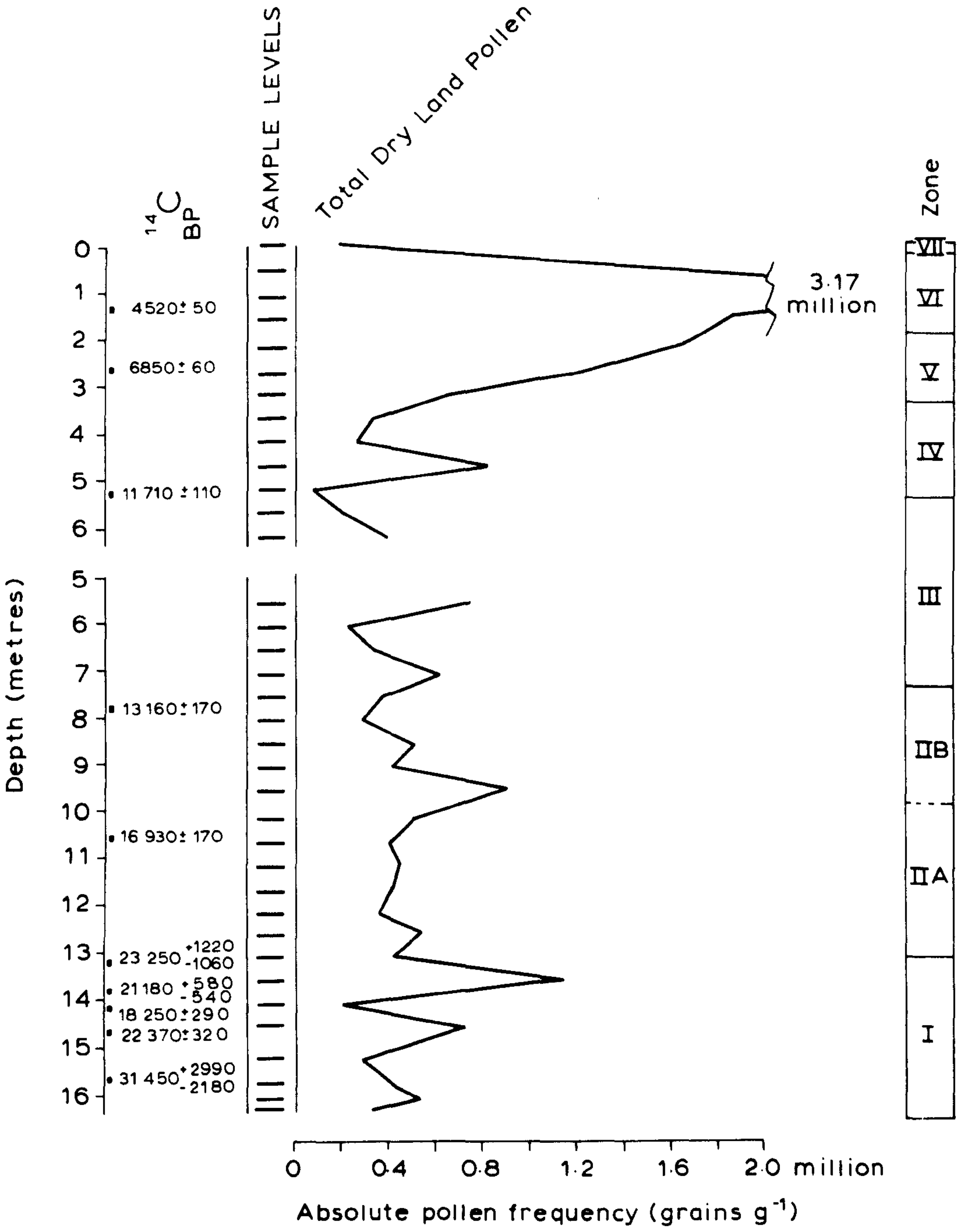
From 11.20 m to 10.20 m (c. 16000 years B.P.) influx values decline steadily to 5240 grains cm^{-2} yr^{-1}. Over the section 10.20 m to 7.60 m (c. 13000 years B.P.) values fluctuate between 3000 and 17000 grains cm^{-2} yr^{-1}. The sample at 7.60 m marks the start of a section of relatively high influx values (over 17000 grains cm^{-2} yr^{-1}) which ends at 5.60 m (c. 11800 years B.P.). This is followed, from 5.20 m to 2.75 m (c. 11500 to c. 7000 years B.P.) by a section in which Total Dry Land Pollen influx values are much lower, less than 10000 grains cm^{-2} yr^{-1} and frequently less than 5000 grains cm^{-2} yr^{-1}. Thereafter influx values increase steadily, reaching a peak of over 34000 grains cm^{-2} yr^{-1} at 1.10 m (c. 3600 years B.P.) before declining towards the surface. Surface values are very low at 517 grains cm^{-2} yr^{-1}.

Because the Total Dry Land Pollen influx values are so variable, the absolute pollen influx curves for selected taxa are more difficult to interpret. However, they are still of great value in assessing the real nature of pollen events depicted in the percentage pollen diagrams.

Total aquatic pollen influx (Fig. 6.5).

Pollen having aquatic taxa as its source is recorded mainly between the depths of 14.10 m and 6.10 m (c. 18200 to c. 12400 years B.P.). Two peaks of pollen influx occur, at 11.70 m (c. 17400 years B.P.) and 6.60 m (c. 12400 years B.P.). In both

Fig. 6.6
DDA: absolute pollen frequencies of dry land pollen (grains g^{-1})



14C BP
SAMPLE LEVELS
Total Dry Land Pollen
Zone
Depth (metres)
0
1
2
3
4
5
6
5
6
7
8
9
10
11
12
13
14
15
16
4520±50
6850±60
11 710±110
13 160±170
16 930±170
23 250 +1220 -1060
21 180 +580 -540
18 250±290
22 370±320
31 450 +2990 -2180
3·17 million
VII
VI
V
IV
III
IIB
IIA
I
0
0·4
0·8
1·2
1·6
2·0 million
Absolute pollen frequency (grains g-1)

events Potamogeton is the major contributor of pollen, and at these points an increase in the percentage of aquatic pollen is also recorded. These increases may therefore indicate an increase in the importance of Potamogeton in the vegetation around the site.

Total pteridophyte spore influx (Fig. 6.5).

Pteridophyte spore influx throughout the core is even more variable than that of pollen. Influx values are low at the base of the core (less than 2000 spores cm^{-2} yr^{-1}) up to, and including 14.60 m (c. 22370 years B.P.). A large increase in influx values occurs between 14.60 m and 14.10 m and reaches a maximum of 37030 spores cm^{-2} yr^{-1} at 14.10 m (c. 18200 years B.P.), the lowest part of the reworked core section.

Above 14.10 m influx values decline and between 12.20 m (c. 17500 years B.P.) and 5.20 m (c. 11500 years B.P.) they are very variable, but generally less than 6000 spores cm^{-2} yr^{-1}. From 5.20 m to 2.75 m (c. 7000 years B.P.) the pteridophyte spore influx is consistently low, less than 540 spores cm^{-2} yr^{-1}. There is a steady increase in influx values between 2.75 m and 1.10 m (c. 3600 years B.P.) and a value of 17600 grains cm^{-2} yr^{-1} is recorded at 1.10m. Above this the values decline and are very low at the surface of the core (198 grains cm^{-2} yr^{-1}).

Absolute pollen frequencies for Total Dry Land Pollen (Fig. 6.6).

Absolute pollen frequency is quite variable, even between adjacent samples, for much of the DDA sequence. However, below

2.75 m depth there are no sections in which pollen concentration is consistently increased, although high values do occur in some samples, notably at 13.60 m and 9.60 m. Most values below 2.75 m are in the range c. 200000 - c. 700000 grains g^{-1}. Only over the section 2.75 m to 0.55 m do absolute pollen frequencies increase significantly, to reach a maximum of over 3.1 million grains g^{-1} at 1.10 m although at the surface of the core there is a return to lower values.

6.6b Influx of selected pollen taxa

Dacrycarpus (Fig. 6.7).

Pollen influx values for this taxon are low at the base of the core; this may at least partly be a reflection of the low Total Dry Land Pollen influx in this section. By 14.10 m (c. 18200 years B.P.) the influx values start to rise, and although they fluctuate they remain high, generally above 2000 grains cm^{-2} yr^{-1} until 10.70 m (c. 16950 years B.P.). The section 10.20 m to 7.60 m has lower levels of pollen influx (in the region of 1000 grains cm^{-2} yr^{-1}). There is another increase in influx around 6.60 m (c. 12400 years B.P.) where over 4000 grains cm^{-2} yr^{-1} are recorded. However, above this the influx values decline to very low levels, and pollen is absent from the section above 5.20 m (c. 11500 years B.P.), except for the surface sample.

The increase in percentage representation of Dacrycarpus observed in zone DDA-IIA (Fig. 6.2) corresponds therefore with an increase in pollen influx to the site, and the decline in percentages at the top of zone III (Fig. 6.2) corresponds with a decrease in pollen influx.

Dacrydium (Fig. 6.7).

The pattern of pollen influx for Dacrydium is very similar to that of Dacrycarpus. An initial phase of low pollen influx is followed at 14.10 m (c. 18200 years B.P.) by a period of high pollen influx, often over 3000 grains cm^{-2} yr^{-1} are recorded. This persists until 11.70 m (c. 17400 years B.P.) when values decline steadily to 8.10 m (c. 13500 years B.P.), frequently being less than 1000 grains cm^{-2} yr^{-1}. There is another increase in pollen influx around 6.60 m (c. 12400 years B.P.) when values of over 3000 grains cm^{-2} yr^{-1} are again recorded. Influx declines rapidly in the overlying samples and is very low from 6.10 m (c. 12100 years B.P.) until 3.70 m (c. 8800 years B.P.) after which Dacrydium is recorded only rarely.

Pinus (Fig. 6.7).

Influx values for Pinus, where this is present, are low, rarely greater than 100 grains cm^{-2} yr^{-1}. Pinus is only recorded below 14.60 m (c. 22370 years B.P.) and over the section 9.60 m to 7.60 m (c. 15500 to c. 13000 years B.P.). The low influx values may be interpreted as infrequent or rare occurrence of Pinus in the vegetation, or perhaps even long distance transport of pollen, at those times when it is recorded.

Podocarpus (Fig. 6.7).

Although influx values for Podocarpus are greater than those for Pinus, they are never as great as values of Dacrycarpus and

Dacrydium. Podocarpus is found predominantly in the section below 6.20 m (c. 12200 years B.P.) and occurs only very rarely above this. Influx values are at their greatest over the section 13.10 m to 10.70 m (c. 17800 to c. 16950 years B.P.) when they are often greater than 400 grains cm^{-2} yr^{-1}. Elsewhere values are generally less than 200 grains cm^{-2} yr^{-1}.

Adinandra comp. (Fig. 6.7).

Pollen influx values for this taxon are low through most of the sequence, increasing slightly only between 12.60 m and 11.70 m (c. 17700 to c. 17400 years B.P.) and again at 1.10 m (c. 3600 years B.P.).

Altingia comp. (Fig. 6.7).

Pollen influx values for Altingia comp. are low throughout the lower part of the sequence. They increase slightly from 7.10 m to 5.70 m (c. 12700 to c. 11900 years B.P.), a change also reflected in a slight increase in percentage representation over this section (Fig. 6.2). However a major increase in pollen influx occurs above 2.75 m (c. 7000 years B.P.), where values of over 1000 grains cm^{-2} yr^{-1} are recorded. This coincides with an increase in the percentage representation of the taxon, and possibly relates to a real increase in Altingia comp. sources in the area. Above 1.10 m (c. 3600 years B.P.) the influx values fall to low levels. Of further interest is the absence of Altingia comp. in samples from 14.10 m to 12.20 m (c. 18200 to c. 17500 years B.P.).

Engelhardtia comp. (Fig. 6.7).

Influx values for *Engelhardtia* comp. are generally quite low, and never exceed 800 grains cm^{-2} yr^{-1}. For much of the sequence they are less than 200 grains cm^{-2} yr^{-1}. Influx values increase slightly from 13.60 m to 11.20 m (c. 18000 to c. 17100 years B.P.) and again at 1.60 m (c. 3600 years B.P.). However these possibly merely reflect peaks of Total Dry Land Pollen influx which occur at these parts of the sequence.

Ilex cymosa (Fig. 6.7).

Pollen influx values for *Ilex cymosa* are fairly low for much of the sequence, values of less than 500 grains cm^{-2} yr^{-1} predominate below 2.20 m (c. 6000 years B.P.) and are often less than 200 grains cm^{-2} yr^{-1}. Influx increases from 2.20 m to 1.10 m (c. 6000 to c. 3600 years B.P.); this event is also reflected in increased percentage representation of the taxon at this time (Fig. 6.2). Influx values return to low levels at the surface of the core.

Lithocarpus/*Castanopsis* comp. (Fig. 6.7).

Influx values for this taxon are low at the base of the core but increase sharply by 14.10 m (c. 18200 years B.P.), reaching peaks of over 5000 grains cm^{-2} yr^{-1}. Thereafter pollen influx decreases steadily to 10.20 m (c. 16000 years B.P.) a feature also reflected in percentage representation of this pollen taxon (Fig. 6.2). Influx remains fairly low until 7.10 m, and from 7.10 m to 5.60 m (c. 12700 to c. 11800 years B.P.) both pollen influx and percentages are slightly higher. Influx values then decline and remain fairly low until 2.20 m (c. 6000 years B.P.).

From 2.20 m to 1.60 m (c. 4900 years B.P.) influx values increase rapidly to levels of over 4000 grains cm^{-2} yr^{-1}. However above 1.60 m they decline rapidly towards the surface of the core where values are very low (7 grains cm^{-2} yr^{-1}).

Quercus comp. (Fig. 6.7).

The patterns of pollen influx for Quercus comp. are broadly similar to those for Lithocarpus/Castanopsis comp. Influx values are low in the basal section of the core but increase at 14.10 m (c. 18200 years B.P.) to over 3000 grains cm^{-2} yr^{-1}. Over the section 13.60 m to 10.70 m (c. 18000 to c. 16950 years B.P.) they are fairly high but decline steadily, and for the section 10.70 m to 7.60 m (c. 13000 years B.P.) remain fairly low, at less than 800 grains cm^{-2} yr^{-1}. There are two more sections of increased influx in the sequence, from 7.10 m to 5.20 m (c. 12700 to c. 11500 years B.P.) and from 2.20 m to 1.10 m (c. 6000 to c. 3600 years B.P.), otherwise values are rather low, particularly at the surface.

Symingtonia (Fig. 6.7).

Influx values for Symingtonia are generally low to moderate (less than 1000 grains cm^{-2} yr^{-1}). They are extremely low at the base of the sequence but increase over the section 14.10 m to 13.10 m (c. 18200 to c. 17800 years B.P.) before steadily declining again. There is a slight increase in influx values over the section 6.60m to 5.60m (c. 12400 to c. 18000 years B.P.) and again at 2.75 m to 1.60 m (c. 7000 to c. 4900 years B.P.). This latter increase is also reflected in increased percentage representation of the taxon over this period (Fig. 6.2). Otherwise influxes remain at very low levels.

Elaeocarpus comp. (Fig. 6.7).

At the base of the core, influx rates for *Elaeocarpus* comp. pollen are low, but they increase at 14.10 m (c. 18200 years B.P.) and thereafter fluctuate quite widely until 11.20 m (c. 17100 years B.P.). Peaks of influx of over 1000 grains cm^{-2} yr^{-1} are recorded over this section. Influx values are generally low in the overlying sections but increase to over 1000 grains cm^{-2} yr^{-1} at 2.20 m (c. 6000 years B.P.). This increase is also reflected in increased percentage representation (Fig. 6.2). Influx values fall markedly above 1.10 m (c. 3600 years B.P.).

Ilex comp. (Fig. 6.7).

Low influx values of *Ilex* comp. are recorded at the base of the sequence but these increase at 14.10 m (c. 18200 years B.P.) and remain at these moderate levels (400-800 grains cm^{-2} yr^{-1}) until 10.70 m (c. 16950 years B.P.). Thereafter influx values are low, except for a slight increase over the section 7.60 m to 5.60 m (c. 13000 to c. 11800 years B.P.). Above this, to the surface, influx values are very low and there is no peak in the top section around 1 m to 2 m, as found in influx curves for many other taxa. This suggests that the source of *Ilex* comp. pollen may have become scarcer at this time.

Linociera comp. (Fig. 6.7).

This occurs only sporadically in the basal section of the core, where influx values are very low. The taxon exhibits one phase of increased influx, from 2.20 m to 1.10 m (c. 6000 to c. 3600 years B.P.) but values are very low above this at the top of the core. The increased influx at 1.10 m to 1920 grains cm^{-2} yr^{-1}, and increased percentage representation at this time (Fig. 6.2) may indicate a change in the importance of source taxa in the vegetation.

Macaranga comp. (both large and small types) (Fig. 6.7).
Macaranga comp. occurs only sporadically at the base of the sequence, where influx values are low. However it is consistently represented from 7.60 m to 5.20 m (c. 13000 to c. 11500 years B.P.) but influx values remain low, less than 300 grains cm^{-2} yr^{-1}. Above 5.20 m *Macaranga* comp. occurs only rarely until 3.20 m (c. 7800 years B.P.) but there is then a steady increase in influx values rising from 161 grains cm^{-2} yr^{-1} at 3.20 m to 817 grains cm^{-2} yr^{-1}at 1.60 m (C. 4900 years B.P.). Low influx values of less than 100 grains cm^{-2} yr^{-1} occur at the top of the section in samples from 0.55 m and 0 m. Of particular interest is the significant increase in influx values for *Macaranga* comp. only towards the top of the sequence.

Medinilla comp. (Fig. 6.7).
Low influx values of less than 100 grains cm^{-2} yr^{-1} occur for this taxon at the base of the sequence. At 14.10 m (c. 18200 years B.P.) influx increases to around 400 grains cm^{-2} yr^{-1} and remains at about this level until 11.70 m (c. 17400 years B.P.). From 11.70 m to 10.70 m (c. 16950 years B.P.) influx values are higher, over 1000 grains cm^{-2} yr^{-1}, and this increase is also reflected in the percentage representation of the taxon (Fig.

6.2). Thereafter influx values are generally low (less than 200 grains cm^{-2} yr^{-1}) until 1.60 m, except for a slight increase over the section 7.10 m to 5.20 m (c. 12700 to c. 11500 years B.P.). There is a large increase in influx values starting at 1.60 m (c. 4900 years B.P.), reaching values of greater than 2000 grains cm^{-2} yr^{-1} at 1.10 m (c. 3600 years B.P.) a change again reflected in the percentage representation of Medinilla comp. Values decline above this and are low at the surface of the core.

Myrsine comp. (Fig. 6.7).

Pollen influx values for Myrsine comp. are low prior to c. 18200 years B.P. (14.10 m), but at this time they increase to over 2000 grains cm^{-2} yr^{-1}. Influx remains high, 1000-2000 grains cm^{-2} yr^{-1} until 10.70 m (c. 16950 years B.P.). Percentage representation of Myrsine comp. is also high throughout this section (Fig. 6.2) suggesting the possibility of an increase, in the vegetation, of its source. Influx values decline above 10.20m (c. 16000 years B.P.) but increase again at 7.60 m (c. 13000 years B.P.) and thereafter fluctuate at moderate levels until 4.20 m (c. 9600 years B.P.). Above this influx levels are low, exceeding 300 grains cm^{-2} yr^{-1} only once at 1.10 m (c. 3600 years B.P.). It seems likely that the sources in the vegetation of Myrsine comp. were more widespread before c. 9600 years B.P. (4.20 m) and especially prior to c. 16950 years B.P. (10.70 m).

Myrtaceae (all types) (Fig. 6.7).

The pollen influx pattern for all Myrtaceae is closely similar to that produced by Total Dry Land Pollen (Fig. 6.5). However there is a major deviation from this pattern from 3.20 m to 2.75 m, where influx values of Myrtaceae increase sharply compared with those for Total Dry Land Pollen, perhaps indicating a real increase in the importance of the Myrtaceae in the vegetation.

Myrtaceae type 1 (Fig. 6.7).

Influx values for this taxon are very low (less than 100 grains cm^{-2} yr^{-1}) in the basal part of the core, below 14.10 m (c. 18200 years B.P.). Over the section from 14.10 m to 10.20 m (c. 16000 years B.P.) influx increases and values are high but variable, (800 - 2770 grains cm^{-2} yr^{-1}). Influx values decrease above 10.20 m and are at moderate to low levels until 7.60 m (c. 13000 years B.P.). Values fluctuate quite widely over the next section 7.60 m to 3.70 m (c. 8800 years B.P.). From 3.20 m to 2.75 m (c. 7800 to c. 7000 years B.P.) influx is high, over 2500 grains cm^{-2} yr^{-1}, corresponding with a large increase in the percentage representation of the taxon (Fig. 6.2). This may indicate a real increase in the importance of source taxa in the area at this time. Influxes fall slightly at 2.20 m (c. 6000 years B.P.) but then increase again, and at 1.10 m over 5000 grains cm^{-2} yr^{-1} are recorded. Values then decline towards the surface of the core.

Myrtaceae type 2 (Fig. 6.7).

Pollen influxes for Myrtaceae type 2 are very similar to those for Myrtaceae type 1, in the bottom part of the sequence. However, from 6.20 m to the top of the core the pattern is quite different, influx values for Myrtaceae type 2 are very low above 6.20 m (c. 12200 years B.P.), and above 3.70 m (c. 8800 years B.P.) the taxon is recorded only rarely, and influx values remain extremely low. The decline is also evident in the percentage diagram (Fig. 6.2) and this suggests that a real decline in the importance of this pollen type does occur at this time although unfortunately the specific source of this pollen taxon is not known.

Melastoma comp. (Fig. 6.7).

Influx of *Melastoma* comp. remains fairly low through much of the sequence. Slightly increased influx occurs from 12.60 m to 11.20 m (c. 17700 to c. 17100 years B.P.) and from 7.10 m to 6.10 m (c. 12700 to c. 12100 years B.P.).

Rhododendron comp. (Fig. 6.7).

Pollen influx for this taxon is low throughout the whole sequence, and never exceeds 300 grains cm^{-2} yr^{-1}.

Vaccinium comp. (Fig. 6.7).

Influx values for this taxon are very low at the base of the sequence, below 14.10 m (c. 18200 years B.P.), where they do not exceed 120 grains cm^{-2} yr^{-1}. However at this point influx increases to c. 1000 grains cm^{-2} yr^{-1}, and values remain at similar levels until 10.70 m (c. 16950 years B.P.). Thereafter they fall to lower levels of c. 200-400 grains cm^{-2} yr^{-1} until 5.60 m (c. 11800 years B.P.). Above this influx levels remain very low, less than 150 grains cm^{-2} yr^{-1}, throughout the remainder of the sequence. It appears that a genuine decline in the source of *Vaccinium* comp. takes place at c. 11800 years B.P. but that the source was perhaps even more widespread prior to c. 16950 years B.P.

Cyperaceae (Fig. 6.7).

Influx values for Cyperaceae are extremely variable but are low, less than 500 grains cm^{-2} yr^{-1}, below 14.10 m (c. 18200 years B.P.). Thereafter they are greatly increased, but still variable, a peak influx rate of over 6500 grains cm^{-2} yr^{-1} being recorded at 13.60 m (c. 18000 years B.P.). Despite wide fluctuations in values over the section 13.60 m to 7.60 m (c. 18000 to c. 13000 years B.P.), the trend is towards declining influx values. Influx continues to fluctuate over the section 7.60 m to 2.75 m (c. 7000 years B.P.) with a peak at 5.60 m (c. 11800 years B.P.) of 2780 grains cm^{-2} yr^{-1}. Values are then quite high from 2.20 m to 1.10 m (c. 6000 to c. 3900 years B.P.), over 5000 grains cm^{-2} yr^{-1} being recorded at 2.20 m. Values then decline steadily to low levels at the surface of the core. The majority of this pollen is probably of very local origin and the fluctuations in influx may relate to small scale changes in the local vegetation.

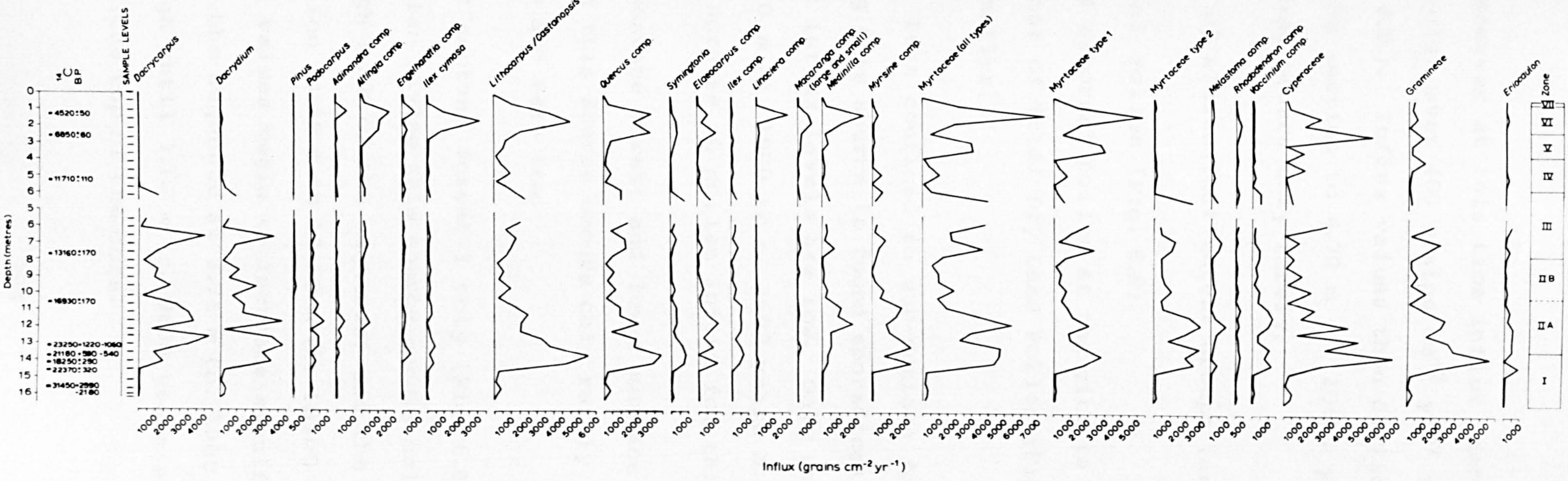
Gramineae (Fig. 6.7).

Influx of this taxon is small (less than 300 grains cm^{-2} yr^{-1}) below 14.10 m. Values then rise to a peak of 5158 grains cm^{-2} yr^{-1} at 13.60 m (c. 18000 years B.P.). Values, although still high, decline steadily to 10.70 m (c. 16950 years B.P.) and thereafter remain at moderate levels until 7.60 m (c. 13000 years B.P.). Influx is very variable above 7.60 m, to the top of the core, 320 grains cm^{-2} yr^{-1} being recorded at the surface.

<u>Eriocaulon</u> (Fig. 6.7).

Influx of <u>Eriocaulon</u> is very low prior to c. 18200 years B.P.

Fig. 6.7
DDA: pollen influx curves for selected pollen taxa



¹⁴C BP
SAMPLE LEVELS
Depth (metres)
4520±50
6850±60
11710±110
13160±170
16930±170
23250+1220-1060
21180+580-540
18250±290
22370±320
31450+2990-2180
Dacrycarpus
Dacrydium
Pinus
Podocarpus
Adinandra comp.
Altingia comp.
Engelhardtia comp.
Ilex cymosa
Lithocarpus/Castanopsis comp.
Quercus comp.
Symingtonia
Elaeocarpus comp.
Ilex comp.
Linociera comp.
Macaranga comp. (large and small)
Medinilla comp.
Myrsine comp.
Myrtaceae (all types)
Myrtaceae type 1
Myrtaceae type 2
Melastoma comp.
Rhododendron comp.
Vaccinium comp.
Cyperaceae
Gramineae
Eriocaulon
Zone
VII
VI
V
IV
III
II B
II A
I
Influx (grains cm⁻² yr⁻¹)

(14.10 m). However at this time influx increases and remains at moderate levels, over 400 grains cm^{-2} yr^{-1} until 11.70 m (c. 17400 years B.P.). Influx values then decline and are low throughout the section to 4.70 m (c. 10600 years B.P.) above which the taxon occurs only rarely.

6.6c Influx of altitudinal forest groups (arboreal taxa only)

Total Arboreal Pollen (Fig. 6.8).
The influx of arboreal pollen at the site is broadly similar in pattern to that of Total Dry Land Pollen (Fig. 6.5) except that values are smaller.

Taxa more or less confined to sub-montane forest (Fig. 6.8).
Pollen having this source is found sporadically throughout the sequence, but influx levels are low. Only over the section 1.60 m to 1.10 m (c. 4900 to c. 3600 years B.P.) is there a significant increase in pollen influx for this group.

Taxa of sub-montane forest and lower montane forest I (Fig. 6.8).
Pollen having this source occurs only rarely in the sequence, and influx values are very low.

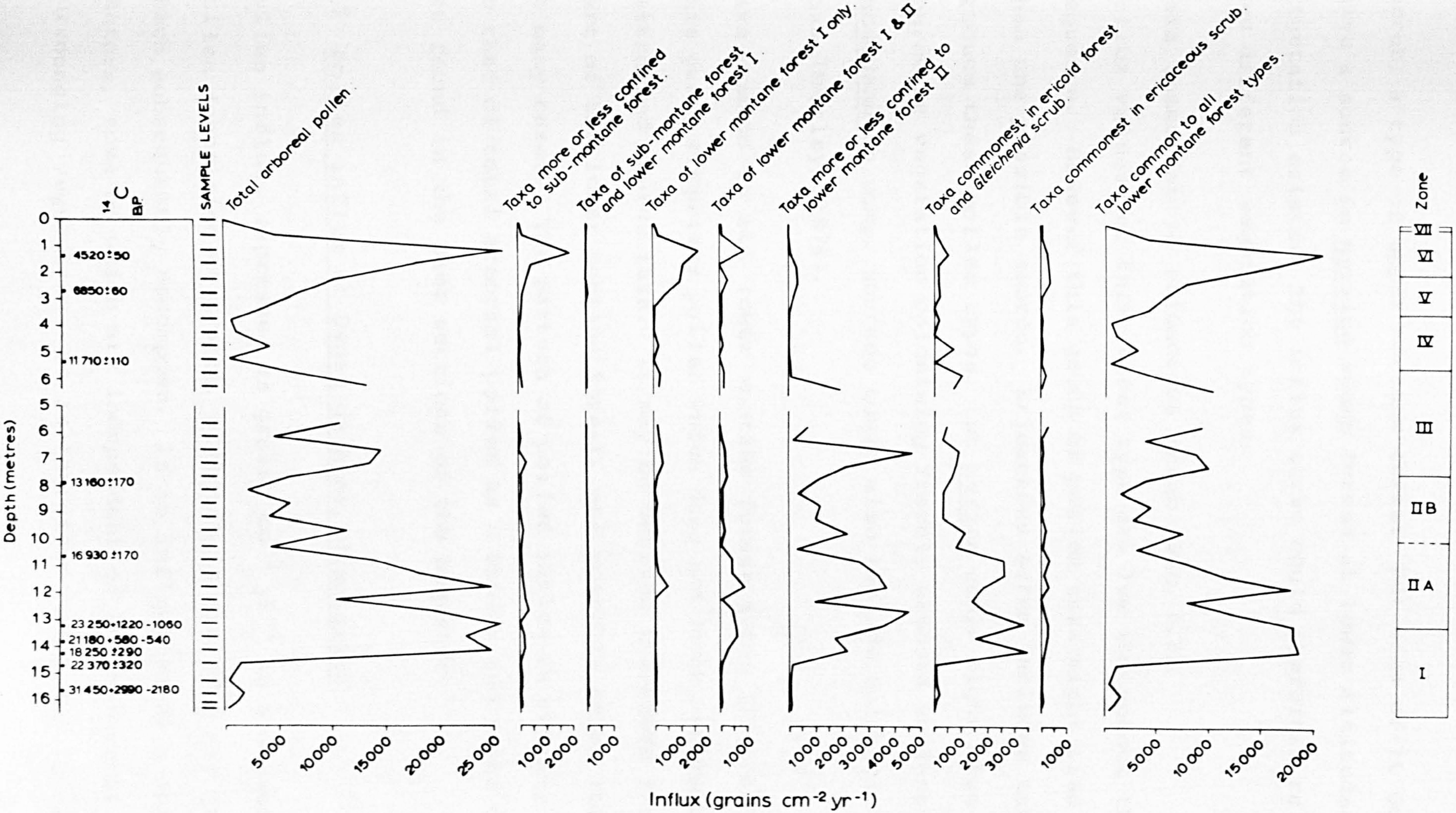
Taxa of lower montane forest I only (Fig. 6.8).
Influx of pollen having this source occurs only in very small amounts through much of the sequence, and the pollen is absent from the section 14.10 m to 12.60 m (c. 18200 to c. 17700 years B.P.). Influx values begin to increase significantly in the upper part of the sequence at 2.75 m (c. 7000 years B.P.) and values are high until 1.10 m (c. 3600 years B.P.) but decline to low levels at the top of the core.

Taxa of lower montane forest I and II (Fig. 6.8).
Pollen having this source has low influx values at the base of the sequence. However, influx increases over the section 14.10 m to 10.70 m (c. 18200 to c. 16950 years B.P.) where up to 860 grains cm^{-2} yr^{-1} are recorded. Influx values are then low, generally less than 200 grains cm^{-2} yr^{-1}, for the rest of the sequence, except for a peak at 1.10 m (c. 3600 years B.P.) of 960 grains cm^{-2} yr^{-1}.

Taxa more or less confined to lower montane forest II (Fig. 6.8).
The influx values of pollen having this source are low below 14.10 m (c. 18200 years B.P.), but increase to high levels at this point (over 2000 grains cm^{-2} yr^{-1}). Influx continues at high levels over the section 14.10 m to 10.70 m (c. 16950 years B.P.), is lower from 10.20 m to 7.60 m (c. 16000 to c. 13000 years B.P.) but increases again from 7.10 m to 6.20 m (c. 12700 to c. 12200 years B.P.). Above this influx falls to low levels, generally less than 400 grains cm^{-2} yr^{-1}, which are maintained throughout the remainder of the sequence.

Taxa commonest in ericoid forest and Gleichenia scrub (Fig. 6.8).
Influx values for pollen having this source are low at the base of the sequence but rise to values of 2000-3000 grains cm^{-2} yr^{-1} over the section 14.10 m to 10.70 m (c. 18200 to c. 16950 years B.P.). Influx levels decline above this to moderate levels, generally still greater than 300 grains cm^{-2} yr^{-1}. Above 4.70 m (c. 10600 years B.P.) influx declines further, and is usually less than 200 grains cm^{-2} yr^{-1}. This pollen is considered as being derived from ericoid forest and Gleichenia

Fig. 6.8
DDA: pollen influx curves for altitudinal forest groups


14C BP
SAMPLE LEVELS
Total arboreal pollen
Taxa more or less confined to sub-montane forest.
Taxa of sub-montane forest and lower montane forest I.
Taxa of lower montane forest I only.
Taxa of lower montane forest I & II
Taxa more or less confined to lower montane forest II
Taxa commonest in ericoid forest and Gleichenia scrub.
Taxa commonest in ericaceous scrub.
Taxa common to all lower montane forest types.
Zone
Depth (metres)
0
1
2
3
4
5
6
5
6
7
8
9
10
11
12
13
14
15
16
4520±50
6850±60
11 710±110
13 160±170
16 930±170
23 250+1220 -1060
21 180+580 -540
18 250±290
22 370±320
31 450+2990 -2180
VII
VI
V
IV
III
II B
II A
I
5000
10000
15000
20000
25000
1000
2000
1000
1000
2000
1000
1000
2000
3000
4000
5000
1000
2000
3000
1000
5000
10000
15000
20000
Influx (grains $cm^{-2} yr^{-1}$)

scrub, a type of upper montane forest, but some of it could also have a source in Myrsine swamp forest at lower altitudes, if this vegetation exists. The influx curve could therefore relate to two different vegetation types.

Taxa commonest in ericaceous scrub (Fig. 6.7).
Influx values for this forest type are low throughout the sequence. However this group of pollen taxa might also have more than one possible source. Ericaceous scrub includes taxa which produce these pollen types, but Myrica comp. might also have a source in vegetation colonising freshly exposed surfaces, while Rhododendron comp. sources could also include epiphytic and swamp taxa (Morley, 1976).

Taxa common to all lower montane forest types (Fig. 6.7).
This group comprises pollen which does not have altitudinally restrained source taxa. It may be derived therefore from any part of the lower montane forest, and possibly other forest types in many cases. The pattern of pollen influx is broadly similar to that of total arboreal pollen as a whole, and peaks of influx are found in the same sections of the sequence.

6.7 Pollen influx at Danau di Atas, discussion

Pollen influx, expressed as grains cm^{-2} yr^{-1} is a measure of pollen deposition at a site, although it excludes any grains which subsequently decompose. It is influenced by a number of factors, some of which are independent of the nature of the surrounding vegetation. It is therefore essential to consider the effects of these before drawing any conclusions as to the meaning of influx recorded at a site.

The attributes of the deposition site itself, for example, the type of lake, swamp or bog, can affect the levels of pollen influx it receives, through its effects on deposition patterns. Sites may vary widely in their levels of pollen influx even when situated in the same type of vegetation (eg. Davis *et al.*, 1973).

The effects of sedimentation patterns in lakes on pollen influx have been the subject of a number of studies (eg. Maher, 1977). Total deposition in lakes is a sum of several pollen components, and includes pollen deposited directly on the water surface, pollen washed in from the catchment by surface run-off and often also pollen contributed by inflowing streams. Lakes which have a large throughflow of water tend to collect less pollen than lakes without this as much pollen may be washed straight through (Pennington, 1973). Sedimentary processes within a lake vary, but there is a tendency for fine sediment, which includes pollen, to be accumulated in deeper water, while coarser sediments are deposited marginally. Because of this it is possible for pollen influx to vary even at different parts of the same sedimentary basin. Lehman (1975) demonstrated that different shapes of lake basin would accumulate sediments at different rates. It is therefore possible that pollen influx may be affected by changes in sedimentary processes within a lake, and if a water body shallows, or otherwise alters its shape, then pollen influx is likely to be affected. Reworking and redeposition of sediments may also affect pollen influx; often this takes the form of a net movement from marginal deposits to the centre of the depositional basin (Davis, 1968). As a lake becomes infilled, perhaps developing into a swamp or bog, then pollen influx is again likely to be affected. A whole source of pollen input may be lost if, as a lake, the site was provided with pollen by inflow streams, but as a swamp or bog collects pollen only from the aerial and perhaps surface run-off components.

Changes in sedimentary processes are not however the only changes which may have an effect on pollen influx, and the latter is also affected by the type of vegetation surrounding the site. Work from temperate regions clearly demonstrates that treeless environments produce less pollen than those with tree or shrub vegetation (Davis _et_ _al_., 1973). Changes from one type of vegetation to the other may be apparent in pollen influx curves even when such changes are not clear, due to long distance transport of arboreal pollen, in percentage diagrams (Pennington and Bonny, 1970). Migration of taxa into an area, and movement of treelines can also be elucidated by such use of pollen influx values (eg. Maher, 1972; Davis _et_ _al_., 1973; Walker and Flenley, 1979).

One other feature which has been recognized as having an effect on pollen influx levels is the presence of arboreal vegetation on the site. This is well illustrated by the work of Hicks (1975) in Finland. The study showed that pollen influx recorded at the site increased as trees colonised the area in post-glacial times, but then fell when they occupied the bog surface, and filtered pollen from surrounding areas. When the trees declined on the bog surface, the pollen influx rose again, since the filtration effect was removed.

The total pollen influx at Danau di Atas will have been affected by environmental events which occurred during the duration of deposition at the site.

Prior to c. 18200 years B.P. (below 14.10 m) the sediment had a slow accumulation rate, perhaps apparent rather than real, if due in part to post depositional compression. All samples from this section do however show very low levels of pollen influx of the order of 1000-2000 grains cm^{-2} yr^{-1}. This might be an indication of low pollen production by the surrounding vegetation but could also be a result of some aspect of the depositional environment at the site. Perhaps at this time it was a poor pollen collector.

By c. 18200 years B.P. (14.10 m) pollen influx to the site had increased dramatically, to very high levels, and these levels persisted for some time, possibly over a thousand years, but had declined by c. 16950 years B.P. (10.70 m). It is in the basal part of these deposits that a ^{14}C age reversal is recorded. As previously described (Section 6.3) this age reversal might have been a result of slumping of older sediment into the site, but might also have been due to a slower event such as erosion of pre-existing sediments and their redeposition into the profile. This latter hypothesis is linked with the idea of lowered lake level and would explain the high pollen influx encountered over this section; pollen would have been rapidly redeposited from the older sediments, and contemporaneous pollen would also have been deposited at the same time. However, slumping of older sediments into the profile would also produce an apparently increased pollen influx, even if their actual pollen content was itself fairly low, since a large amount of polliniferous sediment would be deposited in the profile over a relatively short time span. The high influx values recorded over the section 10.70 m to 14.10 m do not necessarily therefore reflect increased pollen production by the surrounding vegetation, and it is also unlikely that an explanation in terms of an increase in density of the vegetation, increased flowering, or colonisation of bare ground is needed to explain the changes in pollen influx. Absolute pollen frequencies (grains g^{-1}) for Total Dry Land Pollen over the section from and above 14.10 m do not show the same pattern as pollen influx, being instead very variable and, except for the sample at 13.60 m, values are no higher than those in samples from 14.60 m and below. This supports the idea that the increased pollen influx at and above 14.10 m is due to sedimentary events in the depositional basin and not to changes in pollen production by the surrounding vegetation.

The exact point where the redeposition phase ended cannot be determined but it is unlikely to have extended much above 10.70 m (c. 16950 years B.P.), as described in Section 6.3. Influx values recorded over overlying sections probably reflect more realistically the pollen production of the vegetation.

Pollen influx was of the order of 5000-10000 grains cm^{-2} yr^{-1}

from 10.20 m to 7.60 m (c. 16000 to c. 13000 years B.P.), although it fluctuated. This is a real increase compared with the period prior to 18200 years B.P. and might actually relate to pollen production by the surrounding vegetation. However, changes in the physical environment within the deposition site might also have affected pollen influx. The possible changes might have included alterations in water depth due to infilling of the basin, a process which had progressed considerably by this time.

Pollen influx increased further over the section 7.10 m to 5.60 m (c. 12700 to c. 11800 years B.P.) and was often 15000-20000 grains cm^{-2} yr^{-1}. This might be an indication that densely forested conditions prevailed in the vicinity of the site at this time, although it is impossible to confirm this as the cause, and not changed depositional environments, on the basis of influx values only. Above 6.10 m (c. 12100 years B.P.) deposition of aquatic pollen taxa ceased and could indicate vastly changed water conditions at or near the site at this time.

Samples from the section 5.20 m to 3.20 m (c. 11500 to c. 7800 years B.P.) have low pollen influx levels, frequently less than 5000 grains cm^{-2} yr^{-1}. There are indications at this time that the sedimentary basin had little or no open water. No aquatic taxa are recorded, while the lithology above 11.0 m contains wood fragments. These become increasingly numerous, and larger, particularly in the upper core section above 5.50 m, before disappearing from the profile at 3.00 m (Table 6.1). It seems quite probable therefore that the sedimentary basin had infilled to a large extent by this time, and presence on the site of a swamp forest of some type seems very likely. This could in fact also account for the decrease in pollen influx over the section, if the forest was acting as a filter to pollen from surrounding areas, similar to that described by Hicks (1975).

Pollen influx steadily increases over the section 3.20 m to 1.10 m (c. 7800 to c. 3600 years B.P.). If, indeed, a swamp forest had occupied the site, as described above, the disappearance of woody fragments from the sediment at 3.00 m could indicate the decline of swamp forest at this time. This would in turn remove any filter effect and could explain the increase in pollen influx. Absolute pollen frequencies of dry land pollen (grains g^{-1}) also increase over this section.

The return to low pollen influx values above 1.10 m (c. 3600 years B.P. to the present) may at least in part be due to the effect of human interference on the vegetation, with removal of forest and replacement with open vegetation, and agricultural crops which presumably have lower levels of pollen production.

The large number of changes in the Total Dry Land Pollen influx curve complicates the interpretation of changes in the influxes of individual taxa and groups of taxa. However, some points do emerge and these are discussed below.

There are significant changes in both the representation (as a percentage) and the pollen influx of the altitudinal forest groups over the duration of the sequence. Of particular note are the high influx levels of the higher altitude forest groups in the lower section of the core. Influx for the group more or less confined to lower montane forest II is especially high in the section below 6.20 m (c. 12200 years B.P.). For taxa commonest in ericoid forest and Gleichenia scrub high influxes occur below 9.60 m (c. 15500 years B.P.). However for all groups influxes are extremely low from 14.60 m to the base of the sequence, representing the period prior to c. 18250 years B.P.

Taxa common to the lower altitudinal forests have a greater influx in the upper part of the core, and are generally represented by very small influx values over the lower sections. For the group of taxa more or less confined to sub-montane forest, pollen influx increases above 1.60 m (c. 4900 years B.P.) and for taxa of lower montane forest I only, influx increases at 2.75 m (c. 7000 years B.P.). Little can be concluded from the pollen influx curve of taxa common to all lower montane forest types since ecological preferences for this large group of taxa are wide.

Influx curves for individual pollen taxa also show changes over the sequence, and these are also often reflected in changes in percentage representation. These changes are particularly marked for the altitudinally restricted taxa, but do also occur in pollen curves of more widespread taxa (Fig. 6.7).

The patterns of pollen influx often seem to reflect many of the changes observed in the percentage curves for taxa and groups of taxa, throughout the sequence. It therefore seems highly probable that in these cases the significance of the respective source taxa in the vegetation has also varied over the period represented. The implications of these changes in pollen influx and percentage representation in terms of past vegetation and environment are discussed in Chapter 8.

CHAPTER 7

STRATIGRAPHY AND POLLEN ANALYSIS OF THE TELAGO CORE

7.1 Collection of the core

The short Telago core was studied briefly in order to assess the regionality of changes as observed in the top section (approximately the top 4 m) of the Danau di Atas core section. Telago Swamp (Plate 12), from which the core originates, lies at the western edge of the broad, flat plain which runs northwards from Alahan Panjang village (Fig. 2.1). It is about 2km from the Danau di Atas site, and at a similar altitude, 1550 m a.s.l.

The core was collected by R.J. Morley, J.R. Flenley and M.K. Kardin in 1972 using a Russian sampler. The swamp was found to contain 10.10 m of coarse and fine detritus muds, lying above an impenetrable base. Slices of 1 cm thickness were removed from the core at 10 cm intervals, in the field. These were sealed in polythene bags for transportation back to England, where they were subsequently stored at the Hull laboratory at c. 5°C. In addition a section 5 cm long was taken from 10.00 m-10.05 m for ^{14}C analysis. Remaining pieces of the core were discarded.

The vegetation of the Telago Swamp was not studied by the present author but is described briefly in Morley et al. (1973) as outlined below. No authorities were given for the plant identifications.

"A yellow Utricularia sp. and two species of Eriocaulon (E. brownianum and E. hollyanum) were abundant ... Xyris cf. capensis was common. Also present were Leersia hexandra, Polygala sp. and Burmannia cf. disticha. In small open water areas Azolla cf. pinnata was very common. The surrounding vegetation ... consisted of low shrubs of Melastoma, together with Gleichenia sp. and Dipteris conjugata. Lycopodium sp. were common. Particularly striking was the general absence of tree seedlings. An occasional Weinmannia sp. seedling was seen."

7.2 Stratigraphy of the core

Field stratigraphic characters of the core, as provided by Dr J.R. Flenley are presented in Table 7.1. No further examination was possible in the laboratory due to the small size of the samples and the considerable dehydration which had occurred after collection.

The percentage weight loss on ignition was calculated for a number of depths throughout the core, as described in Section 3.4. The results are shown in Fig. 7.1, and provide an indication of the relative changes in the organic carbon content of the sediment. Values of percentage weight loss on ignition are generally fairly high in the top part of the core, above c. 5.00 m depth, often of the order of 80-90%, and always greater than 50%. In the bottom section the values are much lower and are mostly less than 45%. These values may reflect to some extent the detritus content of the sediments and particularly the wood content, which is greatest over the section 4.88 m to 1.90 m.

TABLE 7.1

The stratigraphy of the Telago Core

Depth (m)	Description	Nigror	Stratificatio	Elasticitas	Siccitas	Humocitas	Components
0 - 1.15	Vegetation mat, failed to sample						
1.15-1.65	Coarse, very soft detritus	3	0	0	1	1	Dh 3 Sh 1
1.65-2.35	Very soft detritus, finer than above with wood fragments at 1.90m	3	0	0	1	1-2	Dh 3 Sh 1
2.35-2.65	More compact detritus with wood fragments	2-3	0-1	0	2	1-2	Dh 2 Dl 1 Sh 1
2.65-3.50	Medium detritus with wood fragments	2-3	0-1	1	2	1-2	Dh 2 Dl 1 Sh 1
3.50-3.65	Finer detritus mud with wood fragments	3	0	1	2	2	Dh 2 Sh 2
3.65-4.88	Finer detritus mud with wood fragments, less wood fragments from 4.15-4.88	3	0	1	2	2	Dh 1 Dl 1 Sh 2
4.88-4.93	Coarse detritus with seeds	3	2	2	2	2	Dh 2 Sh 2
4.93-5.35	Finer detritus mud with some wood	3	0	1	2	2	Dh 2 Dl + Sh 2
5.35-5.61	Fine detritus mud with occasional fragments	3	1-2	1	2	2	Dh 2 Sh 2
5.61-5.65	Coarse detritus, no wood	3	0	1	2	2	Dh2 Sh2
5.65-6.15	Fine detritus with fragments (monocotyledon fragments and dicotyledon leaves)	3	1-2	1	2	2	Dh2 Sh2
6.15-7.15	As 5.65-6.15, with distinct stratification	3	2	1	2	2	Dh 2 Sh 2
7.15-8.15	Fine detritus with monocotyledon fragments	3	2	1	2	2	Dh 2 Sh 2
8.15-8.45	As 7.15-8.15, more humified	3	2	1	2	3	Dh 1 Sh 3
8.45-8.85	Fine detritus with few coarse fragments	4	0	1	3	3	Ld 1 Sh 3 Dh +
8.85-9.15	Gyttja	4	0	0	3	3-4	Ld 2 Sh 2
9.15-10.10	Gyttja	4	0	0	3	4	Ld 2 Sh 2
	Impenetrable Base						

7.3 Radiocarbon dating of the core

One sample, from 10.00 m - 10.05 m was sent to the Scottish Universities Research and Reactor Centre for ^{14}C dating in order to determine a basal age for the core. It was subsequently not possible to send other material for ^{14}C dating because of the small size of the samples collected. Details of the dated sample are provided below.

Sample no.	Depth	^{14}C age	$\delta^{13}C$
SRR-466	10.00 m-10.05 m	9105 ± 200	-27.4‰

Clearly the 10 m long Telago core corresponds in age with approximately the top 4 m of the Danau di Atas core (Fig. 6.1). The sediment accumulation rate, based on this one date, and assuming the top of the core to be contemporary is of the order of 1.10 mm yr^{-1}. This rate is considerably higher than that for the top part of the Danau di Atas core. However, this assumes no changes in the sediment accumulation rate, which is unlikely in view of the changes observed in the stratigraphy. It is probable that the accumulation rate has varied considerably from this value over the period represented by the sequence. It cannot therefore be used as a basis for calculating pollen influx.

7.4 Pollen analysis of the core

7.4a Introduction

A total of eleven samples from the Telago (TEL) core were analysed palynologically. They included the surface sample which was collected by hand since the Russian sampler failed to obtain any material from this vegetation mat. The sample interval was thus approximately 1.0 m. Preparation and counting were as described in Chapter 3 and Appendix 2.

Fig. 7.1 shows the values for all taxa indentified from the core as a percentage of Total Dry Land Pollen. A total of 113 distinct palynomorph types were identified. The figure also shows the lithology, ^{14}C date and percentage weight loss on ignition of the core. Figs 7.2 and 7.3 are summary diagrams. Fig. 7.2 shows the composition of the arboreal pollen sum in terms of altitudinal forest types while Fig. 7.3 shows the dry land pollen sum (excluding unidentified grains) in terms of source habitats.

7.4b Zonation of the pollen diagram

Despite the problems associated with the use of the POLZON programme on the Danau di Atas data (Section 6.4b), it was decided to use the analysis to aid zonation of the Telago data set. In all four different data sets were used in the analysis, these being :

i) All pollen and spores.

ii) Dry land pollen only, excluding unknown types.

iii) All pollen and spores occurring as greater than 0.5% TDLP in any sample.

iv) Dry land pollen only occurring as greater than 0.5% TDLP in any sample.

The POLZON technique proved to be successful when used with the

Telago data, possibly because variation inherent in the data was smaller than for Danau di Atas. A summary of the results of POLZON is given below. The results are presented in Appendix 7.

i) All pollen and spores.

Highest order amalgamations using CONSLINK were between 0 m-1.20 m, 9.10 m-10.10 m, 8.10 m-9.10 m and 4.10 m-5.10 m.

Highest order divisions with SPLITINF were between 4.10 m-5.10 m, 0 m-1.20 m, 8.10 m-9.10 m and 9.10 m-10.10 m.

Highest order divisions with SPLITSQ were 8.10 m-9.10 m, 9.10 m-10.10 m; 0 m-1.20 m and 4.10 m-5.10 m.

ii) Dry land pollen only, excluding unknowns.

Highest order amalgamations using CONSLINK were 9.10 m-10.10 m, 8.10 m-9.10 m, 0 m-1.20 m and 4.10 m-5.10 m.

Highest order divisions with SPLITINF were 4.10 m-5.10 m, 0 m-1.20 m, 8.10 m-9.10 m and 9.10 m-10.10 m.

Highest order divisions with SPLITSQ were 8.10 m-9.10 m, 9.10 m - 10.10 m, 0 m-1.20 m and 4.10 m - 5.10 m.

iii) All pollen and spores occurring as greater than 0.5% TDLP in any sample.

Highest order amalgamations with CONSLINK were 0 m- 1.20 m, 9.10 m-10.10 m, 4.10 m-5.10 m and 3.10 m-4.10 m.

Highest order divisions with SPLITINF were 0 m-1.20 m, 4.10 m-5.10 m, 8.10 m-9.10 m and 6.10 m-7.10 m.

Highest order divisions with SPLITSQ were 0 m-1.20 m, 4.10 m-5.10 m, 9.10 m-10.10 m and 8.10 m-9.10 m.

iv) Dry land pollen only occurring as greater than 0.5% TDLP in any sample

Highest order amalgamations with CONSLINK were 0 m-1.20 m, 4.10 m-5.10 m, 3.10 m-4.10 m and 9.10 m-10.10 m.

Highest order divisions with SPLITINF were 0 m-1.20 m, 4.10 m-5.10 m, 6.10 m-7.10 m and 9.10 m-10.10 m.

Highest order divisions with SPLITSQ were 4.10 m-5.10 m, 0 m-1.20 m, 9.10 m-10.10 m and 6.10 m-7.10 m.

In each of the above examples the four highest order amalgamations or divisions are listed in order of importance.

All three analyses on each of the four data sets picked out 0 m-1.20 m as a 1st-3rd order amalgamation or division, accounting for a considerable proportion of the variance in the data set. A zone boundary was therefore placed between the samples at 0 m and 1.20 m. All analyses on the four data sets suggested 4.10 m-5.10 m as a 1st-4th order amalgamation or division. A zone boundary was therefore placed between these two samples. Two possible positions were suggested for a third zone boundary, 8.10 m-9.10 m and 9.10 m-10.10 m. Neither was as consistently suggested by the analyses as were 0 m-1.20 m and 4.10 m-5.10 m. The boundary was actually placed between the samples 9.10 m and 10.10 m since this position was selected more consistently than 8.10 m-9.10 m.

Other positions of 1st-4th order amalgamations or divisions picked out in the analyses were 3.10 m-4.10 m and 6.10 m-7.10 m, but these were suggested infrequently and were not therefore used as zone boundaries.

Zone boundaries were actually placed in the Telago sequence between samples 0 m and 1.20 m, 4.10 m and 5.10 m and 9.10 m and 10.10 m. Since these were suggested for all or most analyses on four slightly different data sets they would therefore be useable with pollen data alone, pollen and spore data, and data which included or excluded rare pollen or spores (i.e. those not occurring as greater than 0.5% TDLP in any sample).

7.5 Description of the pollen zones

Four pollen zones were established on the Telago data set, using the POLZON analysis. These zones, TEL-I to TEL-IV are described below.

Zone TEL-I, 10.10 m to 9.60 m

This zone is taken as extending from the base of the core at 10.10 m to some point between the samples at 10.10 m and 9.10 m, taken as 9.60 m. A ^{14}C date of 9105 ± 200 years B.P. was obtained from the section 10.00 m-10.05 m, and is the only date available for the core. The sediments of this zone comprised gyttja.

The arboreal pollen component of the zone is dominated by taxa common to all lower montane forest types, although small percentages of pollen from taxa of restricted altitudinal range also occur (Fig. 7.2). About 52% DLP is derived from forest, with a further 38% from non-forest and swamp. Small amounts are also contributed by taxa which may have a source in forest, secondary forest or non-forest (Fig. 7.3).

Small amounts of gymnosperm pollen, totalling less than 2% TDLP are recorded in this zone (Fig. 7.1). Fagaceae are well represented by *Lithocarpus*/*Castanopsis* comp. (14% TDLP) and *Quercus* comp. (9%). *Vernonia arborea* sim. is also well represented. Small percentages of TDLP are contributed by other arboreal taxa, including *Adinandra* comp., *Altingia* comp., *Engelhardtia* comp., *Helicia javanica* sim., *Symingtonia*, *Symplocos* comp., *Linociera* comp. and *Macaranga* comp.

Pollen taxa having a dry land or swamp forest source include *Elaeocarpus* comp. (4%) and *Ilex cymosa*. Myrtaceae types 1 and 4 are also represented although they are not particularly common (5% TDLP).

Non-arboreal taxa recorded include *Galium* comp., Liliaceae comp. and *Hydrocotyle* comp. along with common Cyperaceae and Gramineae. Urticaceae/Moraceae of various types are also recorded and could have a non-arboreal source.

Pteridophyte spores are abundant in this zone, Filices undifferentiated being particularly well represented (equivalent to 106% TDLP). A number of other taxa are also quite common. These include *Humata* sim., *Davallia* sim., Dennstaedtiaceae comp. and *Cyclosorus* comp. 1 and 2. Also recorded are *Gleichenia* comp., *Cyathea* comp., *Pteridium* and *Pteris* comp.

No aquatic pollen is recorded in this zone despite evidence from the sediment that open water prevailed at the site at this time.

Zone TEL-II, 9.60 m to 4.60 m

This zone extends from 9.60 m to a point between samples at 5.10 m and 4.10 m, taken as 4.60 m. No ^{14}C dates were available for this section. The sediment comprised gyttja overlain by mostly fine, herbaceous, detritus mud at 8.85 m and fine, woody detritus mud at 5.61m.

Pollen of taxa common to all lower montane forest types continues to dominate the arboreal pollen component throughout this zone. Pollen derived from taxa more or less confined to sub-montane forest is slightly more common in this zone than in zone TEL-I, while pollen of taxa more or less confined to lower montane forest II is more common at the base of the zone, diminishing in importance through it (Fig. 7.2). Pollen derived from a forest source comprises 46-77% DLP throughout the zone (Fig. 7.3). Pollen from a non-forest and swamp source is also important in the zone (up to 50% DLP) but becomes less important towards the top of it.

Small amounts of gymnosperm pollen are recorded and Dacrycarpus, Dacrydium, Pinus and Podocarpus are all represented (Fig. 7.1). However total gymnosperm pollen nowhere exceeds 2% TDLP. The Fagaceae remain well represented, Lithocarpus/Castanopsis comp. accounting for 9-17% TDLP and Quercus comp. a further 7-11%. Vernonia arborea sim. is considerably less common in this zone than in zone TEL-I, and accounts for less than 1% TDLP. Adinandra comp., which increases steadily through the zone, and Engelhardtia comp. are recorded consistently. A number of other taxa are recorded sporadically in the zone, they include Randia comp., *Symingtonia*, *Symplocos* comp., *Antidesma* comp., *Ilex* comp., *Linociera malabarica* sim., *Macaranga* comp. and *Myrica* comp. *Linociera* comp. becomes quite common towards the top of the zone while *Medinilla* comp. is also frequently recorded. *Altingia* comp. is virtually absent from this zone.

Pollen taxa having a possible dry land or swamp forest source are represented in the zone by *Ilex cymosa* (0-2% TDLP), *Elaeocarpus* comp. (3-8%) and occasional *Myrsine* comp. Myrtaceae increase slightly in percentage representation through the zone and are more common than in zone I.

Non-arboreal taxa are represented by *Impatiens* and Compositae (Tubuliflorae) along with Cyperaceae and Gramineae. Cyperaceae (3-6% TDLP) are less well represented in this zone than in the previous zone whereas Gramineae (10-38%) are much more common. *Pandanus* (1-18%) is also abundant in this zone.

Pteridophyte spores are very common throughout the zone and include large quantities of Filices undifferentiated (equivalent to 36-65% TDLP) and *Cyclosorus* comp. 2 (up to 60%). Also common are *Davallia* sim., and *Cyclosorus* comp. 1, while *Cyathea* comp. psilate and *Gleichenia* comp. are common in some samples. *Cyathea* comp. verrucate, *Humata* sim., *Lycopodium cernuum*, *L. phlegmaria* comp., *Athyrium* comp., *Dicranopteris* comp., *Pteridium* and *Pteris* comp. are also recorded.

Aquatic pollen is not recorded in this zone.

Zone TEL-III, 4.60 m to 0.60 m

This zone extends from 4.60 m to a point between samples at 1.20 m and 0 m, taken as 0.60 m. No ^{14}C dates were available for this section. The sediment comprised a fine, woody detritus mud at the base of the zone, overlain by a medium, woody detritus mud at 3.50 m, coarse detritus mud at 2.35 m and very fibrous vegetation mat at 1.15 m.

Pollen of taxa common to all lower montane forest types dominates the arboreal pollen component throughout the zone. Pollen of taxa more or less confined to sub-montane forest reach a peak at the base of the zone but decline in importance above this. Pollen of lower montane forest I taxa also becomes slightly more common in this zone (Fig. 7.2). Pollen derived from a forest source is more important in this zone than in zones TEL-I and TEL-II while that from a non-forest and swamp source is less so. However pollen having a source in forest, secondary forest or non-forest increases steadily in abundance throughout the zone (Fig. 7.3).

Gymnosperm pollen is recorded only rarely at the base of this section, and consists of Dacrycarpus and Dacrydium (Fig. 7.1). Fagaceae are again well represented although Lithocarpus/Castanopis comp. (6-13% TDLP) is less common than in zone TEL-III, and Quercus comp. (4-18%) is more variable in its representation. Altingia comp., which is virtually absent in zone TEL-II is present throughout zone TEL-III as small percentages of TDLP and Linociera comp. is also present. Macaranga comp. contributes small amounts of TDLP at the base of the zone but becomes more common at the top (4-5%). Other taxa consistently recorded are *Adinandra* comp., *Engelhardtia* comp., *Symingtonia*, *Ilex* comp. and *Medinilla* comp. *Schima*, *Randia* comp. and *Memecylon* comp. are also present but *Symplocos* comp. and *Vernonia arborea* sim. are not recorded in this zone.

Pollen taxa having a possible dry land or swamp forest source are represented in the zone by common *Elaeocarpus* comp. (4-9%), *Ilex cymosa* (0-3%) and occasional *Myrsine* comp. and *Glochidion* comp. Myrtaceae are abundant throughout the zone and Myrtaceae type 1 is particularly so (21-36%) showing a large increase in percentage representation compared with zone TEL-II.

Non-arboreal taxa are represented by occasional occurrences of Compositae (Tubuliflorae), *Oldenlandia uncinella* sim., and *Galium* comp. and relatively low frequencies of Cyperaceae (2-8%) and Gramineae (1-12%). The latter exhibits very much lower frequencies through most of the zone compared with zone TEL-II. *Pandanus* is not recorded in this zone.

Pteridophyte spores are abundant, Filices undifferentiated (equivalent to 35-56% TDLP) being particularly common. Other taxa recorded include *Cyathea* comp. psilate, *Davallia* sim., *Lycopodium cernuum*, *Gleichenia* comp., *Nephrolepis* comp., *Ophioglossum* comp., *Sphenomeris* comp. and Dennstaedtiaceae comp. *Cyclosorus* comp. 1 and comp. 2 are present in low frequencies throughout this zone but are nowhere near so abundant as in zone TEL-II.

Zone TEL-IV, 0.60 m to 0.0 m

This zone extends from 0.60 m to the surface of the core at 0.0 m, but consists of one sample only, that from 0.0 m. This is thought to be of contemporary age. The sediment consists of very fibrous vegetation mat.

The arboreal pollen of the zone is dominated by pollen of Rhododendron comp., which is normally allocated to the category 'commonest in ericaceous scrub'. However, this vegetation type is clearly not contributing over 50% of the arboreal pollen to the site at present, and the Rhododendron comp. is more likely to be derived from regrowth vegetation in these circumstances. A further 25% of the arboreal pollen is of taxa common to all lower montane forest types, while more restricted groups contribute only very small amounts of pollen to the total (Fig. 7.2). Pollen having a forest source contributes only about 15% of the DLP (Fig. 7.3). That having a possible source in forest, secondary forest or non-forest is more important than formerly, contributing c. 40%, much of this being Rhododendron comp. Non-forest and swamp taxa also contribute significantly to the assemblage (32%) as do taxa restricted to swamp only (9%).

Gymnosperms are represented in this zone only by Pinus (less than 0.5% TDLP), this is probably derived from plantations. Fagaceae are represented by much reduced percentages of Lithocarpus/Castanopsis comp. (2%) and Quercus comp. (4%) (Fig. 7.1). Very few other arboreal taxa are represented, but include Altingia comp., Engelhardtia comp., Adinandra comp., Symingtonia, Celtis comp., Macaranga comp., Mallotus comp., Trema comp. and

Fig. 7.1
Pollen diagram for Telago

Fig. 7.2
Summary pollen diagram for Telago showing the composition of the arboreal pollen in terms of altitudinal forest types

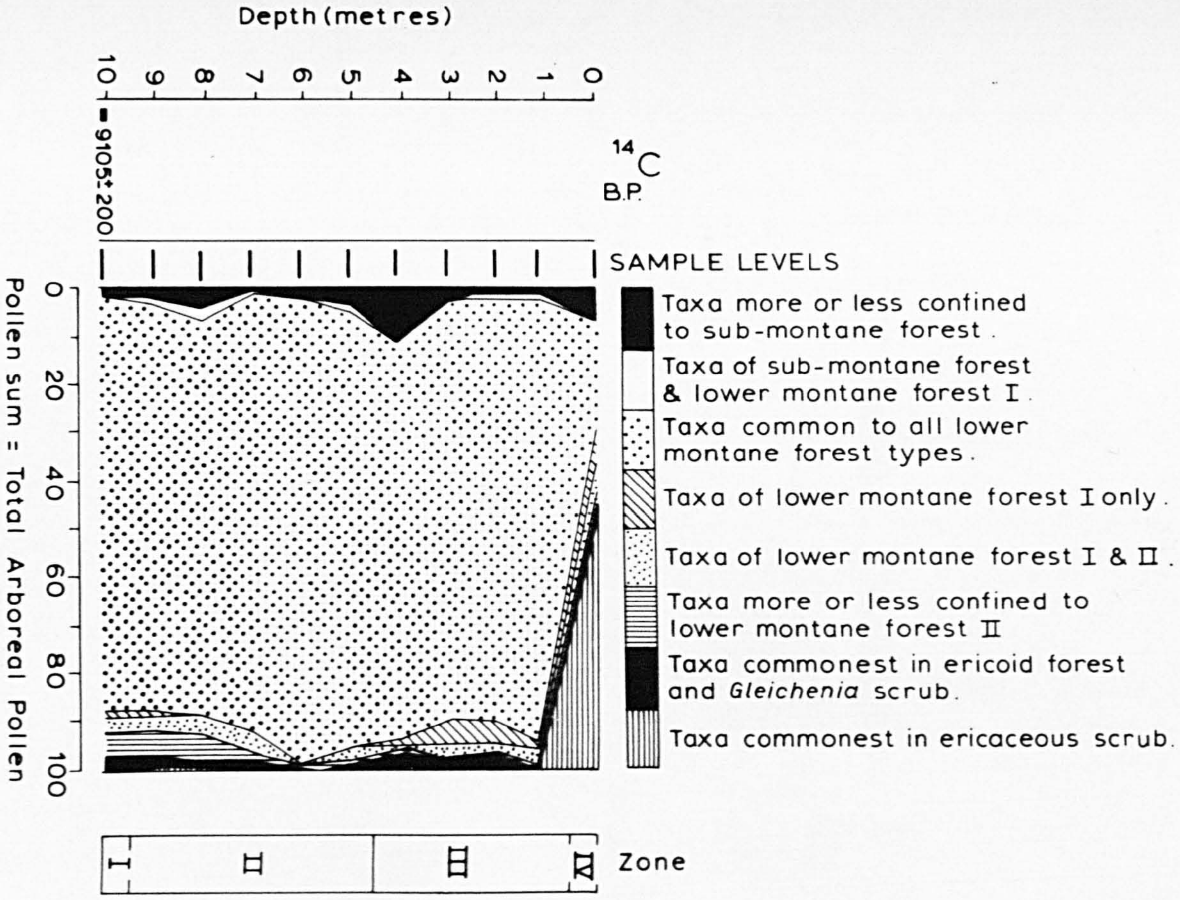
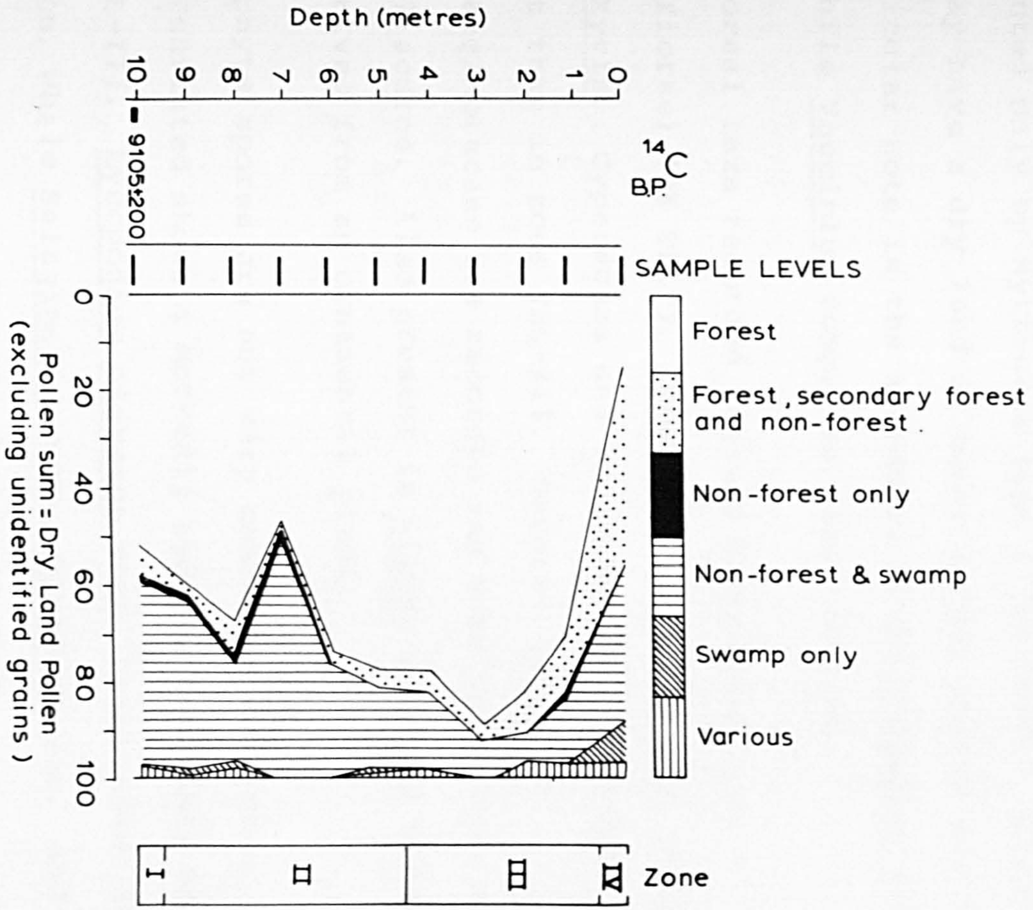

Depth (metres)
10
9
8
7
6
5
4
3
2
1
0
9105±200
^{14}C B.P.
SAMPLE LEVELS
Pollen sum = Total Arboreal Pollen
0
20
40
60
80
100
Taxa more or less confined to sub-montane forest.
Taxa of sub-montane forest & lower montane forest I.
Taxa common to all lower montane forest types.
Taxa of lower montane forest I only.
Taxa of lower montane forest I & II.
Taxa more or less confined to lower montane forest II
Taxa commonest in ericoid forest and *Gleichenia* scrub.
Taxa commonest in ericaceous scrub.
I
II
III
IV
Zone

Fig. 7.3
Summary pollen diagram for Telago showing the composition of the dry land pollen in terms of source habitats


Depth (metres)
0
1
2
3
4
5
6
7
8
9
10
14C B.P.
9105±200
SAMPLE LEVELS
Forest
Forest, secondary forest and non-forest.
Non-forest only
Non-forest & swamp
Swamp only
Various
0
20
40
60
80
100
Pollen sum = Dry Land Pollen
(excluding unidentified grains)
I
II
III
IV
Zone

Myrica comp. Myrtaceae, which were abundant in zone TEL-III are represented only by Myrtaceae type 1 (1% TDLP). No other taxa which may have a dry land or swamp forest source are recorded. Of particular note is the abundance of Rhododendron comp. (21% TDLP) while Vaccinium comp. is also recorded.

Non-arboreal taxa recorded include Compositae type 1 (Tubuliflorae) (9% TDLP), Impatiens, Laurembergia comp. and common Xyris. Cyperaceae and Gramineae are also much more abundant than in zone TEL-III. Several types of Urticaceae/Moraceae are recorded and some might have a non-arboreal source. Also present is Alnus, which is likely to have been derived from an ornamental plant.

Pteridophyte spores are not very common in this zone, and Filices undifferentiated shows a markedly reduced frequency compared with zone TEL-III. Lycopodium clavatum comp. (equivalent to 12% TDLP) is common, while Selaginella comp., Davallia sim. and Gleichenia comp. are all recorded as less than 2% TDLP.

7.6 Pollen analysis: absolute pollen frequencies

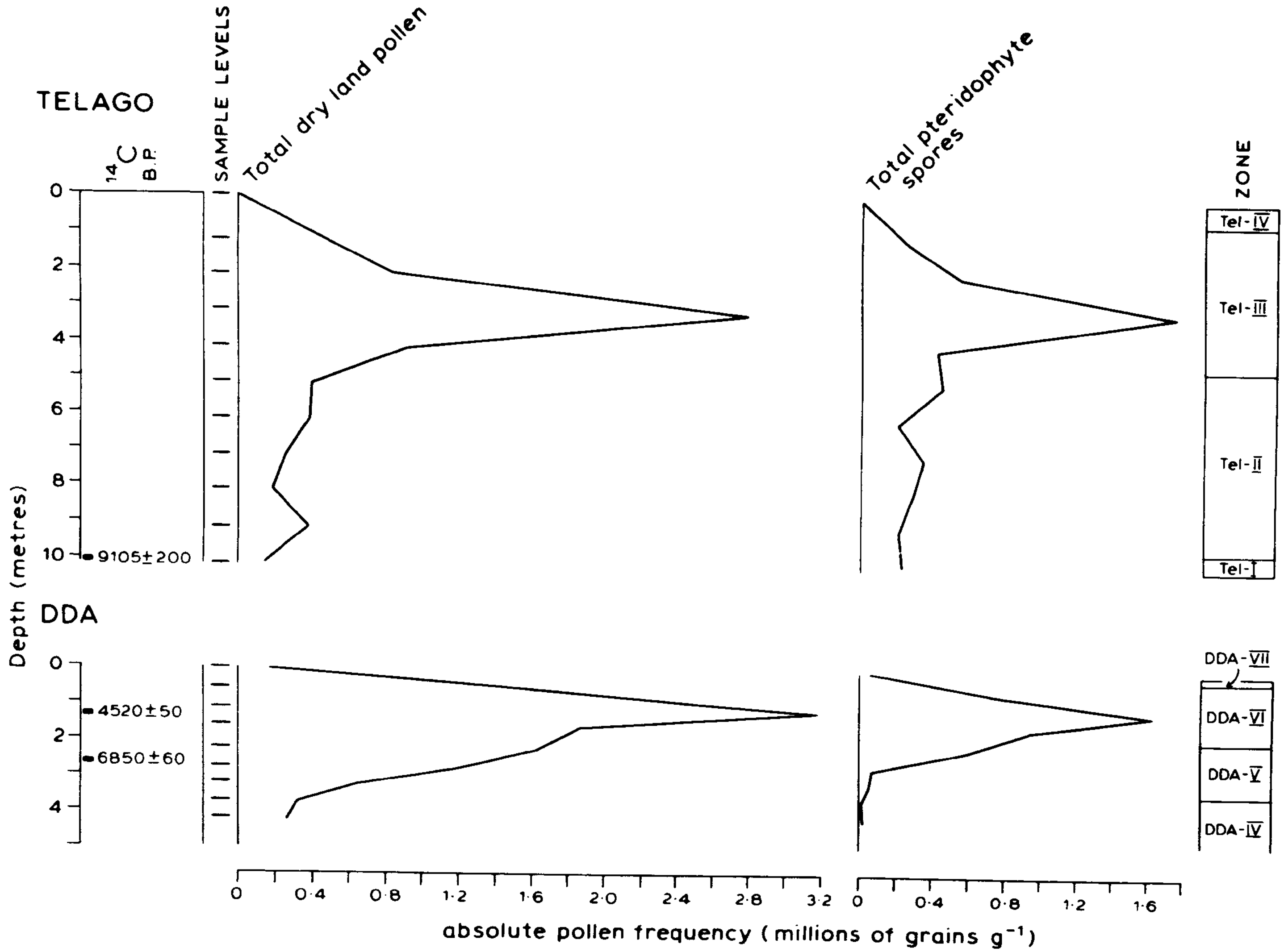
It was not possible to calculate pollen influx values for the Telago core, since the one ^{14}C date available was not sufficient for accurate assessment of sediment accumulation rates over the 10 m sequence. However it was possible to calculate absolute pollen frequencies for the samples examined. This can be expressed as grains cm^{-3} sediment or grains g^{-1} sediment. Since some of the Telago samples were rather dehydrated by the time palynological analysis was carried out, it proved difficult to measure 1 cm^3 of sediment accurately for processing. To avoid inaccuracies due to measurement of initial sediment prepared, the absolute pollen frequencies were therefore calculated in terms of grains g^{-1} sediment, as shown in Appendix 3. Because the Telago core was studied in order to assess regionality of changes observed in the top section of the DDA core, absolute pollen frequencies expressed as grains g^{-1} were also calculated for the upper 4.20 m of the latter. This approximately corresponds in age with the Telago core. In each case absolute pollen frequencies were calculated for total pollen, total spores, selected taxa and groups of taxa. These results are shown in Figs 7.4, 7.5, and 7.6 and are described briefly below.

7.6a Absolute pollen frequencies of major palynomorph groups

Total Pollen (Fig. 7.4).

The absolute pollen frequencies (APFs) of this group increase steadily in the Telago sequence from c. 0.2 million grains g^{-1} at 10.10 m to c. 0.4 million grains g^{-1} at 5.10 m. Thereafter APF increases enormously to values of 2.8 million grains g^{-1} at 3.10 m. Above this, values fall rapidly towards the top of the core and are low in the surface sample. It is of interest that the upper section of the DDA core exhibits some similarities with this. Values are relatively low (c. 0.25 million grains g^{-1}) at 4.10 m but thereafter increase rapidly, to over 3.0 million grains g^{-1} at 1.10 m before declining rapidly again towards the top of the sequence.

Fig. 7.4
Telago: absolute pollen frequencies for major palynomorph groups


TELAGO
^{14}C B.P.
SAMPLE LEVELS
Total dry land pollen
Total pteridophyte spores
ZONE
0
2
4
6
8
10
9105±200
Tel-IV
Tel-III
Tel-II
Tel-I
Depth (metres)
DDA
0
2
4
4520±50
6850±60
DDA-VII
DDA-VI
DDA-V
DDA-IV
0
0·4
0·8
1·2
1·6
2·0
2·4
2·8
3·2
0
0·4
0·8
1·2
1·6
absolute pollen frequency (millions of grains g^{-1})

Total pteridophyte spores (Fig. 7.4).

The pattern of absolute frequency for pteridophyte spores is similar to that of pollen, for the Telago sequence, although the frequencies are lower. Absolute spore frequency reaches a maximum of over 1.7 million spores g^{-1} at 3.10 m. In the upper DDA sequence absolute spore frequencies are relatively low until 2.20 m, where they increase, reaching a maximum value of c. 1.6 million at 1.10 m. Again there is a decline to low levels at the top of the sequence.

7.6b Absolute pollen frequencies of selected taxa (Fig. 7.5)

APF for Dacrycarpus is low throughout the Telago core, less than 6000 grains g^{-1} being recorded. The taxon does not occur above 4.10 m. It is virtually absent in the upper DDA sequence.

Values of APF for Adinandra comp. are also relatively low throughout the Telago sequence, with just a slight increase over the section 7.10 m to 2.10 m. Values are variable but generally low in the upper part of the DDA core, although a maximum value of c. 60000 grains g^{-1} is recorded at 1.10 m.

For Altingia comp. APF values are low throughout the lower part of the sequence but increase at 3.10 m to over 115000 grains g^{-1}, before declining towards the surface. In the upper DDA sequence there is an increase in Altingia comp. from low levels, above 3.20 m. At 1.10 m the APF is almost 160000 grains g^{-1}. Above this the values decline to very low levels at the surface of the core.

Engelhardtia comp. exhibits relatively low APFs throughout the Telago sequence, except at 3.10 m where over 45000 grains g^{-1} are recorded. In the upper DDA sequence values are low below 2.20 m but increase above this. A maximum value of almost 70000 grains g^{-1} is recorded at 1.10 m. Values are low at the surface of the core.

Ilex cymosa also exhibits relatively low APFs throughout the Telago sequence except at 3.10 m, where over 72000 grains g^{-1} are recorded. In the upper DDA sequence APF values are very high from 2.20 m to 1.10 m, and over 245000 grains g^{-1} are recorded at 1.60 m.

Lithocarpus/*Castanopsis* comp. exhibits higher APFs than any of the taxa described so far. In the Telago sequence values of c. 20000 grains g^{-1} are recorded at the base of the core, but these increase steadily to 60000 grains g^{-1} at 4.10 m. A value of 225000 grains g^{-1} is recorded at 3.10 m; above this values decline to the top of the section. In the upper DDA sequence values increase steadily above 3.70 m where they are c. 19000 grains g^{-1}, reaching a maximum of over 345000 grains g^{-1} at 1.60 m. Values remain high to 0.55 m but are very low (c. 2300 grains g^{-1}) in the surface sample.

Quercus comp. values increase steadily over the base of the Telago sequence from 13000 grains g^{-1} at 10.10 m to 42000 grains g^{-1} at 4.10. A maximum APF of 520000 grains g^{-1} is recorded at 3.10 m, declining to 80000 grains g^{-1} at 2.10 m and very low values at the top of the sequence. In the upper DDA sequence APF increases from 9000 grains g^{-1} at 4.20 m to 60000 grains g^{-1} at 2.75 m. The section 2.20 m to 1.10 m has high frequencies, up to 267000 grains g^{-1}. Values are lower above this, and particularly at the surface of the core.

APFs for Symingtonia are low throughout much of the Telago core, the highest value of 18000 grains g^{-1} being recorded at 3.10 m. Values are slightly higher in the upper DDA section, and particularly from 2.75 m to 1.60 m, but even so do not exceed 36000 grains g^{-1}.

Elaeocarpus comp. exhibits moderate APFs at the base of the Telago sequence. These increase steadily from 6000 grains g^{-1} at 10.10 m to 48000 grains g^{-1} at 4.10 m. Above this values increase, with a maximum of 250000 grains g^{-1} at 3.10. Values at the surface of the core are however low. In the upper DDA sequence values of this taxon are low except over the section 2.75 m to 1.10 m, although even here they are lower than in the Telago sequence, being in the range 22000-93000 grains g^{-1}.

APFs of Ilex comp. are generally low in both core sections. In the Telago sequence they do however increase slightly at 3.10 m to 2.10 m where up to 36000 grains g^{-1} are recorded.

Macaranga comp. (small) has its highest APF in the Telago core from 2.10 m to 1.20 m where 23000-35000 grains g^{-1} are recorded. The taxon is absent at the base of the Telago core. In the upper DDA sequence the taxon is recorded at 3.20 m and above and APF's of c. 14000 grains g^{-1} or more prevail. A maximum of 60000 grains g^{-1} is recorded at 1.10 m but above this values decline.

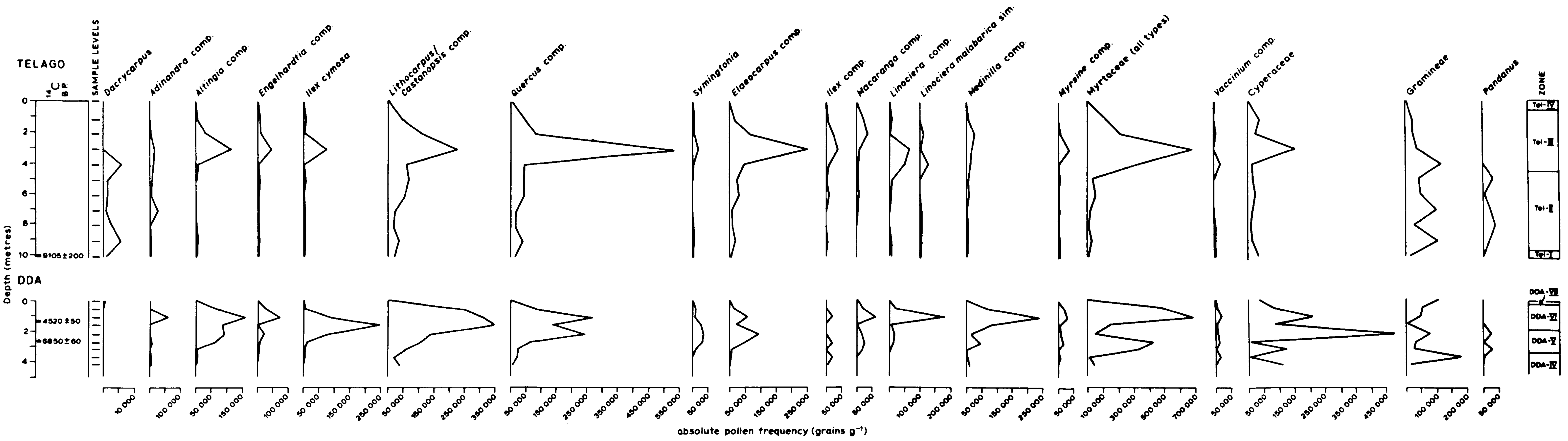
Values for Linociera comp. peak in the Telago sequence at 4.10 m to 3.10 m where up to 63000 grains g^{-1} are recorded. In the upper DDA sequence there is a peak at 1.10 m of 178000 grains g^{-1}. L. malabarica sim. is not recorded in the upper DDA sequence. Values for this in the Telago core are generally very low except at 4.10 m where 24000 grains g^{-1} are recorded.

Medinilla comp. has low APFs in much of the Telago sequence although they do increase to 29000 grains g^{-1} at 2.10 m. This taxon is much more abundant in the upper DDA sequence, particularly from 1.60 m to 0.55 m. Here a maximum of 238000 grains g^{-1} is recorded.

Values of APF for Myrsine comp. are also low throughout much of the Telago sequence, there being an increase only at 3.10 m to 36000 grains g^{-1}. The taxon seems to be generally more abundant in the upper DDA sequence but even here the values do not exceed 30000 grains g^{-1}.

The APFs of Myrtaceae (all types) are at moderate levels at the base of the Telago sequence, to 5.10 m, where they do not exceed 52000 grains g^{-1}. Much higher values are found over the section from 4.10 m to 2.10 m, up to 685000 grains g^{-1}. Values are lower above this and are low at the surface of the core. In the upper DDA sequence there are two maxima in APF, at 3.20 m to 2.75 m (327000 - 422000 grains g^{-1}) and at 1.10 m to 0.55 m (478000 - 684000 grains g^{-1}). Values are very low at the surface of the core. The bulk of the Myrtaceae pollen is composed of Myrtaceae

Fig. 7.5
Telago: absolute pollen frequencies for selected taxa


TELAGO
DDA
¹⁴C B.P.
SAMPLE LEVELS
Depth (metres)
9105±200
4520±50
6850±60
Dacrycarpus
Adinandra comp.
Altingia comp.
Engelhardtia comp.
Ilex cymosa
Lithocarpus/Castanopsis comp.
Quercus comp.
Symingtonia
Elaeocarpus comp.
Ilex comp.
Macaranga comp.
Linociera comp.
Linociera malabarica sim.
Medinilla comp.
Myrsine comp.
Myrtaceae (all types)
Vaccinium comp.
Cyperaceae
Gramineae
Pandanus
ZONE
Tel-IV
Tel-III
Tel-II
Tel-I
DDA-VII
DDA-VI
DDA-V
DDA-IV
absolute pollen frequency (grains g⁻¹)

type 1, which accounts for over 80% of the Myrtaceae pollen in most samples.

Values for Vaccinium comp. are relatively low throughout most of the Telago sequence, increasing slightly only at 4.10 m and 2.10 m, with a maximum value of 18000 grains g^{-1} at 4.10 m. The taxon appears to be better represented in the upper DDA section, but values still do not exceed 20000 grains g^{-1}.

Cyperaceae APF values are relatively low throughout much of the Telago core, increasing at 3.10 m to 153000 grains g^{-1}. At the surface only 1700 grains g^{-1} are recorded. In the upper DDA sequence the APFs are very variable, and generally much higher than in the Telago sequence. Over 477000 grains g^{-1} are recorded at 2.20 m.

APF values for Gramineae are higher in the Telago sequence than are Cyperaceae values. Below 3.10 m they are quite variable, 12000 - 114000 grains g^{-1}. Above 3.10 m they are less variable but decline steadily from 36000 grains g^{-1} at 3.10 m to 1600 grains g^{-1} at the surface of the core. Values for this taxon are more variable in the upper part of the DDA sequence, ranging from 6000 - 178000 grains g^{-1}. Values at the surface are also quite high, 110000 grains g^{-1}.

Values of APF for Pandanus are moderate in both core sections although in both the taxon is only recorded in part of the sequence. In the Telago core Pandanus occurs from 9.10 m to 5.10 m, and APFs of up to 36000 grains g^{-1} are recorded. In the upper

DDA section the taxon is found only from 3.70 m to 2.20 m with maximum APFs of 26000 grains g^{-1}.

7.6c Absolute pollen frequencies of altitudinal forest groups (arboreal taxa only) (Fig. 7.6)

APF values for total arboreal pollen in the Telago sequence are of the order of 66000 - 229000 grains g^{-1} below 4.10 m. At 4.10 m there is a large increase, and values of over 600000 grains g^{-1} are recorded from 4.10 m to 2.10 m, with a maximum of c. 2.2 million grains g^{-1} recorded at 3.10 m. Above this the APF declines, and at the surface of the core is low, c. 5000 grains g^{-1}. In the upper DDA sequence values increase steadily from 113000 grains g^{-1} at 4.20 to c. 2.4 million at 1.10 m. They then decline above this and are low at the top of the sequence (c. 15000 grains g^{-1}).

The APF values for taxa common to all lower montane forest types show a pattern similar to that for total arboreal pollen, but actual values are lower.

APF values for the group of taxa more or less restricted to sub-montane forest are low throughout much of the Telago sequence, except at 4.10 m to 3.10 m where over 60000 grains g^{-1} are recorded. Values for the group also show an increase in the upper DDA sequence from 2.75 m to 0.55 m, and especially at 1.10 m where 178000 grains g^{-1} are recorded.

APFs of the taxa of sub-montane forest and lower montane forest I are very low in both sequences, and are rarely greater than 3000 grains g^{-1}. The group is represented throughout the Telago core but only at 2.75 m in the upper DDA sequence.

Taxa restricted to lower montane forest I, have low APFs through much of the Telago sequence but are markedly increased at 3.10m and 2.10 m, with 117000 grains g^{-1} recorded at 3.10 m. In the upper DDA sequence the group has increased APFs from 2.75 m to 0.55 m.

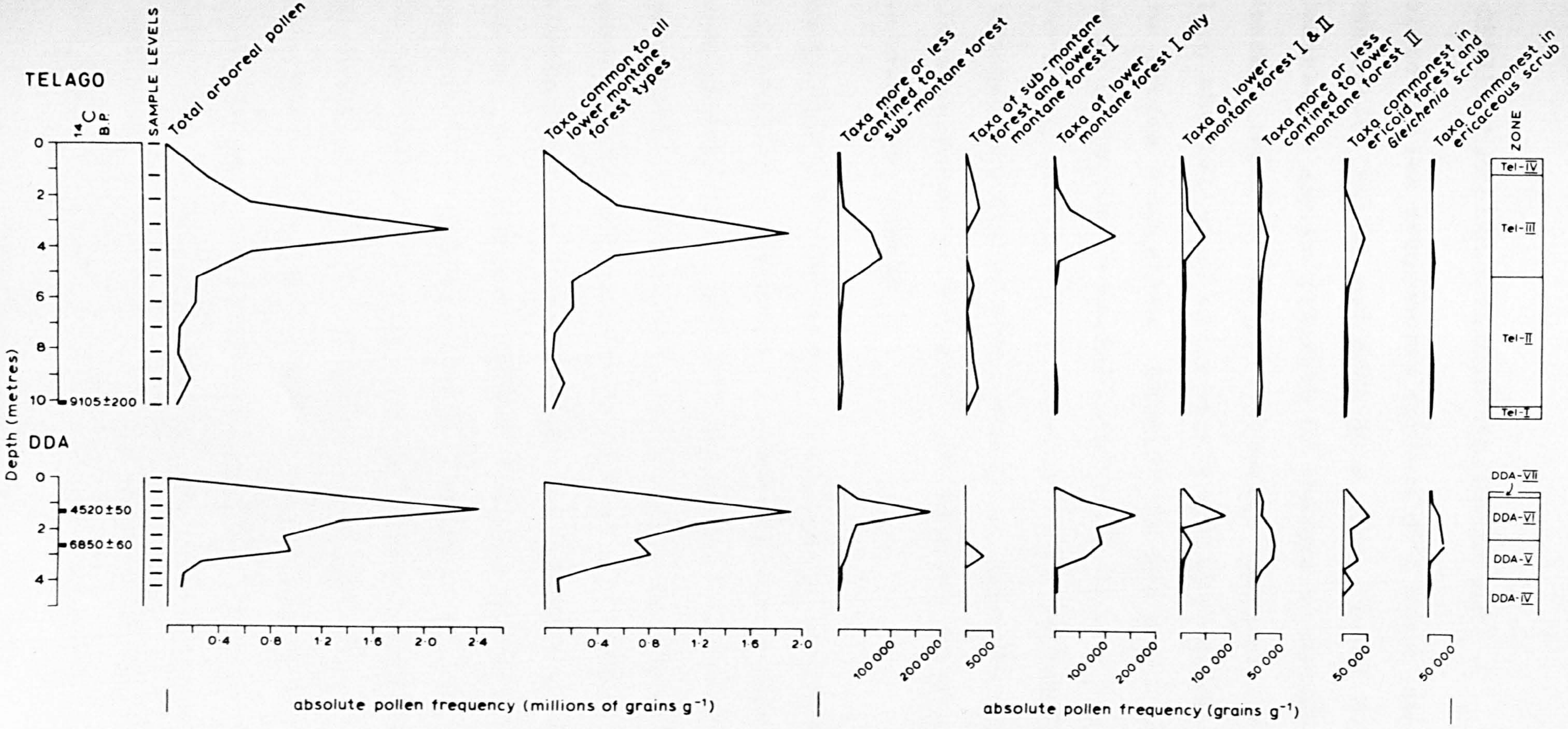
For taxa of lower montane forest I and II fairly low APFs prevail throughout most of the Telago sequence, with an increase only at 3.10 m. In the upper DDA sequence the highest values occur over the section 2.20 m to 0.55 m.

APFs of the group of taxa more or less confined to lower montane forest II are low throughout the Telago sequence, increasing only slightly at 3.10 m. In the upper DDA sequence APF values are higher than in Telago, especially from 2.75 m to 1.60 m but still do not exceed 40000 grains g^{-1}.

Values for the group of taxa commonest in ericoid forest and Gleichenia scrub are low throughout most of the Telago sequence, increasing only from 4.10 m to 2.10 m, with a maximum value of 36000 grains g^{-1} at 3.10 m. Values are more variable in the upper DDA sequence but still do not exceed 50000 grains g^{-1}.

APFs for the group of taxa commonest in ericaceous scrub are extremely low throughout the Telago sequence, but are slightly higher in the upper part of DDA. Values of 20000 - 30000 grains g^{-1} are recorded in the latter from 2.20 m to 1.10 m.

Fig. 7.6
Telago: absolute pollen frequencies for altitudinal forest groups


TELAGO
DDA
Depth (metres)
0
2
4
6
8
10
0
2
4
^{14}C B.P.
9105±200
4520±50
6850±60
SAMPLE LEVELS
Total arboreal pollen
Taxa common to all lower montane forest types
Taxa more or less confined to sub-montane forest
Taxa of sub-montane forest and lower montane forest I
Taxa of lower montane forest I only
Taxa of lower montane forest I & II
Taxa more or less confined to lower montane forest II
Taxa commonest in ericoid forest and *Gleichenia* scrub
Taxa commonest in ericaceous scrub
ZONE
Tel-IV
Tel-III
Tel-II
Tel-I
DDA-VII
DDA-VI
DDA-V
DDA-IV
0·4
0·8
1·2
1·6
2·0
2·4
0·4
0·8
1·2
1·6
2·0
100 000
200 000
5000
100 000
200 000
100 000
50 000
50 000
50 000
absolute pollen frequency (millions of grains g^{-1})
absolute pollen frequency (grains g^{-1})

7.7 Absolute pollen frequencies: discussion

Absolute pollen frequencies (grains g^{-1}) are a measure of pollen concentration in the sediment at a site. Total Dry Land Pollen concentration may be affected by changes in sedimentation processes, input of non-polleniferous sediment and input of pollen, the latter of which may be due to changes in the nature of the source vegetation. Because the APF may change even if there is no change in pollen production by the vegetation, APF curves may be difficult to interpret with certainty. For example APF changes associated with changes in sediment type may be of little significance, and need not indicate changes in the surrounding vegetation.

At the Telago site there are three main phases in APF of Total Dry Land Pollen. Below 4.10 m APFs are relatively low but increasing steadily. The stratigraphy of much of this section is gyttja or fine detritus muds with few or no wood fragments. APFs are much higher over the section 4.10 m to 2.10 m. The stratigraphy of the section comprises detritus muds with wood fragments. The increased pollen frequencies at this time could be a result of increased pollen production by the local vegetation and/or a decrease in the accumulation rate of non-polleniferous material. The decline in APF to very low levels at the top of the core, above 2.10 m, is likely to be related to both the change in the sediment to a very fibrous vegetation mat, and a decline in pollen production by the surrounding vegetation as a result of deforestation. It is of interest that APFs show a similar pattern in the top part of the DDA core, despite the difference in the stratigraphy of most of the sequence (Table 6.1). It could be, therefore, that these parallels in pollen concentration relate to a considerable extent to changes in pollen production by the vegetation, as well as to depositional features at the two sites.

The similarities in the APF curves for many taxa at the two sites also tends to support this idea. Some taxa show dissimilar curves at the two sites, for example, Cyperaceae and Gramineae, and this may be an indication that the source of this pollen is largely very local. In the case of Cyperaceae and Gramineae a local source for most pollen would be expected, and would reflect the hydroseral development at the sites. Differences in the APF curves at the two sites for taxa such as Myrtaceae, Medinilla comp. and Elaeocarpus comp. are also of interest and may also indicate a local rather than regional source for some of this pollen. In these cases a possible local source is in swamp forest growing at one or other site.

The cause of the high APFs in the top sections of both cores is not clear.

CHAPTER 8

THE VEGETATIONAL AND ENVIRONMENTAL HISTORY OF THE DANAU DI ATAS REGION DURING THE LATE QUATERNARY PERIOD

8.1 The vegetational history of the Danau di Atas region

Both the DDA and Telago cores contribute valuable palynological information which may be interpreted in terms of the past vegetation of the surrounding areas. In Chapter 5 the present day patterns of pollen production and deposition were considered, and it was concluded that much of the pollen deposited at the Danau di Atas Swamp site is from the aerial component of the pollen rain with some contributions from surface runoff and, perhaps more importantly in the past, from inflowing streams. Although the Telago Swamp site was not the subject of any modern studies, it is quite likely that the sources of pollen at this site are rather similar.

The modern pollen studies also showed that vegetation growing locally contributes quite large amounts of pollen to all modern samples. For samples from the Danau di Atas Swamp surface a significant proportion of the pollen also has a regional arboreal source.

These findings are important for the interpretation of the two core sequences examined. If pollen deposition patterns have been the same in the past then it is likely that a considerable proportion of their contained pollen and spores are derived from vegetation growing locally; this will include both swamp and dry land vegetation. However some pollen, and these studies suggest

10-25% TDLP will be regionally derived and will therefore represent the arboreal vegetation at further distances from the sites. The pollen assemblages from the cores can thus be used to reconstruct both the local and regional vegetation. Since the pollen is derived from a wide source area and the topography of the region is varied, the pollen may be representative of not only a range of habitats such as swamp and dry land, but quite possibly, where the dry land is largely forested, more than one altitudinal forest type. It is clearly possible to have a situation where the lower lying areas in the vicinity of the site have a different vegetation to that of the higher mountain and ridge areas which lie slightly further afield. Yet all may be represented to a greater or lesser extent in the pollen deposited at the sites.

Although on G. Kerinci most pollen appears to be deposited within the altitudinal range of its source vegetation, some movement out of the source areas occurs and is predominantly uphill. Studies in the Danau di Atas area did not conclusively demonstrate that this occurs in this region, but the possibility of some movement of pollen uphill also has to be considered when the fossil pollen assemblages are interpreted. To a much lesser extent there may also be movement of pollen out of the source vegetation to slightly lower altitudes.

8.2 Interpretation of the Danau di Atas core

For convenience the vegetational history is considered in terms of the pollen zones described in Chapter 6.

Zone DDA-1, 16.50 m to 13.15 m (Fig. 6.2)

The lithology of zone DDA-I comprises fine detritus muds with silt. This strongly suggests deposition in open water conditions with perhaps a considerable water depth (West, 1977). The detritus content of the muds is fairly low compared with elsewhere in the profile (Table 6.1) and percentage weight loss on ignition, an indicator of organic carbon present is also fairly low; both are also suggestive of open water conditions. The detritus content and percentage weight loss on ignition of the sediment increase above c. 13.90 m and c. 14.10 m respectively.

The top section of this zone, above 14.15 m shows a reversal of ^{14}C dates which is thought to be the result of incorporation of older reworked sediments in the sequence. This event coincides with an increase in pollen influx from very low levels over the section 16.30 m to 14.60 m to some of the highest values recorded in the entire sequence (at 14.10 m and above). The cause of these high influx values appears to be the very rapid accumulation rate of sediments over this section, as pollen concentration (as grains g^{-1}) does not increase significantly in these samples (Fig. 6.6). The possible causes of the reworking of sediments are discussed in Section 6.3 and include mass movement of sediments into the profile by slumping, and erosion and redeposition of marginal sediments perhaps associated with lower water level. Whatever the cause, the event presents some problems for interpretation of the pollen diagram as the sequence, as a result, contains fossil pollen of different ages.

It is therefore important to know the extent of the redeposited sediments, if possible.

In this sequence the maximum depth of the redeposited sediments would appear to be 14.15 m as the ^{14}C date from 14.15 m - 14.25 m of 18250 ± 290 years B.P. appears to fit quite normally with the basal sequence of ^{14}C dates (Fig. 6.1). That the redeposited sequence starts fairly close to 14.15 m seems likely since old ^{14}C dates are obtained at 13.75 m - 13.85 m and 13.15 m - 13.25 m (Table 6.2). How far above 13.15 m, into zone DDA-II the reworked material extends is discussed in Section 6.3, and the conclusion is that it is unlikely to extend above 10.65 m. There is a change in the sediment type at 13.90 m, from a fine detritus mud with silt, to a coarse detritus mud. This might mark the point at which the reworked sequence starts. Similarly there is a change in sediment type at 11.00 m from coarse detritus mud to coarse woody detritus mud, which might mark the top of the reworked sequence, although it might be purely a result of swamp vegetation development adjacent to the site. It appears nonetheless, safe to assume that pollen assemblages in the upper part of zone DDA-I above 14.15 m are not a true reflection of the vegetation of that time, being either totally reworked, or a mixture of fossil pollen of different ages. Below 14.15 m the pollen assemblages should be a reflection of the vegetation of that period.

Pollen assemblages recorded in the zone, covering a time span possibly from c. 39000 and certainly from c. 31000 to c. 17900 years B.P. (Fig. 6.1) suggest the presence of a largely herbaceous swamp vegetation in the vicinity of the site. The major components of this vegetation appear to have been Cyperaceae and Gramineae although *Laurembergia* sp., *Eriocaulon* sp. and possibly *Impatiens* sp. were also present. The presence of *Typha* comp. in the zone suggests the presence of *Typha* or *Sparganium* in the vicinity perhaps at the margins of the body of water. *Pandanus* pollen is also recorded, and could indicate the presence of this taxon in the swamp vegetation, although *Pandanus* sp. also occur in the understory of dry land forests so the exact source of this pollen cannot be elucidated.

Many of the abundant pteridophyte spores recorded in the zone are probably also derived from the swamp vegetation. A large proportion of the group Filices undifferentiated comprise monolete spores in which the exosporium has been lost, a feature also described by Morley (1976), who noted that this was a frequent occurrence thus making reconstruction of the pteridophyte flora quite difficult. It seems likely that a large proportion of the Filices undifferentiated recorded were from a local source, principally the swamp vegetation. Other pteridophyte components of the swamp vegetation may have included *Lycopodium cernuum* and *Nephrolepis* sp., both of which are recorded in the pollen assemblages of the zone. *Pteridium* spores recorded in the zone may have had their source in *Pteridium* growing in the swamp vegetation. Although this was not observed on swamps in the Danau di Atas area at present, Morley (1976) found that *P. aquilinum* was common on the swamp at Danau Padang in the Kerinci area where it was associated with burnt areas.

Swamp vegetation present in the vicinity of the site during the period appears to have been herbaceous, and there are no indications from the sediment that woody taxa were prevalent around the site, since the detritus is entirely herbaceous. Pollen of _Ilex cymosa_, _Elaeocarpus_ comp., Myrtaceae, _Myrsine_ comp. and _Glochidion_ comp. would appear therefore to be derived from dry land rather than swamp vegetation, or from swamp forest elsewhere in the region.

About 60-75% of the Dry Land Pollen in the zone was derived from forest sources suggesting that the area may have been largely forested at this time. This appears to be the most likely situation although another possibility does exist. The very low levels of pollen influx recorded in the zone below 14.60 m could possibly indicate that the area was not forested at all during this period. This would be the case if open vegetation with few or no arboreal taxa and possibly considerable areas of bare ground, such as is now found at high altitudes on G. Kerinci, prevailed in the area. Arboreal pollen would then have its source at lower altitudes, and be transported into the area as part of the regional pollen rain. However the low influx levels might be unrelated to the nature of the surrounding vegetation if due to sedimentary processes within the depositional basin, so this interpretation of the vegetation during the period of zone DDA-1 is rather tenuous. Further indications that the influxes are a reflection of sedimentation processes are provided by the influx curves for some individual taxa. Curves for Cyperaceae and Gramineae, both of which might be expected to be widespread in vegetation having an open nature, increase above 14.60 m, not only in the reworked section, but also in the section above this. Influxes of these taxa would not be expected to increase if there was a change from non-forest to forested conditions unless the environment accompanying the non-forested conditions was extremely severe such that very little pollen was produced. The indications are therefore in favour of forested conditions at this time, the composition of these forests is discussed below.

Representation of gymnosperm pollen is moderate to low in this zone. Morley (1976) found that *Dacrycarpus imbricatus* (there called *Podocarpus imbricatus*) was a prolific pollen producer, although this was not found to be the case in the Danau di Atas region where *Dacrycarpus* was not well represented in the modern pollen assemblages. However gymnosperms often produce large amounts of pollen since they are wind pollinated, and therefore the relatively low levels of *Dacrycarpus*, *Podocarpus* and *Pinus*, and moderate amounts of *Dacrydium* recorded in this zone may indicate low representation of these taxa in the vegetation. Some *Dacrydium* spp. are found in swamp forests (Whitmore, 1975) and this may therefore have been a component of swamp or dry land vegetation in the region although it is unlikely that the Danau di Atas Swamp supported vegetation of this type during zone DDA-I.

Fagaceae are well represented in the pollen assemblages of the zone. Studies of modern pollen dispersal and vegetation in the

Danau di Atas area (Chapters 4 and 5) indicated that *Quercus* comp. had a tendency to be over-represented in samples, which tends to agree with Soepadmo (1973) that *Quercus* are anemophilous, and that therefore pollen of *Quercus* may be abundantly produced and widely dispersed (Morley, 1976). *Lithocarpus*/*Castanopsis* comp. was variably represented in these studies but was not consistently over-represented as was *Quercus* comp. The representation of Fagaceae in the zone probably does indicate that this family was well represented in the forest vegetation at this time, probably by the genera *Lithocarpus*, *Castanopsis* and *Quercus* although other genera could also have been present, while *Quercus* might have been less significant than its pollen representation suggests. The members of the Fagaceae are common in all lower montane forest types and could therefore be indicative of sub-montane, lower montane I or lower montane II type forests.

Although *Adinandra* comp. tended to be over-represented in the modern pollen rain of the area, the forest vegetation probably also included some *Adinandra* sp. Other sources of this pollen type are *Ternstroemia* sp. and other Theaceae. This group may have been well distributed throughout the vegetation at this time, but is unlikely to have been a major component. *Schima* pollen is recorded only once in the zone and indicates the presence of *Schima* sp., also a member of the Theaceae. This taxon appears to be very under-represented in the modern pollen rain in the Danau di Atas region, and also in the Kerinci area (Morley, 1976). It might therefore have been a more important component of the vegetation than its representation suggests.

Myrtaceae pollen provides some interesting problems for the interpretation of the assemblages, since the different forms of pollen recovered cannot be related to particular genera or species with certainty. Myrtaceae type 1 was commonly observed in *Eugenia* spp. and *Syzygium* spp. (some *Eugenia* spp. have been reclassified as the latter), although other taxa also have similar pollen. Myrtaceae type 2 was likewise observed in *Syzygium* spp., but other taxa including *Leptospermum* spp. also have pollen of this type. The diversity of forms of Myrtaceae pollen observed in this zone could indicate that a variety of species were acting as source taxa. *Eugenia* spp. may have featured strongly amongst these, but other genera such as *Rhodomyrtus* and *Leptospermum* may also have been included. Whatever the composition in terms of genera and species, the Myrtaceae appear to have been an important component of the forest vegetation during this period.

Other taxa which appear to have occurred in the zone DDA-I forests include *Altingia* sp. (probably *A. excelsa*), *Symingtonia* sp. (probably *S. populnea*), *Ilex* sp., Araliaceae, *Medinilla* sp. and other Melastomataceae, *Ilex cymosa*, *Elaeocarpus* sp., *Symplocos* sp. and *Cyathea* sp. As was discussed previously, this forest was unlikely to have been of uniform composition, and these taxa need not have occurred together. Most of these would have formed a minor part of the forest as a whole, although some may have been more significant than is suggested by the low percentages of pollen recorded. Symingtonia is one such taxon, and tends to be under-represented in modern surface samples. S. populnea is considered to be a taxon primarily of lower montane forest II, and is often found in conjunction with Dacrycarpus imbricatus. Tarenna fragrans was recorded in only three samples in this zone, and is another taxon which tended to be under-represented in modern surface samples (Chapter 5). At present the taxon occurs throughout the lower montane forest of the area, as a minor forest constituent. During the duration of zone DDA-I it appears also to have been a minor component of the forest.

Members of the family Lauraceae produce pollen which is thin walled and appears not to preserve well. As a result of this it is recorded in very few modern surface samples in this study, despite the abundance of the family in the surrounding forest vegetation, and in none of the fossil assemblages. This presents some problems to the interpretation of the latter since the family might be an important component of the forest vegetation and yet not be represented at all in the pollen assemblages. The forest present during the period represented by zone DDA-I appear to have been largely lower montane in nature, with Myrtaceae and Fagaceae as important components. Lauraceae may have also been present at this time, indeed this seems quite likely on the basis of modern vegetation studies in the area, which show Lauraceae to be a common component of lower montane forest.

Linociera comp. is recorded rarely in the zone. The most likely source, Linociera spp., has lowland rather than montane affinities although some species do extend into sub-montane forest, while L. oxycarpa was recorded in one lower montane forest I plot studied in the area. The existence of low frequencies of Linociera comp. in the zone may indicate the presence of rare individuals of the genus in the vegetation at or around the site, but could also be the result of long distance transport of pollen grains from lower altitude forest notably to the west of the lake, Danau di Atas.

The presence of Macaranga comp. in the zone may be of little significance, as this taxon tends to be over-represented in the pollen rain (Chapter 5). Large increases in Macaranga comp. may be an indication of increased areas of seral vegetation communities as Macaranga spp. are common in secondary forest. In zone DDA-I the low representation of Macaranga comp. is not indicative of the widespread existence of such vegetation. Trema sp. is also indicative of seral vegetation (Morley, 1976) but its pollen is recorded only rarely in this zone and is therefore unlikely to be of significance. This taxon is presently found predominantly in vegetation below 1300 m a.s.l., although its pollen was readily transported to high altitudes in the Kerinci area (Morley, 1976). The occurrence of Trema comp. in fossil samples should therefore be interpreted with some caution, as it may be entirely a result of long distance transport.

Vaccinium comp. is recorded in moderately low amounts in the zone, and Rhododendron comp. is recorded sporadically; both taxa tend to be under-represented in the pollen rain. There are several possible sources for this pollen. It could be from epiphytic *Rhododendron* spp. and *Vaccinium* spp. in the forest vegetation, from *Rhododendron* spp. and *Vaccinium* spp. growing in swamp vegetation or from the same genera growing in one of the upper montane forest types, either ericoid forest or ericaceous scrub. *Myrsine* comp. which is also recorded in the zone may also have a source either in the swamp forest or in the ericoid forest, where its source may include *Myrsine affinis*.

The dry land vegetation of the Danau di Atas area during the duration of zone DDA-I appears to have comprised forests in which lower montane forest elements predominated. These forests included some lower montane forest II elements, although the extent of these is difficult to assess with certainty. The presence of *Vaccinium* comp., *Rhododendron* comp. and *Myrsine* comp. could indicate the presence of ericaceous upper montane forests in the area. It is likely that this, if present, was not prevalent around the site itself as the percentage representation, and influx values for these taxa are relatively low. Such vegetation might have occurred on mountains and ridges at some distance from the site. The site appears to have been surrounded by lower montane forest, but the exact nature of this, whether having lower montane forest I or II affinities is not clear. The other possibility, that the area was not forested at all during this period, and that almost all arboreal pollen was transported over long distances to the site was discussed earlier in the section, but is considered to be a rather more tenuous interpretation of the pollen assemblages.

Pollen influx values in the zone are complicated by the redeposition of sediments in the profile. They are very low, c. 1000-3000 grains cm^{-2} yr^{-1} for TDLP, until c. 18250 years B.P. but thereafter increase to high levels, over 30000 grains cm^{-2} yr^{-1} for TDLP in the reworked section. Most taxa show increased pollen influx at this time, but some, such as *Macaranga* comp. and *Altingia* comp. remain at low levels, an indication that they were probably of little significance in the vegetation at this time.

Zone DDA-II, 13.15 m to 7.40 m

The basal part of this zone, below 10.65 m, may include reworked sediments, and therefore reworked pollen and spores, as was discussed in the previous section. If a section is entirely reworked, without any addition of contemporaneous pollen, then the contained palynomorph assemblages should be similar to those of unaffected, similar deposits of the same age, in this case similar to those at the base of zone DDA-I. However, if during the reworking of the sediment, contemporaneous pollen is also deposited then the resulting assemblages may be quite different from the unaffected older deposits, and also from purely contemporaneous deposits. In the DDA sequence there are some quite distinct pollen changes at the zone DDA-I/II boundary, and more gradual changes in other pollen curves occur over this section, so that many of the individual pollen curves in zone DDA-II are quite different from those in the early part of zone DDA-I. This suggests that even if the basal part of zone DDA-II includes some reworked pollen, a considerable contemporaneous component may also have been deposited, changes in this perhaps resulting in the changes in the pollen curves observed. The basal part of the zone can still therefore be interpreted in terms of its source vegetation.

The lithology of this zone comprises coarse detritus muds. Below 11.00 m the detritus consists of herbaceous fragments but above this it is very woody. The lithology alone suggests that below 11.00 m (c. 17000 years B.P.) the hydrophytic vegetation in the vicinity of the site was largely herbaceous in nature, with swamp forest, if existing, only of very limited extent, perhaps at the periphery of any swamp vegetation. The appearance of large amounts of wood in the detritus above 11.00 m suggests a greater prevalence of woody taxa. If the wood is <u>in situ</u> then there is a possibility that it may be derived from roots, growing down into the sediment at a later date than that at which the rest of the sediments were deposited. This would certainly confirm the presence of swamp forest or shrubby vegetation at the site but its arrival would post date the sediment and would be after c.17000 years B.P. If however the wood is from fragments which have fallen into the deposition basin, then these will be the same age as the sediments. The likely source is still swamp forest, shrubby swamp vegetation or perhaps, less likely, peripheral dry land forest. This could indicate the presence of swamp forest in some parts of what is now the Danau di Atas Swamp, c. 17000 years B.P. Even so, herbaceous swamp taxa remain well represented in pollen assemblages and must have constituted an important component of the swamp vegetation.

Pollen assemblages in the zone, covering the period c. 17900 to

c. 12900 years B.P. suggest that throughout the interval Gramineae and Cyperaceae were major components of the herbaceous swamp vegetation. *Eriocaulon* spp. also appear to have been consistently present in this vegetation, but might have been slightly less common during the later part of the zone (subzone DDA-IIB). Less common components of this vegetation appear to have included *Xyris* sp. and possibly *Laurembergia* sp. although these are recorded only occasionally in the pollen record. The rare records of Monocotyledon undifferentiated might also have had a swamp source, although the actual source of this pollen could not be determined. Another possible component of the swamp vegetation was *Pandanus* sp. although this can also occur in dry land vegetation and does not in any case appear to have been common, pollen being recorded in only one sample.

Pteridophytes were probably well represented in the swamp vegetation, and may have included, at various times, *Lycopodium cernuum*, *L. clavatum*, *Cyclosorus* sp., *Nephrolepis* sp., *Dicranopteris* sp. and possibly even *Pteridium* sp. In addition much of the Filices undifferentiated is likely to have had its source in swamp vegetation.

The presence throughout the zone of *Typha* comp. and *Potamogeton* is indicative of some open water with the named taxa, and perhaps *Sparganium* sp.

The occurrence of woody fragments in the lithology above 11.00 m is, as previously described, suggestive of the presence of swamp forest in the vicinity. Although this vegetation no longer occurs in the Danau di Atas region, and was therefore not studied, Morley (1976, 1982) describes swamp forest from 950 m a.s.l. in the Kerinci area. Arboreal taxa which were important in this swamp vegetation included *Ilex cymosa*, *Elaeocarpus* sp., *Myrsine affinis* D.C., *Eugenia* sp., *Glochidion brunneum* HK.f. and *Euodia* cf. *macrophylla* BL. Minor taxa included *Melastoma malabathricum* L., *Rhododendron javanicum* (BL.)BERM, *Vaccinium accuminatissum* MIQ., *Ficus* sp. and *Ficus deltoidea* JACK. A swamp forest at or near the site during the later part of the period covered by zone DDA-II, may have included according to pollen assemblages, *Ilex cymosa*, *Elaeocarpus* sp., *Myrsine* sp., *Eugenia* sp. and possibly *Melastoma* sp., *Rhododendron* sp. and *Vaccinium* sp. It is also possible that *Dacrydium* sp. may have occurred in swamp vegetation. All of these taxa are represented in the pollen assemblages of the zone, however since none of these taxa are better represented above 11.00 m than below it the actual composition of swamp forest, if this existed, is not clear.

The bulk of the Dry Land Pollen recorded throughout the zone has its origins in forest (Fig. 6.4). Pollen of the gymnosperms is abundant, increases being particularly marked for *Dacrycarpus* and *Podocarpus*, and pollen influx values for these taxa are also higher than in zone DDA-I. Although *Dacrycarpus imbricatus* may be a prolific producer of pollen the high levels of this pollen recorded do suggest a real increase in the importance of this taxon in the vegetation of the area at this time, perhaps indicating an extension of lower montane forest II. *Dacrydium* values are also high throughout the zone. This genus has a much wider distribution than *Dacrycarpus*, and in addition at least one species is common in swamp vegetation (Whitmore, 1975). This genus also appears to have been of some importance in the area during the period represented by zone DDA-II, either in the dry land or swamp forest vegetation or both. *Podocarpus* sp. also appears to have been a component of the regional vegetation, but probably of less importance than either *Dacrydium* or *Dacrycarpus*. *Pinus* sp. (possibly *P. merkussii*) has an interesting temporal distribution. It appears to have been rare or absent from the vegetation during the duration represented by subzone DDA-IIA, but present either as a minor forest component or at some distance from the area during the subzone DDA-IIB.

The Fagaceae are well represented in the zone but by reduced pollen percentages compared with in zone DDA-I. Influx values however are fairly high and it therefore seems likely that the source genera *Lithocarpus*, *Castanopsis*, *Quercus* and perhaps others, remained an important component of the forest vegetation at this time, despite the increasing importance of taxa such as *Dacrycarpus*. Another component of the forest vegetation may have been the Theaceae, represented by *Adinandra* sp. and perhaps other genera. *Engelhardtia* sp. may also have been present. However the pollen of this taxon, *Engelhardtia* comp. is not consistently recorded in the zone. *Engelhardtia* is considered by Morley (1976) to be a prolific pollen producer which suggests that this may have been only a minor component of the vegetation. *Symingtonia* is recorded throughout zone DDA-II, and since this tends to be under-represented in surface samples, this may indicate that

Symingtonia (perhaps *S. populnea*) was a widespread or locally important component of the forest vegetation. Its consistent presence in the pollen record may be an indication of lower montane forest II in the area.

Altingia comp., most likely derived from *A. excelsa*, is present in low frequencies in the zone, and the influx values for this taxon are also low. *A. excelsa* occurs principally, it is thought, in lower montane forest I. However this is an important timber tree which has been largely removed from many forests at present, as a result of which it was not recorded in the study area forest plots. Consequently no data on its pollen production and representation in samples was available. The low representation of the taxon in this zone perhaps indicates that *A. excelsa* was rare in these forests.

Other components of the dry land forests during this period, suggested by the pollen assemblages, were *Ilex* sp., *Symplocos* sp., *Wendlandia* sp. and possibly other Rubiaceae, *Eugenia* sp. and probably other Myrtaceae, perhaps *Leptospermum* sp. The Myrtaceae in particular may have been important components of the forest. Pollen of Lauraceae is not recorded in any of the assemblages, nonetheless the family may well have been represented in the forest vegetation. *Ilex cymosa* and *Elaeocarpus* sp. could have been present in either the dry land or swamp forest vegetation of the area, and possibly both, while the tree fern genus *Cyathea* seems to have been a feature of the dry land pteridophyte flora.

Linociera comp. and *Celtis* comp. are both recorded in the zone, but the percentage representation of these primarily sub-montane taxa is very low, and could be the result of long distance, uphill transport from sub-montane forest at lower altitudes. Even if this is not the case, the pollen percentages indicate that *Linociera* and *Celtis* are rare components of the vegetation. The very low representation of *Macaranga* comp. in the zone suggests rarity of this taxon in the vegetation, and therefore seral vegetation does not appear to have been widespread during this period.

The presence of abundant *Myrsine* comp. and *Vaccinium* comp., with smaller amounts of *Rhododendron* comp. in the zone could indicate the presence of these taxa in swamp vegetation. However, these pollen taxa were very common in the pollen rain from upper montane forest (ericoid forest and *Gleichenia* scrub, and ericaceous scrub zones, Fig. 5.6) and thus could also indicate the presence of some type of upper montane forest fairly close to the site.

Dry land forest herbs and shrubs are rarely present in the pollen record of the zone, but of some interest is the quite frequent representation of *Strobilanthes* and other Acanthaceae. *Strobilanthes* often occurs gregariously and has a very unusual flowering pattern, all plants in the same area flower at the same time, approximately every seven or more years (van Steenis, 1972). The taxon would not therefore be expected in the pollen record unless it was quite common in the vegetation. Loranthaceae, a family in which the members are hemiparasitic on arboreal taxa, is also recorded, indicating the presence of these hemiparasites on some of the arboreal vegetation.

The dry land vegetation throughout the time represented by zone DDA-II appears to consist largely of forests which are predominantly of lower montane character. However, some upper montane forest may also have been present during this period. The quite high representation of taxa having sources in lower montane forest II at present suggests that the lower montane forest may have included significant proportions with characteristics akin to lower montane forest II. Many of the other taxa recorded neither confirm or disprove this as they are common to all lower montane forest types. Possibly forests surrounding the site had a character similar to that presently found in lower montane forest II, with abundant *Dacrycarpus* and *Symingtonia*. Upper montane forest of a predominantly ericaceous nature but also with *Myrsine* sp. probably also occurred in the area, possibly on the ridges and mountains rather than adjacent to the site.

Few differences are apparent in the vegetation of subzones DDA-IIA and DDA-IIB. Subzone DDA-IIA appears to have had a slightly greater representation of *Medinilla* sp. and possibly other Melastomataceae. *Myrsine* sp. may also have been commoner at this time. *Impatiens*, a herb which may have occurred in the forest or swamp vegetation, is only recorded in this subzone, as is *Gentiana*. The present distribution of the latter genus in Sumatra and Java (van Steenis, 1934, 1972) varies with the particular species. *G. quadrifaria* is found from 1650 m to 3350 m a.s.l., while G. sumatrana at present occurs at high altitudes on G. Kerinci, from c. 3000 to 3300 m a.s.l. Clearly the presence of Gentiana pollen could indicate the presence of any of a wide range of altitudinal vegetation types, including high altitude vegetation of an open nature.

Pinus appears to be more significant in the vegetation during the duration of subzone DDA-IIB, and may have been absent during DDA-IIA, although these small amounts of pollen might have been transported into the area. Meliaceae/Sapotaceae and a Symplocos sp. having pollen similar to that of S. sessilifolia, seem to have been present only during subzone DDA-IIB. The latter is presently found in forests above 1500 m a.s.l. and particularly above 2000 m a.s.l. in Java (Backer and Bakhuizen van den Brink, 1965) and certainly occurs at high altitudes on G. Kerinci (Jacobs, 1958; see also Section 4.12). It provides, perhaps, further evidence for the presence of lower montane forest II and upper montane forest in the area during the duration of subzone DDA-IIB.

Zone DDA-III, 7.40 m to 5.40 m

The lithology of this zone comprises coarse detritus muds with abundant woody fragments, suggesting that some form of woody swamp vegetation was present in the vicinity of the site. However, the pollen assemblages of the zone, which represents the period from c. 12900 to c. 11750 years B.P. (Fig. 6.1), indicate that herbaceous swamp vegetation also existed during this period. The swamp vegetation may therefore have taken the form of swamp forest or shrubs with a well developed ground flora, swamp forest of a fairly open nature, or different parts of the swamp may even have had distinct types of vegetation such as forest, scrub or herbaceous swamp communities, related to different environmental conditions.

The herbaceous aspect of the swamp vegetation appears to have been composed largely of Cyperaceae and Gramineae with *Eriocaulon* sp. and *Xyris* sp. as minor components. Pteridophytes may well have been less important in the vegetation than formerly, as the percentage representation and influx of pteridophyte spores in the zone is generally low. However, the pteridophyte swamp flora probably did include, at times, *Lycopodium cernuum*, other *Lycopodium* spp., *Cyclosorus* sp., *Nephrolepis* sp. (either arboreal or terrestrial forms), and possibly also *Pteridium*. Epiphytic pteridophyte taxa may have occurred in any swamp forest and could have included *Asplenium* sp. Filices undifferentiated would have had various sources but probably most were within the swamp vegetation. Both *Potamogeton* sp. and *Typha* sp. (and/or *Sparganium* sp.) appear to have been present, but may have declined in the later part of the period represented. Zone DDA-III in fact marks the most recent occurrence of aquatic pollen in the DDA core.

Any swamp forest present may itself have been composed of one or more of several species. The pollen assemblages suggest that any or all of the following taxa may have been represented: *Elaeocarpus* sp., *Ilex cymosa*, *Eugenia* sp., *Myrsine* sp. (probably *M. affinis*), *Vaccinium* sp., *Rhododendron* sp., *Melastoma* sp. and *Dacrydium* sp. It is not possible to state more specifically the composition of the swamp forest, all of the taxa listed are known to occur as components of swamp forest elsewhere. However, a swamp vegetation dominated by *Melastoma* sp., *Myrsine* sp., *Vaccinium* sp. or *Rhododendron* sp. would be shrubbier in nature than one composed of *Ilex cymosa*, *Elaeocarpus* sp., *Eugenia* sp. or *Dacrydium* sp. The swamp vegetation may have consisted of a mixture of communities as described previously, each perhaps related to slightly different environmental conditions.

Pollen having a forest source predominates in the zone, contributing 60-80% of the Dry Land Pollen (Fig. 6.4), indicating that the dry land vegetation of the area consisted largely of forest. The composition of these forests was not, however, identical with that of zone DDA-II. Decreases in the pollen frequencies of *Dacrycarpus* and *Dacrydium* in the upper part of zone DDA-III are also reflected by sharp decreases in actual pollen influxes, and it therefore appears likely that during this period these taxa had become less important components of the vegetation. The zone may also have seen *Pinus* sp. disappear from the vegetation had it formerly been present, or become more rare in it, as *Pinus* pollen is not recorded at all in the pollen assemblages. *Podocarpus* sp., if present, may also have become extremely rare. The decline in *Dacrycarpus* possibly indicates a diminished area of lower montane forest II in the region.

Pollen of the family Fagaceae increases as both percentage TDLP and influx in the zone. It seems quite likely that the genera *Lithocarpus*, *Castanopsis*, *Quercus*, and perhaps others, were better represented in the vegetation at this time than during the duration of zone DDA-II. Other components of the forest vegetation, suggested by the pollen assemblages, were *Symingtonia* sp. (probably *S. populnea*), *Engelhardtia* sp., *Symplocos* sp., *Ilex* sp. and *Ardisia* sp. although these were probably of much less importance in basal area terms than the Fagaceae. *Schima* sp. may have been important during the later part of the period. Although recorded in only one sample, this taxon is subject to very poor representation, so even a seemingly unimportant occurrence such as this could be of some significance. Lauraceae may also have been a component of these forests, even though not recorded in the pollen assemblages. Minor forest components present included *Adinandra* sp. (and possibly other Theaceae), Meliaceae/Sapotaceae and *Cyathea* sp.

The increase in *Altingia* comp. pollen in the zone may indicate that *A. excelsa* became more common in the vegetation than formerly. Myrtaceae also appear to have been well represented in the vegetation of the area. Although some of the Myrtaceae pollen may have been contributed by *Eugenia* spp. occurring in swamp forest, it is probable that significant amounts were also contributed from *Eugenia* and other genera, eg. *Leptospermum* sp., in dry land forests. *Ilex cymosa*, *Elaeocarpus* sp. and *Dacrydium* sp. may also have occurred in these forests.

Myrsine sp. (probably *M. affinis*), *Rhododendron* sp. and *Vaccinium* sp. may have been components of swamp vegetation, as described previously, or of some type of upper montane forest, or even both. The percentage representation of these taxa, and their influx values, suggest that whatever their sources, these were becoming less important in the vegetation of the area during this period than they were formerly.

Macaranga spp. may have been slightly better represented in the vegetation during this period, but even so were probably still only a minor component, which does not suggest the presence of significantly increased amounts of seral vegetation in the area.

Forest shrubs and herbs are not well represented in the pollen assemblages and therefore the nature of this vegetation cannot be reconstructed. However Strobilanthes sp. certainly occurred at the beginning of the interval, while occasional records of Loranthaceae pollen suggest the presence of these hemiparasites on arboreal taxa.

The dry land vegetation prevalent during the duration of zone DDA-III appears to have been forests of predominantly lower montane character. Lower montane forest II elements were of much less significance in the pollen spectra than they were formerly, suggesting reduced extent of lower montane forest II during this period. Some sort of upper montane forest perhaps persisted, but pollen from this source also exhibits reduced frequencies in the zone, suggesting that this vegetation type was also of lesser extent than previously. Taxa common to all lower montane forest types are common throughout the period, and taxa of lower montane forest I are better represented in pollen assemblages (Fig. 6.3). The zone may therefore have seen a reduction in the extent of forest with the characteristics of lower montane forest II, with this perhaps occurring on higher areas at a greater distance from the site than during zone DDA-II, and its replacement around the site during the period by lower montane forest I.

Zone DDA-IV, 5.40 m to 3.40 m

The lithology of this zone comprises very woody, coarse detritus muds, suggesting the presence of woody swamp vegetation in the vicinity of the site during the period, from c. 11750 to c. 8200 years B.P. Herbaceous taxa are also well represented in the pollen assemblages of the zone, and much of this pollen is also likely to be derived from swamp vegetation. This indicates either the presence of a well developed ground flora within the swamp forest, or separate areas of herbaceous swamp vegetation. This herbaceous aspect of the swamp vegetation was dominated by Cyperaceae and Gramineae. *Eriocaulon* sp. and possibly also *Nepenthes* sp. also formed part of this vegetation, although they were of much less importance. *Nepenthes* sp. may have had a terrestrial or climbing form, so could also have been part of the swamp forest vegetation. *Pandanus* is recorded in the pollen assemblages from the zone, and this taxon may also have been a component of the swamp vegetation, although a dry land source is also possible.

Pteridophytes do not appear to have been an important part of the swamp vegetation during this period, as pteridophyte spores are not abundant. However the pteridophyte swamp flora may have included *Lycopodium cernuum*, *L. clavatum*, *Cyclosorus* sp. and perhaps *Pteridium*, and in addition was probably a source of many of the spores which contribute to the Filices undifferentiated category.

A well developed swamp forest seems to have been present at the site during this period. Pollen assemblages suggest that it may have included *Elaeocarpus* sp., *Myrsine* sp. (probably *M. affinis*), *Eugenia* sp., *Vaccinium* sp., *Dacrydium* sp. and perhaps also *Ilex cymosa*, *Rhododendron* sp. and *Melastoma* sp., although pollen of these three taxa is not recorded consistently in the zone. The low pollen influx values recorded throughout the zone for all taxa would also be explained by the presence of dense swamp forest growing at the site, as this might filter pollen from surrounding areas, and also affect aerial deposition patterns. The exact nature of the swamp forest is difficult to ascertain from the pollen data since pollen curves of the possible swamp taxa do not clearly show any taxon to dominate the pollen rain. Possibly the swamp forest was of mixed composition and also changeable in nature.

The percentage of Dry Land Pollen derived from forest falls in this zone, largely due to the high percentages of Gramineae and Cyperaceae recorded. This may be an effect of filtration of the regional pollen by swamp forest vegetation such that local pollen of herbaceous taxa have assumed greater importance in the pollen assemblages. Interference in the vegetation by man seems to be rather less likely as there is no other evidence to support this. The pollen assemblages recovered from the zone indicate that dry land areas were still largely forested.

Gymnosperms are poorly represented in the pollen assemblages of the zone, and in pollen influx terms, only *Dacrydium* and rare *Podocarpus* being recorded. It therefore seems likely that the gymnosperms were of limited importance in the vegetation during this period, and that taxa such as *Pinus* and *Dacrycarpus* were rare or even absent from the area at this time.

The family Fagaceae continues to be well represented in the pollen assemblages although influx values are actually lower than in the preceeding zone. However low influx values are recorded for all taxa during the period and it thus seems likely that the genera *Lithocarpus*, *Castanopsis* and *Quercus* remained important components of the dry land forest vegetation. Other forest components included *Adinandra* sp. (and possibly other Theaceae), *Altingia* (probably *A. excelsa*), *Ilex* sp., *Medinilla* sp. and *Symingtonia* (probably *S. populnea*). *Eugenia* spp. and other Myrtaceae were also probably represented in this dry land vegetation, although *Eugenia* spp. may also have formed part of the swamp forest vegetation. It is interesting that Myrtaceae type 2 pollen is much less common in this zone than formerly, and is actually uncommon in higher samples. The meaning of this in ecological terms is difficult to ascertain due to the taxonomic problems associated with the pollen of this family. One possible explanation, although admittedly rather speculative, is that this pollen is derived largely from a genus or species which had become less common in the area than formerly, during the duration of this zone. One such possible genus is *Leptospermum* which presently occurs mainly in upper montane forest, as some

Leptospermum spp. do have pollen of this type. However other genera could also be involved. *Elaeocarpus* sp. and *Ilex cymosa* may have occurred in either the dry land or swamp forest during this period.

Altingia (probably *A. excelsa*) continued to increase in importance in the vegetation of the area, possible an indication of further extension of lower montane forest I. Lauraceae may also have featured in the zone DDA-IV forests although again no pollen of this group is recorded in the assemblages. *Engelhardtia* sp. and *Symplocos* sp. appear to have been uncommon components of the forest vegetation at this time as is indicated by their rare or sporadic representation in the pollen spectra of the zone. *Macaranga* comp. is also recorded only rarely, and therefore the occurrence of widespread seral vegetation with *Macaranga* spp. seems very unlikely.

Myrsine sp., *Vaccinium* sp. and *Rhododendron* sp. occurred in the vegetation of the area where they could have been minor components of the swamp vegetation or of some type of upper montane forest, or both. *Vaccinium* sp. and *Rhododendron* sp. could possibly also have occurred as epiphytes in forests of the area. Overall, the pollen of these taxa declines in the zone, so, whatever the actual sources were, they appear to have been declining in importance during this period.

The dry land vegetation of the area during the duration of zone DDA-IV appears to have consisted of lower montane forest types, with possibly limited extents of upper montane forest remaining, perhaps at higher altitudes. The lower montane forest II pollen component is not well represented in the zone, suggesting that lower montane forest II may also have been of limited extent during this period. The forests prevalent around the site appear to have been similar in character to the present lower montane forest I.

Zone DDA-V, 3.40 m to 1.90 m

The lithology of this zone, which extends over the period from c. 8200 to c. 5400 years B.P., comprises coarse detritus muds which are woody below 3.00 m (c. 7500 years B.P.), but herbaceous above this. Swamp forest may have been present in the vicinity of the site prior to c. 7500 years B.P. but after this the sediment suggests the presence of a herbaceous swamp vegetation in the immediate vicinity, perhaps with swamp forest persisting in vegetation further from the site.

The herbaceous aspect of the swamp vegetation was apparently composed mainly of Cyperaceae and Gramineae, Cyperaceae being particularly well represented in the pollen assemblages of the zone. Pandanus appears at times to have been of some significance in the vegetation during this period, and might have been a component of the swamp vegetation, although it could also have occurred in dry land forest vegetation. The pollen assemblages indicate that the herbaceous swamp vegetation may have been less species rich than formerly.

Pteridophyte spores are not abundant in the zone and pteridophytes therefore seem to have been of minor importance in the swamp vegetation. These may have included, at times, *Lycopodium cernuum*, *L. clavatum*, *Cyclosorus* sp., *Nephrolepis* sp. and possibly *Pteridium* sp; in addition the swamp vegetation was probably a source of much of the Filices undifferentiated recorded in the zone.

Swamp forest, which occurred in the vicinity of the site at least to c. 7500 years B.P. and which may have existed throughout the duration of the zone at least in some areas of the Danau di Atas Swamp, may have included *Elaeocarpus* sp., *Eugenia* sp. and *Ilex cymosa*. Although *Myrsine* sp. (possibly *M. affinis*), *Glochidion* sp.,*Melastoma* sp., *Rhododendron* sp. and *Vaccinium* sp. may also have occurred in the swamp vegetation, their pollen is recorded infrequently in the zone; it therefore seems unlikely that they were widespread in this vegetation, even if present. *Eugenia* sp. may have been the most significant swamp forest component at this time, as Myrtaceae type 1 pollen, which is probably composed largely of pollen of *Eugenia* spp., exhibits a very sudden large increase in both percentage representation and influx in the basal two samples of the zone. The pollen then declines almost as suddenly at the top of the zone. This large peak in just one type of Myrtaceae pollen is suggestive of a local source.

Pollen having a forest source predominates in the assemblage, although values are variable. No gymnosperm pollen is recorded in the zone, which suggests that the gymnosperm taxa were rare in, or absent from the forests of the area. Fagaceae have a rather variable pollen representation, but influxes increase in the zone, suggesting that the genera *Lithocarpus*, *Castanopsis* and

Quercus probably remained important forest components. *Altingia* sp. (probably *A. excelsa*) also appears to have become more important in the vegetation of the area, as evidenced by further increases in both percentage representation and influx. Other components of the dry land forests at this time probably included *Engelhardtia* sp., *Symingtonia* sp. (possibly *S. populnea*), *Eugenia* spp. and other Myrtaceae. Less common components may have included *Ardisia* sp., *Symplocos* sp., *Ilex* sp., *Medinilla* sp. and possibly other Melastomataceae, *Ilex cymosa*, *Elaeocarpus* sp. and *Cyathea* sp. Lauraceae may also have been represented. The increase in the percentage representation of *Linociera* comp. in the pollen assemblages is also of interest. This occurs consistently but in small amounts for the first time in the DDA sequence, and might indicate that *Linociera* sp. (possibly *L. oxycarpa*) was present in the area, or at least in closer proximity to the site than previously.

Macaranga sp. also appears to have been more common in the vegetation during this period, as evidenced by increased percentage representation and influx values. This might suggest an increase in the seral vegetation in the area, although this event would have to be minor, since *Macaranga* tends to be over-represented in the pollen rain and actual increases in representation in the zone remain of small order.

Vaccinium sp., *Rhododendron* sp. and *Myrsine* sp. appear to have been less important in the vegetation than formerly, as is shown by decreases in both the percentage representation in pollen assemblages and influx of their pollen. This could be due to their reduced importance in either swamp vegetation or dry land vegetation. In the latter example this would indicate further reductions in the extent of upper montane forest types in the area. Possibly the decline of these taxa is due to changes in both the swamp and dry land vegetation.

The dry land vegetation of the Danau di Atas area during the duration of zone DDA-V appears therefore to have consisted of lower montane forests in which lower montane forest I elements were increasing in importance, while lower montane forest II elements were declining. Upper montane forests, if present in the area, were of very limited extent. Forest similar in composition to present lower montane forest probably existed around the site, with forest akin to lower montane forest II more distant from the site, perhaps on higher areas, as is the situation in the area at present. Sub-montane type forests, which are also a type of lower montane forest, may have been in closer proximity to the site than formerly, as is indicated by the presence of _Linociera_ comp. in the zone.

Zone DDA-VI, 1.90 m to 0.20 m

The period represented by this zone began c. 5400 years B.P. Because the upper zone boundary marks a major change in the areas vegetation, its actual position and the age of this event are important. Unfortunately this cannot be accurately measured but seems to post-date 1800 years B.P. the estimated age of the top sample examined in zone DDA-VI.

The lithology of this zone consists of coarse detritus muds, overlain at 1.20 m by a fibrous vegetation mat. This does not suggest the presence of swamp forest at or close to the site, although this could have existed elsewhere on the swamp surface during this period. Despite this, herbaceous swamp taxa are relatively poorly represented in terms of percentage TDLP. Herbaceous swamp vegetation appears to have been composed mainly of Cyperaceae and Gramineae, while *Eriocaulon* sp. may have been a rare, or local component. Pollen of Monocotyledon undifferentiated may also have been derived from the swamp vegetation although its source could not be identified.

Pteridophyte spores are more common in zone DDA-VI than in the preceeding zones, and many are probably derived from swamp sources. The swamp vegetation during this period may therefore have had a more significant pteridophyte component than during the preceeding periods. This may have included *Lycopodium cernuum*, *Nephrolepis* sp. and perhaps less commonly *Cyclosorus* sp. and *Pteridium* sp. In addition much of the Filices undifferentiated recorded probably also had its source in the swamp vegetation. Another possible component of swamp vegetation was *Selaginella* sp. Although this was not recorded in this vegetation in the present vegetation study it is thought to be a component of swamp vegetation elsewhere (Morley, 1976). The source of *Sphenomeris* comp. is of some interest as *Sphenomeris* spp. do not tolerate deep shade (Holttum, 1954). The species might have occurred in more open areas, perhaps exposed banks around the swamp site.

If swamp forest was in existence during the duration of zone DDA-VI then it was of limited extent on the Danau di Atas Swamp. Possible components of such a vegetation were *Ilex cymosa*, *Elaeocarpus* sp., *Eugenia* sp. and *Glochidion* sp. *Myrsine* sp., *Rhododendron* sp., *Vaccinium* sp. and *Melastoma* sp., if present in this swamp vegetation must have been only minor components, as they are not common in pollen assemblages recorded in the zone and their influx values are also fairly low. The pollen of *Glochidion* comp. appears quite suddenly in zone DDA-V and is consistently present throughout zone DDA-VI. Possibly *Glochidion* sp. occurred in the swamp vegetation even when swamp forest was in decline. It is of interest that stumps of *Glochidion* sp. (collection number 155) were observed in the present herbaceous swamp vegetation on the Danau di Atas Swamp (Chapter 4).

Dry land vegetation appears to have been dominated by forest during the duration of zone DDA-VI, with over 80% DLP being derived from forest sources (Fig. 6.4). Pollen of the gymnosperms *Dacrydium* and *Podocarpus* is recorded rarely in the zone, suggesting that these remained a rare component of the vegetation, or that their pollen had been transported over considerable distances prior to deposition. The family Fagaceae remains important in percentage terms and pollen influx is high in the zone; it therefore seems likely that the genera *Lithocarpus*, *Castanopsis* and *Quercus* were important components of the forest vegetation. Other taxa present in these forests appear to have included *Engelhardtia* sp., *Symplocos* sp., *Antidesma* sp., *Medinilla* sp. and possibly other Melastomataceae, *Vernonia arborea* and Myrtaceae, probably largely *Eugenia* spp. *Altingia* sp. (probably *A. excelsa*) may have been quite important in the forest vegetation during this period, suggesting the predominance of lower montane forest I. *Symingtonia* sp. (probably *S. populnea*), typically a lower montane forest II taxon, was also apparently present in the forests at this time, though was perhaps less common than previously. Minor forest components also included *Adinandra* sp. (and other Theaceae), *Ilex* sp., *I. cymosa*, Araliaceae, *Celtis* sp., *Evodia* sp., *Elaeocarpus* sp. and *Cyathea* sp. Lauraceae may have been an important component of these forests but again, unfortunately, no pollen of this family was recorded.

Linociera comp. is consistently recorded in this zone, again suggesting the presence of *Linociera* sp. at or near the site. *Macaranga* sp. appears to have been present at similar levels to those in zone DDA-V indicating perhaps some limited areas of seral vegetation in the vicinity. The low percentages of *Myrsine* comp., *Vaccinium* comp. and *Rhododendron* comp. recorded suggest that these named taxa were not particularly abundant components of the vegetation, whatever the habitat they occurred in.

The dry land forests existing in the Danau di Atas area during the duration of zone DDA-VI were undoubtedly of lower montane affinity, with forests similar to the present lower montane forest I present around the site. Lower montane forest II probably existed in the area, as pollen derived from this is recorded in the zone. However it seems likely that such forest existed at higher altitudes within the area, at some distance from the site. Sub-montane forest may also have occurred, in closer proximity to the site than in any previous period covered by the core sequence, as is suggested by records of *Linociera* comp. and rare *Fagraea* comp., and *Celtis* comp. Little evidence remains for the presence of any type of upper montane forest in the area, and if present this must have been of extremely limited extent, perhaps occurring only on the highest mountain and ridge tops.

Zone DDA-VII, 0.20 m to 0 m

This zone is based on the palynomorph content of a single sample, from the surface of the core, which is presumed to be of contemporary age. The characteristics of the pollen assemblage recovered are very similar, as expected, to the modern surface pollen samples examined from other parts of the Danau di Atas Swamp (Section 5.5). The effects of widespread forest clearance are shown, as forest pollen contributes less than 10% Dry Land Pollen (Fig. 6.4). The large percentages of Gramineae and Cyperaceae recorded reflect the open nature of the swamp vegetation and of surrounding deforested areas, Gramineae pollen being particularly abundant. The pollen assemblage also reflects the presence in the vegetation of other swamp taxa such as *Hydrocotyle* sp. (possibly *H. sibthorpioides*), *Laurembergia* sp. (possibly *L. coccinea*) and *Xyris* sp. (probably *X. capensis*). Pteridophyte spores, although neither diverse nor common, indicate the presence in the swamp vegetation of *Lycopodium cernuum* (which was present in the swamp vegetation, Section 4.7) and *L. clavatum* (which was not recorded in this vegetation), in addition to sources of Filices undifferentiated. The low levels of pteridophyte spores recorded seem to be related to the relatively uncommon occurrences of pteridophytes in the swamp vegetation (Section 4.7).

No swamp forest occurs at present, and it is interesting to note that pollen of *Elaeocarpus* comp., *Ilex cymosa* and *Myrsine* comp. disappears from the pollen record in zone DDA-VII. However many dry land taxa recorded in previous zones are also absent in this one.

A number of taxa indicative of dry land forest which are recorded in the zone include *Lithocarpus*/*Castanopsis* comp., *Quercus* comp., *Engelhardtia* comp., *Altingia* comp., *Medinilla* comp., *Symplocos* comp., *Symingtonia* and Myrtaceae; possible sources for most of these pollen taxa were recorded in the forest plots studied in the area (Chapter 4). Many species known to occur in the forest of the area were not recorded in the assemblage, notably Lauraceae and *Schima* sp., perhaps due to factors of pollen production and preservation.

Pollen of taxa such as *Melastoma* comp. and *Vaccinium* comp. is probably derived largely from these species in regrowth communities in the area; it is therefore interesting that despite the widespread occurrence of such vegetation the representation of these taxa in the pollen assemblage is very poor.

Influx values for most pollen types are very low in the zone. Only the influx of Gramineae remains at the level of previous zones, all other pollen groups exhibit reduced pollen influx at the surface of the core. The reason for such low influx may be due in large part to the general deforestation, cultivation and grazing carried out over much of the area. It seems that forest produces more pollen, which is better dispersed, than the open vegetation which replaces it after deforestation. This clearly agrees with findings from temperate regions where treeless environments also produce less pollen than those with tree or shrub vegetation (Davis *et al.*, 1973).

8.3 Interpretation of the Telago core

Zone TEL-I, 10.10 m to 9.60 m

This zone includes the single ^{14}C measurement obtained for the core, which provides a date of 9105 ± 200 years B.P. for the section 10.00 m to 10.05 m.

The lithology of this zone is gyttja which suggests that open water conditions prevailed at the site during this time. However, the pollen assemblage suggests that some swamp vegetation may have been present, this may have been purely herbaceous in nature, or primarily herbaceous with some woody taxa. The high percentages of Cyperaceae and moderate amounts of Gramineae recorded in the zone suggest that the swamp vegetation was dominated by these two families. *Hydrocotyle* sp., Liliaceae and *Galium* sp. may also have featured in this swamp vegetation.

Pteridophyte spores are recorded abundantly in the zone, suggesting a local source, and it seems likely that many were derived from swamp vegetation. This may have included *Cyclosorus* sp. and possibly Pteridium sp. as well as sources for much of the Filices undifferentiated.

There is no direct evidence for the occurrence of swamp forest in the vicinity of the site. If this had been present, it might have been composed of Elaeocarpus sp. and perhaps rare Ilex cymosa. It is of interest that no pollen of aquatic taxa is recorded in the zone, despite the prevalence of open water conditions at this time.

Forest taxa contribute just over 50% Dry Land Pollen in the zone (Fig. 7.3), much of the remainder being contributed by non-forest and swamp taxa, as described above. Gymnosperms, represented by Dacrycarpus and Podocarpus are recorded only rarely in the zone, suggesting that if they were present in the forests of the area then they were a fairly rare component of these. Fagaceae are well represented in the pollen assemblage, which suggests that the genera Lithocarpus, Castanopsis and Quercus were important in the forests of the area. Other likely forest components were Vernonia arborea, Altingia sp. (probably A. excelsa), Symplocos sp., Adinandra sp. and possibly other Theaceae, Engelhardtia sp., Myrtaceae (probably mostly Eugenia spp.), Symingtonia sp. (probably S. populnea), Helicia sp. and Cyathea sp. Elaeocarpus sp. and Ilex cymosa may also have been components of the dry land forests.

Since the Fagaceae were well represented, and Myrtaceae were also present, it is likely that Lauraceae also occurred in these forests, although not recorded in the pollen assemblage. The presence of Linociera comp. in the zone suggests that Linociera sp. (perhaps L. oxycarpa) could have been present in these forests. Widespread occurrence of seral vegetation seems unlikely at this time as Macaranga comp. is not common in the pollen assemblage.

Dry land forest around the Telago site during zone TEL-I appears to have been of lower montane forest character. Indicators of more specific types of forest are not well represented and therefore the more detailed nature of this vegetation is not clear. However, both lower montane forest I and II may have been present within the area at this time, perhaps with lower montane forest I in close proximity to the site, and lower montane forest II on nearby ridge areas.

Zone Tel-II, 9.60 m to 4.60 m

In this zone the gyttja is replaced above 8.85 m by fine herbaceous detritus mud, and above 5.61 m by a generally fine but woody detritus mud. This change in lithology may relate to the development of the swamp vegetation around the site, from a predominantly herbaceous swamp with perhaps limited numbers of arboreal taxa, to one in which arboreal taxa are dominant. The sediment changes probably also indicate the shallowing of the water body.

Pollen assemblages recorded in the zone suggest that the herbaceous aspect of the swamp vegetation was composed largely of Cyperaceae and Gramineae. Impatiens sp. a herb, may also have formed part of the swamp vegetation, as perhaps were some members of the Compositae family (possibly *Spilanthes* sp. or *Enydra* sp., genera which presently occur on the Danau di Atas Swamp). *Pandanus* sp. was also possibly a component of the swamp vegetation at this time, although this could also have occurred in the dry land forests.

Pteridophyte spores remain abundant in the zone, and many may have been from a local source. The pteridophyte swamp flora probably included quite common *Cyclosorus* sp. with some *Lycopodium cernuum* and perhaps *Pteridium* sp. Many of the Filices undifferentiated recorded may also have been derived from the swamp vegetation.

Swamp forest was perhaps present around the site during zone TEL-II and seems particularly likely to have been present during the later part of the zone, when woody fragments were deposited in the sediment. Such a forest may have included *Ilex cymosa* and *Elaeocarpus* sp. *Eugenia* spp. may also have been involved although the percentages of Myrtaceae recorded in the zone are low, and could equally have had a dry land source. Other possible components of the swamp vegetation included *Melastoma* sp. and *Myrsine* sp., although they are represented only sporadically in the pollen assemblages and it therefore seems unlikely that they were important components of the vegetation.

Forest taxa contribute 46-77% Dry Land Pollen in the zone (Fig. 7.3) suggesting prevalence of forest in the surrounding dry land area. Gymnosperm pollen, of *Dacrycarpus*, *Dacrydium*, *Pinus* and *Podocarpus* is recorded sporadically in the zone, but the low percentages involved suggest that these taxa were rare in the vegetation or else the pollen had been transported over long distances into the area prior to deposition. Fagaceae are well represented in the pollen assemblages and it seems likely that the genera *Lithocarpus*, *Castanopsis* and *Quercus* were common components of the dry land forests. Other taxa present probably included *Vernonia arborea*, which seems to have been less important than during zone TEL-I, *Adinandra* sp. and possibly other Theaceae, *Engelhardtia* sp., *Randia* sp., *Symplocos* sp., *Antidesma* sp., *Ilex* sp., *Symingtonia* sp. (probably *S. populnea*), *Medinilla* sp., Myrtaceae and *Cyathea* sp. *Linociera* comp. becomes quite common in the pollen assemblages in the later part of the zone indicating the increasing importance of its sources in the vegetation. Both *Ilex cymosa* and *Elaeocarpus* sp. may also have been present in the dry land forests. Lauraceae, although not recorded in the pollen assemblages, may also have been present. The low percentages of *Macaranga* comp. recorded do not indicate any increase in seral vegetation in the area.

The dry land vegetation during the duration of zone TEL-II appears to have consisted of lower montane forests, and the lack of pollen from taxa restricted to lower montane forest II may indicate that these were predominantly lower montane forest I or sub-montane in character. However there is also a lack of lower montane forest I or sub-montane forest indicators which would clarify the situation. All three lower montane forest types possibly occurred within the region at this time, occupying different positions within it. Sub-montane forests could have occurred in the lower lying areas to the west of the lake, Danau di Atas, with lower montane forest I around the lake and lower montane forest II restricted to higher mountain areas and ridges. The slight decline, within the zone, of lower montane forest II elements and increase of sub-montane elements (Fig. 7.2) may indicate a gradual change in the vegetation of the area during the duration of the zone, with decline of lower montane forest II and its replacement by forests of lower altitudinal affinities.

Zone TEL-III, 4.60 m to 0.60 m

In this zone the woody, fine detritus mud is overlain at 3.50 m by woody, medium detritus mud, at 1.65 m by coarse detritus mud and at 1.15 m by a vegetation mat. The change from finer to coarser detritus suggests the shallowing of water at the site (West, 1977). The low percentages of pollen from herbaceous swamp taxa recorded and the presence of wood in the sediments indicates the presence of some form of swamp forest or shrubby swamp vegetation around the site during much of the period. Some herbaceous taxa were however present either within this swamp forest or as a separate swamp community. These appear to have included Cyperaceae, Gramineae and possibly Galium sp., Compositae and Oldenlandia sp. Pandanus sp. does not appear to have been important in the vegetation during this period, either in swamp vegetation or elsewhere.

Pteridophytes were probably quite important in the swamp vegetation as pteridophyte spores are abundant in the zone, and many would have had a local source. These appear to have included *Lycopodium cernuum*, *Cyclosorus* sp. and *Nephrolepis* sp. Other taxa may also have occurred either as terrestrial or climbing forms or as epiphytes on arboreal swamp taxa, and probably included sources of much of the Filices undifferentiated recorded.

The arboreal component of the swamp vegetation may have included *Elaeocarpus* sp., *Ilex cymosa* and *Eugenia* sp. all of which are well represented in the pollen assemblages of the zone. *Myrsine* sp. and *Glochidion* sp. might have been less common components of the swamp vegetation, as perhaps were *Vaccinium* sp. and *Melastoma* sp.; pollen derived from these is recorded only sporadically in the pollen assemblages. The arboreal swamp vegetation appears to have become less important towards the top of the zone, as evidenced by the disappearance of wood from the lithology at 1.65 m.

Pollen having a forest source is more abundant in this zone than in zones TEL-I and TEL-II (Fig. 7.3). This could in part be a result of an increase in the extent of arboreal swamp vegetation in the vicinity of the site. *Dacrydium* and *Dacrycarpus* are recorded rarely in the pollen assemblages of the zone, suggesting that they remained a rare component of the vegetation, if present in the area at all. The Fagaceae, represented primarily by *Lithocarpus*, *Castanopsis* and *Quercus*, appear to have been an important component of the forest vegetation. *Altingia* sp. (probably *A. excelsa*) may have been more common than formerly, as is suggested by its consistent representation in the pollen assemblages of the zone. *Linociera* sp. also appears to have been present within the forests of the area. Other, mostly minor, constituents of these forests included *Adinandra* sp. and possibly other Theaceae, *Engelhardtia* sp., *Symingtonia* sp. (probably *S. populnea*), *Ilex* sp., *Memecylon* sp., *Medinilla* sp. and possibly other Melastomataceae, and *Schima* sp. The latter may have been more important than its scant occurrence in the pollen record suggests. *Symplocos* comp. and *Vernonia* *arborea* sim. were not recorded in the pollen assemblages, suggesting that their sources may have been much rarer in the forest vegetation than formerly. *Cyathea* spp. were also present in the vegetation of the area during this period, and probably occurred either in the forests, at the forest edges or in gaps within the forests. *Eugenia* spp. and other Myrtaceae may also have been quite important in the dry land forests of the area. A dry land occurrence for *Elaeocarpus* sp. and *Ilex* *cymosa* was also possible, although these may have occurred in swamp vegetation as well.

Pollen of *Macaranga* comp. becomes more abundant at the top of the zone, possibly an indication of an increase in seral vegetation in the area. However, in view of the tendency of this taxon to be over-represented, and the relatively low amounts of *Macaranga* comp. involved, the extent of this appears to have been limited.

The Danau di Atas area appears to have been largely forested during the duration of zone TEL-III, and this appears to have been lower montane forest, perhaps rather similar to present lower montane forest I. Lower montane forest II, if present, was perhaps of limited extent, on higher areas. Some sub-montane forest may also have been present, possibly on lower lying areas principally to the west of the lake, Danau di Atas, but perhaps also on the extensive flat area to the east of Telago Swamp.

Zone TEL-IV, 0.60 m to 0 m

This zone is based on the palynomorph content of only the surface sample, which is thought to be of contemporary age. The pollen assemblage recovered reflects the present vegetation of the area. High percentages of Gramineae and Cyperaceae recorded reflect the open nature of the swamp vegetation and of surrounding deforested areas. The pollen assemblage also indicates the presence of other swamp taxa such as Xyris sp. and possibly also Impatiens sp. and Laurembergia sp. A general description of the site in Morley et al. (1973) provided in Section 7.1 describes a Cyperaceae-Gramineae dominated swamp with common Xyris, although not all species observed at the site were recorded in the pollen assemblage.

Pteridophyte spores were not very common in the assemblage, probable sources of some of these did occur in the swamp and surrounding vegetation, and included Lycopodium sp. and Gleichenia sp. Since the present vegetation of the site has not been studied in detail, it is possible that sources of many of the other taxa recorded in the pollen assemblage are also present in the local area.

The dry land pollen assemblage includes considerable quantities of Rhododendron comp. Rhododendron spp. were not observed in the immediate vicinity of the site but were quite possibly common in the regrowth vegetation of the area. The Total Arboreal Pollen, if Rhododendron comp. is excluded, is low, reflecting the extensive forest clearance in the area. Components of the forests remaining, as suggested by the pollen assemblage include Fagaceae (the genera Lithocarpus, Castanopsis and Quercus in particular), Altingia sp., Engelhardtia sp., Adinandra sp. and possibly other Theaceae, Symingtonia sp., Celtis sp., Eugenia spp. and possibly other Myrtaceae, Macaranga sp. and Mallotus sp. Many of these were actually recorded in the forest plots examined (Chapter 4).

8.4 Comparison of the Telago core with the top section of the Danau di Atas core, in order to assess the regionality of vegetation events

A ^{14}C age of 9105 ± 200 years B.P. was obtained for the section 10.00 - 10.05 m in the Telago core. A corresponding age in the DDA core, according to Fig. 6.1, should be found at c. 3.90 m depth. The nearest sample below this which was analysed palynologically is at 4.20 m. It is therefore considered that the DDA section 0 m to 4.20 m should correspond in age very closely with the Telago sequence (0 m to 10.10 m). A comparison of pollen changes in the two sections should provide some insight into the nature of local and regional vegetation changes in the area during this period. The major problem associated with a direct comparison of the two core sections is that although a fairly close series of ^{14}C dates is available for the DDA sequence, only one date is available for the Telago core. Thus estimates of age at any particular depth can be made for the DDA core using Fig. 6.1, but estimates cannot be made for depths in the Telago core with any degree of certainty. However it is still possible to compare the two cores in a generalized way, on the basis of the one ^{14}C date from the Telago sequence.

Zone TEL-I appears to correspond approximately with the top part of zone DDA-IV, which is known to be of similar age, on the basis of ^{14}C dates. Zones TEL-IV and DDA-VII both consist of surface samples, presumed to be of contemporary age, and thus also correspond. It is not possible to compare the intermediate section, zones TEL-II and TEL-III with the DDA core except at a general level, but they seem to correspond to zones DDA-V and DDA-VI.

Although the hydrophytic vegetation histories at both sites may reflect regional environmental changes if these affect the hydrology of the area, most details of the hydrophytic vegetation changes at the two sites are likely to be quite different, relating to the independent development of hydroseral vegetation at each site. Factors affecting this local development may include depth of water and rate of infilling by sediment. Comparison of the swamp vegetation at the two sites is therefore unlikely to reveal much direct evidence as to the nature of the regional vegetation. However this could be of use in elucidating the source of taxa which may occur in swamp or dry land vegetation. In such a case a peak in pollen of the taxon at one site only might indicate a local source, such as swamp, rather than a regional source.

Zone TEL-I compared with the top part of zone DDA-IV.

The pollen assemblages obtained in zones DDA-IV and TEL-I show many similarities. Gymnosperm pollen is rare in the pollen assemblages of both, indicating that these really were rare components of the regional vegetation at this time, c. 9000 years B.P. Conversely, Fagaceae pollen is common at both sites, and this is an indication of the regional importance of this family in the vegetation. Other components of the regional forest vegetation, suggested by representation in the pollen assemblages at both sites, were *Adinandra* sp. and possibly other Theaceae, *Altingia* sp. (probably *A. excelsa*), *Symingtonia* sp. (probably *S. populnea*), *Eugenia* spp. and possibly other Myrtaceae, *Engelhardtia* sp. and *Symplocos* sp. *Macaranga* comp. is recorded only as low percentages in the assemblages at both sites which supports the idea that there was not widespread seral vegetation on dry land at this time. *Elaeocarpus* comp. and *Ilex cymosa* are not abundant in the pollen spectra at either site, which does not help to clarify the problem of whether their source taxa were components of the swamp or dry land forest.

The dry land vegetation suggested by pollen assemblages at both sites during the period was lower montane forest. The exact nature of this forest is difficult to ascertain due to the scarcity of pollen taxa more or less restricted to particular altitudinal formation types. However, the relatively low representation of lower montane forest II taxa in both cores, compared with its earlier higher levels in the DDA core, suggests that lower montane forest II was of limited extent. Thus the forest occurring in the vicinity of both sites, at altitudes of 1535 m and 1550 m a.s.l., at this time was probably of lower montane forest I, or perhaps less likely, of sub-montane character. The topography of the area complicates the situation as more than one formation type may exist in the area at any time, and each may contribute some pollen to the deposition sites. Thus it is possible that within the period, all three types of lower montane forest occurred within the area, each occupying a different altitudinal range.

Zones TEL-II and TEL-III compared with zones DDA-V and DDA-VI.

The zone boundaries TEL-II/III and DDA-V/VI could possibly relate to the same regional changes in pollen rain. However, since only the age of the zone DDA-V/VI boundary can be estimated, it seems more justifiable to compare the whole of zones TEL-II and TEL-III with zones DDA-V and DDA-VI, in order to assess regionality of vegetation events.

Very local changes, apparently taking place in the swamp vegetation, were different at the two sites. Swamp forest appears to have been established at the Danau di Atas Swamp at the beginning of the period, but thereafter diminished in extent and possibly disappeared. At Telago, swamp forest appears to have developed adjacent to the site at some time during the duration of zone TEL-II, and to have persisted throughout much of the interval. But here too swamp forest appears to have diminished in the later part of the period. There is a large peak in the pollen of Myrtaceae type 1 in the zone DDA-V, which is followed by a fall to low levels. No corresponding peak for this taxon occurs in the Telago sequence, which suggests a local source of this pollen at the Danau di Atas Swamp, a likely source being *Eugenia* spp. in swamp forest vegetation near the site. It is of interest that this peak begins just prior to the disappearance of wood from the DDA core and ends just above this stratigraphic event. A subsequent increase in Myrtaceae type 1 occurs in both the DDA and Telago sequences, within zones TEL-III and DDA-VI. This is perhaps related to increased regional production of this pollen, and could indicate the increased importance of some species of Myrtaceae in the vegetation of the area.

The peak of *Ilex cymosa* recorded in zones DDA-V and DDA-VI is not reflected in the Telago sequence, and might also be an indication of a local source of this pollen, again possibly in swamp forest close to the DDA site. This might indicate that some swamp forest was still in existence at the Danau di Atas Swamp, or in nearby swamps such as the one in the lake outlet bay, at this time.

Gymnosperm pollen is recorded only rarely at both sites during the interval, suggesting a regional, but probably rare, source of this pollen. Fagaceae are well represented in pollen assemblages at both sites and this suggests that they were well represented in the regional vegetation at this time. *Altingia* sp. (probably *A. excelsa*) appears to have been increasing in regional importance, particularly in the later part of the interval, as its representation increases in assemblages from both of the sites. *Linociera* spp. also appear to have been more important in the vegetation during this period than formerly, as percentage representation of *Linociera* comp. and *L. malabarica* sim. increase in the upper part of the sequences.

Other components of the regional vegetation, indicated by both sets of pollen data included *Engelhardtia* sp., *Symingtonia* sp. (probably *S. populnea*), *Eugenia* spp. and possibly other Myrtaceae, *Symplocos* sp., *Ilex* sp., *Medinilla* sp. and other Melastomataceae, *Elaeocarpus* spp. (although some may also have been components of swamp vegetation), *Antidesma* sp., *Adinandra* sp. and possibly other Theaceae, and the tree ferns *Cyathea* spp. Some of these, such as the *Eugenia* spp., are likely to have been more important in terms of basal area than others, such as *Symplocos* sp. Lauraceae are not recorded in pollen assemblages at either site but it is possible that the family was represented in the vegetation during this period.

Macaranga comp. is at its most abundant in zones DDA-V and DDA-VI and zone TEL-III, and may indicate that there was more seral vegetation in the region at this time, than was present previously. *Vaccinium* comp. and *Myrsine* comp. are not particularly common in assemblages from either site during the interval, and *Rhododendron* comp. is recorded, sporadically, at DDA only. Clearly these taxa were not of great importance in either the regional or local vegetation throughout this time, a contrast to their importance during the earlier periods represented in the DDA sequence.

The trends in pollen concentration also show some striking similarities at the two sites, although actual values differ. Pollen concentration increases quite markedly through zone DDA-V and peaks in DDA-VI at 1.10 m before declining sharply. In the Telago core the values increase only slightly through zone TEL-II but increase sharply in zone TEL-III, peaking at 3.10 m, then decline above this. However the causes of these changes in pollen concentration remain unclear.

The dry land vegetation indicated by both sets of pollen data was lower montane forest. This appears to have consisted largely of lower montane forest I, in the vicinity of both sites. Possibly sub-montane forest was more extensive in the area than formerly, and some lower montane forest II may have existed at higher altitudes.

Zone TEL-IV compared with Zone DDA-VII.

The two surface samples show broadly the same features, most pollen recorded having a local or intermediate source, with regional pollen forming a small percentage of the total. Differences in local vegetation at the two sites have resulted in a high percentage of Rhododendron comp. being recorded in zone TEL-IV, where Gramineae and Cyperaceae pollen is less important in percentage terms than in zone DDA-VII. Other interesting similarities are the low pollen concentration at both sites, and the relatively poor representation of pteridophytes despite their now widespread occurrence in both local swamp and regrowth vegetation. Forest taxa recorded at both sites include Lithocarpus/Castanopsis comp., Quercus comp., Engelhardtia comp., Altingia comp., Macaranga comp. and Myrtaceae type 1. Percentages of TDLP involved are low, as expected, due to the extensive deforestation in the region.

8.5 A summary of the vegetation occurring on dry land during at least the last c. 31000 years in the Danau di Atas region

The following are conclusions as to the nature of the dry land vegetation during the period represented by the Danau di Atas pollen sequence, incorporating evidence from the Telago section where this is available.

From pre-31000 to c. 17900 years B.P. the forest in the area appears to have been predominantly of lower montane character. Some upper montane forest may have been present, perhaps on higher ridges and mountains, and lower montane forest II was certainly present within the area and may even have surrounded the DDA site. However the exact nature of the forest around the DDA site is not clear. It seems unlikely that the area was not forested during this period.

From c. 17900 to c. 12900 years B.P. considerable extents of the dry land vegetation of the area were still composed of lower montane type forests, but those of lower montane forest II character appear to have predominated. This type of forest appears to have surrounded the DDA site at 1535 m a.s.l. Upper montane forest, perhaps similar to the ericoid forest now found on G. Kerinci, was probably also important in the area but does not appear to have extended to the altitude of the DDA site. There is no evidence to suggest more open conditions at this time.

From c. 12900 to c. 11750 years B.P. the dry land vegetation was forest, still largely of lower montane character. Lower montane forest II elements appear to have been less significant than formerly, and it therefore seems likely that this type of forest had retreated from the areas around the DDA site, perhaps to slightly higher altitudes than the site itself. Forests similar to the present day lower montane forest I possibly surrounded the site, although the latter may have been close to the lower montane forest I/II transition. Some upper montane forest, perhaps similar to the present ericoid forest, may have been locally common in the area, presumably largely at higher altitudes on ridges and mountains than the lower montane forest II.

From c. 11750 to c. 8200 years B.P. the dry land vegetation seems to have consisted of forests having lower montane characteristics. The extent of lower montane forest II appears to have been further reduced, perhaps occurring at altitudes considerably above that of the site, and any upper montane forest, if present, was of limited extent, perhaps restricted to high altitude sites such as mountain tops and ridges. The area around the DDA site appears to have been occupied by forests of lower montane forest I type, and this was also true of the area surrounding the Telago site at 1550 m a.s.l.

From c. 8200 to c. 5400 years B.P. the dry land vegetation around the two sites continued to consist of forests which were of lower montane character. Lower montane forest I continued to increase in importance in the area, with lower montane forest II present but of limited extent, probably only on higher areas. Sub-montane forest appears to have been closer to the two sites than at any previous time, suggesting a continuing gradual migration of altitudinally restricted forest taxa in an uphill direction.

After c. 5400 years B.P. the vegetation was still largely forests, of lower montane character, which were little changed from those described in the previous period. Lower montane forest I appears to have been present in the vicinity of both sites, and some sub-montane forest may also have existed in the area. Possibly the latter diminished in importance towards the end of the period. Lower montane forest II appears to have been of very limited extent and probably only occurred on higher areas, at some distance from the sites. There is no strong evidence for the existence of any type of upper montane forest in the area, and if present this must have been of very localized distribution, perhaps on the highest mountain peaks. The forest therefore appears to have been similar to that which remains in the area at present. Large scale deforestation has since taken place, and this appears to have been largely a recent event, although quite extensive areas were under cultivation by the mid 1890's A.D. (Fig. 8.2) according to early maps of the area produced by the Batavia Topographic Bureau. Extensive, apparently little altered forest is indicated by the pollen assemblages at 0.55 m in the DDA sequence and at 1.20 m in the Telago sequence. The former has an estimated age of c. 1800 years B.P., thus the major deforestation post-dates this. However, increased extents of seral vegetation are indicated after c. 8200 years B.P. and one possible cause could be human activity in the area.

8.6 A summary of the hydroseral vegetation changes at the two sites

8.6a Danau di Atas Swamp

From pre-31000 to c. 17000 years B.P. the site appears to have been occupied by open water, with some herbaceous swamp vegetation. There is no strong evidence for the existence of any type of arboreal swamp vegetation at this time.

From c. 17000 to c. 11750 years B.P. considerable quantities of wood fragments were deposited in the sediments, suggesting the presence of swamp forest or shrubby swamp vegetation in proximity to the site. Herbaceous swamp taxa were also present, either as separate communities or as ground flora within the woody swamp vegetation. Some open water still prevailed at the site.

From c. 11750 to c. 7500 years B.P. some sort of swamp forest was present at the site, but there was still a well developed herbaceous aspect of the swamp vegetation. There is no evidence to suggest the presence of open water conditions during this period.

After c. 7500 years B.P. there appears to have been a decline in the swamp forest at the site, as woody fragments disappear from the sediment profile above 3.00 m. Herbaceous swamp persisted after this event, but there is no evidence to suggest open water at the site during this period. Although no wood is recorded in the core sediments it is possible that a limited extent of swamp forest, or some type of woody swamp vegetation, persisted locally on the swamp until quite recently. Evidence is provided by the presence of rare, cut tree stumps on the swamp, and even a sprouting trunk of Glochidion sp., described in Section 4.7. At present the swamp surface at the core site is a fibrous vegetation mat, elsewhere on the Danau di Atas Swamp lenses of water may persist below such sediments. However the vegetation mat does not extend over the whole swamp surface as is shown by the sediment profiles of the swamp plots studied (Table 4.11).

8.6b Telago Swamp

Changes which occurred in the hydroseral vegetation of the Telago Swamp cannot be dated due to lack of ^{14}C dates.

From the base of the core at 10.10 m, just below the dated section of 9105 ± 200 years B.P. at 10.00 m - 10.05 m, to 8.85 m depth, the site had open water conditions, and the sediment was gyttja. At this time herbaceous swamp vegetation existed around the site but there is no strong evidence for the existence of swamp forest.

At 8.85 m the sediments become herbaceous detritus muds, indicating some shallowing of water conditions. During the period represented by the section 8.85 m to 5.61 m the swamp vegetation in the vicinity appears to have been largely herbaceous.

Between 5.61 m and 1.65 m wood is common in the sediment profile, suggesting the development of some type of woody swamp vegetation in close proximity to the site, this was probably swamp forest. Herbaceous swamp vegetation still persisted in the area, either as the ground flora of the swamp forest or as a distinct vegetation type.

Above 1.65 m there is no wood in the sediment, which suggests that a predominantly herbaceous vegetation existed during the period represented by this section. At present no open water persists at the site although possibly some lenses of water exist under parts of the swamp surface.

The development of hydroseral vegetation at the two sites appears therefore to have progressed quite independently. Of interest is the disappearance of swamp forest at the two sites. Whether this happened at different times at the two sites, or at the same time, cannot however be elucidated, due to the lack of dates on the Telago section.

8.7 Evidence of climatic change in the Danau di Atas region, and comparison with other areas

8.7a Evidence from the Danau di Atas region.

It is shown in Section 2.4 and Chapter 4, that at present there are a number of altitudinal forest types which can occur in the mountain regions of Sumatra, and the principal controlling factor appears to be climate, particularly temperature. The altitudinal ranges of some of these forest types are summarized below.

		Altitudinal range (m a.s.l.)
Sub-montane forest	Lower Montane Rain Forest Formation	c. 1000 - c. 1400
Lower montane forest I		c. 1400 - c. 1800
Lower montane forest II		c. 1800 - c. 2400
Gleichenia scrub	Upper Montane Rain Forest Formation	c. 2400 - c. 2800
Ericoid forest		c. 2800 - 3000
Ericaceous scrub		3000 - 3600

Gleichenia scrub may be a rather localized feature, common to G. Kerinci but found on few other peaks, therefore for purposes of interpretation of fossil and modern pollen spectra, the *Gleichenia* scrub has been grouped with ericoid forest.

The evidence presented in the previous sections shows that during at least the last c. 31000 years these vegetation types have not been stationary within the area, instead there have been vertical migrations of the taxa which characterize these zones. Although the taxa may not always act with unity the overall result of these migrations is apparent as altitudinal shifts of the vegetation zones. Clearly, only a major environmental change is likely to have such a widespread and long lasting effect on the vegetation of the area. Climatic change appears to be the cause, since it is climatic factors, and particularly temperature, which control the altitudinal distribution of vegetation types at present.

A lapse rate of 0.6^{o}C/100 m is suggested for the region at present (van Steenis, 1962). Although lapse rates can vary, being higher with dry air, higher lapse rates seem unlikely in Sumatra, as humidity is likely to be continuously high in this area. By multiplying this lapse rate by the altitudinal vegetation shifts (as 100 m units) suggested by the pollen evidence, some idea of possible temperature variations in the past can be obtained. The altitudinal vegetation shifts suggested by the pollen evidence, and magnitude of temperature change necessary to cause these, are discussed below. Again pollen evidence from both Danau di Atas at 1535 m a.s.l., and Telago, at 1550 m a.s.l. has been used.

From pre-31000 to c. 17900 years B.P. lower montane forest occurred around the DDA site at 1535 m a.s.l. This possibly included lower montane forest II elements but its exact nature is not certain. If lower montane forest II did occur around the site at this time, this would represent a depression of vegetation by a minimum of c. 265 m and a maximum of c. 865 m. However the pollen evidence does not conclusively demonstrate the presence of lower montane forest II around the site, and this may have been surrounded by lower montane forest I, with lower montane forest II present within the area, above the altitude of the site. If this condition prevailed then the depression of vegetation would be less than c. 265 m. A 265 m depression of vegetation zones would suggest that mean annual temperatures were c. 1.6°C cooler than at present, but the nature of the temperatures during the period cannot be elucidated with certainty.

From c. 17900 to c. 12900 years B.P. lower montane forest II surrounded the DDA site. During this period upper montane forest also appears to have been quite widespread. Although this does not appear to have ever extended down to the altitude of the site, at some periods it may have been quite close by, perhaps on the nearest hills. It is likely that the vegetation was not completely static during this period. The depression of vegetation zones suggested by the presence of lower montane forest II around the site at 1535 m a.s.l. is in the range c. 265 m - c. 865 m. In view of the presence of upper montane forest in the vicinity, actual shifts may have been closer to the maximum suggested than to the minimum, for much of the period. Mean annual temperatures may have been c. 1.6^{o}C - c. 5.2^{o}C cooler than at present, and for much of the period may have been closer to the higher value suggested. For example, a depression of vegetation by 600 m would place the site well within the lower montane forest II and would suggest temperatures c. 3.6^{o}C cooler than at present. Towards the end of the period there may have been upward migration of the vegetation, but with the site continuing to be surrounded by lower montane forest II.

From c. 12900 to c. 11750 years B.P. the lower montane forest II appears to have retreated from its position around the site, being replaced for much of the period by lower montane forest I. The site, at this time, possibly lay close to the transition between lower montane forest I and II, which would suggest a depression of vegetation by slightly less than 265 m. Mean annual temperatures may have been less than or about 1.6^{o}C cooler than at present during this period.

From c. 11750 to c. 8200 years B.P. the DDA site appears to have been surrounded by lower montane forest I. The Telago site, at

1550 m a.s.l. was also surrounded by lower montane forest I at the start of its sequence c. 9100 years B.P. Vegetation zones may still have been slightly depressed during this period. However the maximum depression at the start of the period was less than 265 m at 1535 m a.s.l. At Telago the maximum possible depression of vegetation at c. 9100 years B.P. was 250 m, but actual depression was probably much less than this. These suggest that at the start of the period mean annual temperatures were probably less than 1.6°C cooler, and by c. 9100 years B.P. were probably considerably less than 1.5°C cooler than at present in the area. Throughout this period the vegetation zones may have continued to migrate uphill, in response to continuing climatic amelioration.

From c. 8200 to c. 5400 years B.P. lower montane forest I surrounded both sites. Possibly sub-montane forest was in closer proximity than at any previous time. Vegetation seems to have migrated further uphill, and the vegetation of the area may have been similar to that remaining there at present. There seems to be a slight possibility that sub-montane forest extended a short distance above its present range, either towards the end of this period, or early in the next one. If the vegetation zones lay at approximately similar levels to those at present, or even 100 m higher or lower, mean annual temperatures would have been within 0.6°C of their present values.

From c. 5400 years B.P. to the present, lower montane forest I appears to have surrounded the two sites, except during the most recent period when forest clearance had occurred in the vicinity. Sub-montane forest might, at some point, have extended above its present altitudinal limit, although the evidence for this is slight. Mean annual temperatures during this period were probably more or less similar to those at present, with perhaps slight (up to 0.5°C) variations.

There therefore seems to be good evidence of formerly cooler conditions in the Danau di Atas region, and especially over the period c. 17900 to c. 12900 years B.P. However temperature is not the only climatic factor which may have varied in the past, other types of climatic change may have occurred, and those associated with precipitation are the most likely to have had an effect on the vegetation. The pollen assemblages recovered from the Danau di Atas region during the period to at least 31000 years B.P. do not however indicate any vegetation changes which could result only from a formerly drier or more seasonal climate. This does not necessarily exclude the possibility that climates in the region were drier during this period, for the following reason. The present climates of the area are extremely wet (humid to hyper humid as defined by Fontanel and Chantefort, 1978), and the water supply may be surplus to the needs of many of the taxa in the area. Therefore there could be a decrease in the total precipitation which the area receives, without there necessarily being any recognizable effect on the vegetation. However it seems less likely that increased seasonality would be so well tolerated by the vegetation, as the areas of Indonesia having more seasonal rainfall regimes with a distinct dry season, for example East Java, bear monsoon forests not rain forest, with a flora different from that of Sumatra's everwet regions (Whitmore, 1975).

The redeposition of older sediments within the DDA sequence might, as explained in Section 6.3, have been the result of erosion associated with lower lake levels and a drier climate. However this was only one of several possible explanations for this event, and there was no direct evidence to favour this particular explanation.

There is therefore no evidence from these studies of formerly drier climates in the Danau di Atas region, and no vegetation or other events have occurred which could only be explained in terms of this type of climatic change.

8.7b Comparison of the Danau di Atas evidence with that from other areas

The evidence for vegetation and climatic change in the Danau di Atas region, presented in the previous section can be compared with evidence from montane environments elsewhere in the region, West Malesia, and other tropical areas, in order to look for similarities which would confirm that these events were of regional importance. Other Quaternary palynological work in West Malesia comes principally from two areas, Sumatra and West Java, and the number of sites which have been examined are few. From Sumatra comes evidence from sites in the Toba Highlands (Maloney, 1979, 1980, 1981) and the Kerinci area (Morley 1976, 1982; F. James, pers. comm.). Several sites are being studied in West

Java; preliminary results have so far been published for three of these (van Zeist _et al_., 1979; Stuijts, 1984).

For the period dating beyond c. 13000-12000 years B.P. information is available only from two other sites, both from intermediate altitudes. These are Situ Bayongbong at 1250 m a.s.l. in West Java (Stuijts, 1984) and Pea Sim-sim at 1450 m a.s.l. in the Toba Highlands region of Sumatra (Maloney, 1979, 1980). The sequence at Pea Sim-sim begins c. 18500 years B.P. Maloney describes the vegetation around the site on this plateau area over the period c. 18500 to c. 16500 years B.P. as being ?alpine vegetation with forest patches, which he thinks may be upper montane forest. However the interpretation of alpine vegetation during this period is tentative and Maloney (1980) admits that there are no alpine indicators recorded. The pollen assemblages for this period include _Dacrydium_, _Dacrycarpus imbricatus_, _Lithocarpus_/_Castanopsis_ comp. and _Quercus_ comp. but Maloney considers most of this to have been transported in from lower altitudes. The assemblages also include small amounts of ericaceous taxa and possibly some indicators of open conditions. The pollen assemblages bear some similarities with those from the DDA core for the same period as regards particularly their content of gymnosperm and Fagaceae pollen. From c. 16500 to c. 12000 years B.P. the vegetation of the area is described as Fagaceae forest with _Symingtonia_ and assemblages are again not dissimilar from those of the same period in the DDA sequence.

At Situ Bayongbong (Stuijts, 1984) the pollen assemblages for the period c. 16800 to c. 12360 years B.P. indicate forests of lower montane forest II affinity (Stuijts terms these upper montane forest) in the vicinity of the site. Lower montane forest I (Stuijts refers to this as lower montane forest) is thought to occur at lower elevations during this period. At Danau di Atas the exact nature of the vegetation prior to c. 17900 years B.P. was unclear, but from c. 17900 to c. 12900 years B.P. forests of lower montane II aspect surrounded the site, while upper montane forest occurred elsewhere in the area, probably at slightly higher elevations.

The evidence from all three sites suggests depression of vegetation zones during the period approximating to 18000 to 12000 years ago. The magnitude of this depression is within the range 265-865 m at Danau di Atas, probably being closer to the maximum than minimum value for much of the period; c. 500 m at Situ Bayongbong and perhaps similar at Pea Sim-sim At Danau di Atas and Situ Bayongbong the most likely explanation is considered to be cooler temperatures during this period, and the magnitude of these changes seems to have been similar at both sites. Maloney (1980) is wary of interpreting the vegetation shifts observed in the Toba area purely in terms of temperature changes and considers that in this region it is possible that regional water table conditions linked to sea level changes may have also affected the vegetation in the past. Since there is no information about how these have varied in relation to past sea levels, he concludes that it is very difficult to elucidate past environments on the plateau. This argument may be valid for the Toba plateau area, possibly even for Situ Bayongbong which also lies in a fairly flat area, but in the mountainous terrain of the Danau di Atas region it seems less likely that sea level changes would significantly affect the level of water tables.

At all three sites the period starting c. 12000-13000 years B.P. saw changes in pollen assemblages which indicate that there was an altitudinal shift of vegetation in an uphill direction. At Situ Bayongbong there was a decline in lower montane forest II taxa over the period c. 12360 to c. 10890 years B.P. similar to that which occurred in the Danau di Atas region after c. 12900 years B.P. At Pea Sim-sim lower montane forest II taxa also declined after c. 12000 years B.P. and the forests of the area after this time were Fagaceous, with much Eugenia. The Tao Sipinggan sequence (Maloney, 1979, 1981) from 1445 m a.s.l. in the Toba Highlands begins c. 12000 years B.P. and shows changes similar to those at Pea Sim-sim From c. 12000 to c. 11000 years B.P. the site appears to have been surrounded by Fagaceae forest with Symingtonia and possibly gymnosperms, but this changes to a Fagaceae forest with much Eugenia after c. 11000 years B.P. All four sites, at altitudes from 1250 m to 1535 m a.s.l., appear therefore to have seen the replacement of lower montane II type forest, with gymnosperms and Fagaceae, by lower montane I type forests which are still Fagaceous but in which gymnosperms are not prominent. This uphill shift of vegetation zones occurred at all sites at some time during the period c. 13000 - c. 11000 years B.P. The most likely explanation of this apparently regional event would appear to be climatic amelioration.

After c. 11000 years B.P. events at the sites become less easy to correlate because a new environmental factor, man, begins to influence the vegetation, at different times in the different areas. At Danau di Atas, the higher altitude vegetation (upper montane forest and lower montane forest II) continued to decline in importance in the region after c. 11750 years B.P. and vegetation similar to that of the present day may have occurred by c. 8200 years B.P. At Situ Bayongbong lower montane forest I predominated in the area after c. 10890 years B.P. and the same appears to have been true at the two Toba sites. All three sites later show disturbance phases which possibly may be attributable to man, but no further changes which can be attributed to climate.

At Danau Padang, 950 m a.s.l. in the Kerinci area of Sumatra (Morley, 1982) the pollen record begins c. 10000 years B.P. At the start of the sequence the area, which now lies near the sub-montane/lowland forest transition, appears to have supported forests of lower montane I affinity, and possibly some peaks in the area may have supported some lower montane forest II, since some Dacrycarpus imbricatus pollen was recorded. However, between c. 10000 and c. 8600 years B.P. trees characteristic of lower montane forest I and sub-montane forest increased in importance while any lower montane forest II disappeared from the area. After c. 8600 years B.P. the forest appears to have been little different from undisturbed forests at present occurring in the area; disturbance was indicated c. 4000 years ago. Morley related the vegetation changes over the period c. 10000 to c.

8600 years B.P. to a general climatic amelioration, and suggested that mean annual temperatures may have risen by $2^{o}C$ during this period. Possibly the Danau Padang sequence included the later part of the climatic amelioration recorded in the Danau di Atas, Pea Sim-sim, Tao Sipinggan and Situ Bayongbong sections. It does however seem a little unusual that lower montane forest II should have been indicated in the area, after it had diminished in importance at the other sites, which all lie at higher altitudes.

Other sites which have been studied palynologically include Situ Gunung, at c. 1000 m a.s.l. in West Java (van Zeist et al., 1979) which has a basal date of 7720 ± 40 years B.P. and Danau Bento, at 1350 m a.s.l. in the Kerinci area (F. James, pers. comm.) and dates to c. 8700 years B.P. Both indicate vegetation changes but these do not appear to be related to climatic events. At Danau Bento the vegetation changes indicated appear to relate to hydroseral development and volcanic events. The vegetation changes indicated in the Telaga Patengan sequence, from 1575 m a.s.l. in West Java (van Zeist et al., 1979) similarly do not appear to be related to climate. In fact this sequence proved to be rather young, some 3300 years B.P. only (Stuijts, 1984). Analysis of Pea Sijajap (Maloney, 1984b) in the Toba area at c. 1300 m a.s.l. is not yet complete and no radiocarbon dates have been obtained, so this sequence will not be considered here.

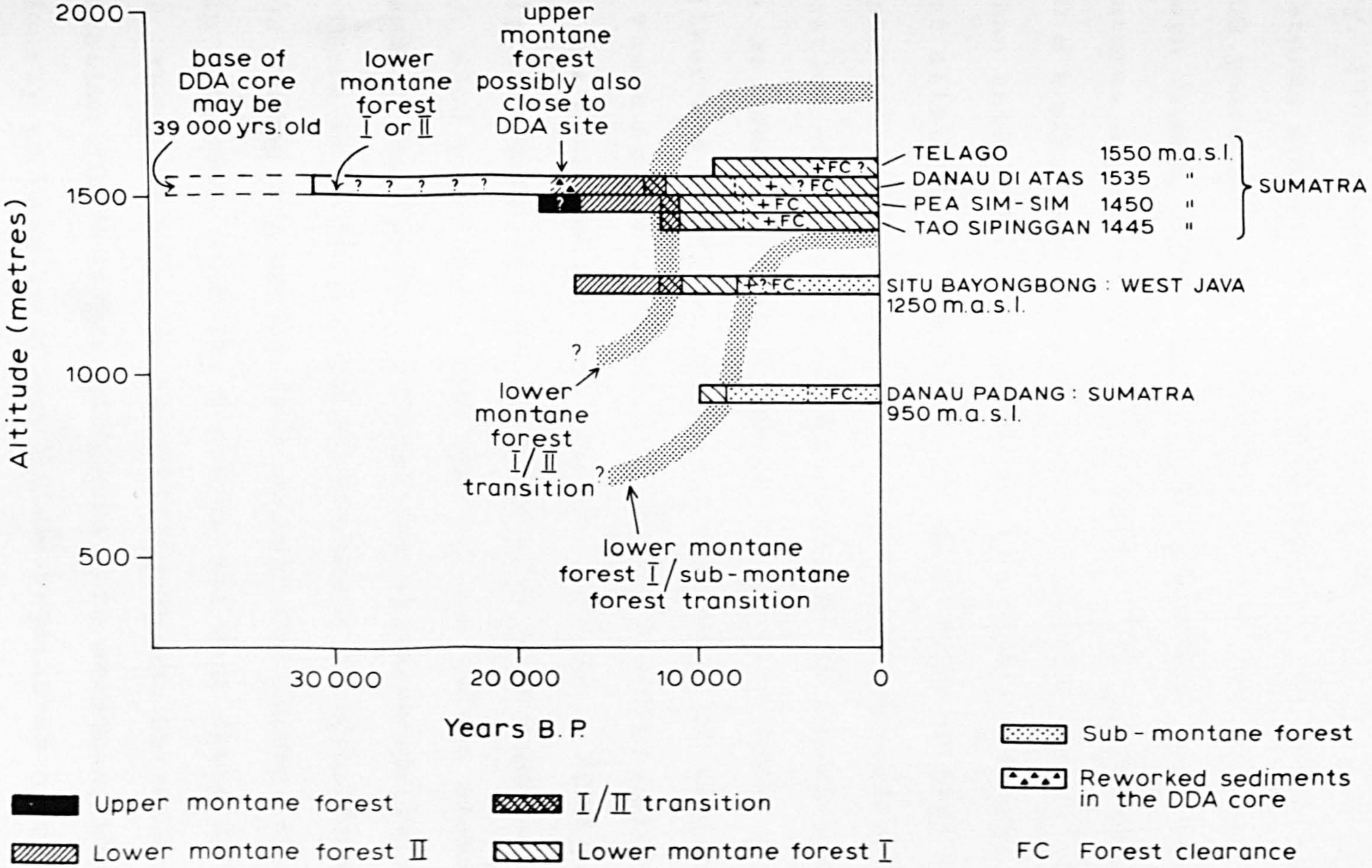
It can be concluded from the available information that similar changes have occurred during the early part of the period (prior to c. 11000 years B.P.) in the vegetation throughout the region, probably in response largely to temperature conditions. Climatic amelioration probably continued in the region after c. 11000 years B.P. and at some time after this the vegetation appears to have taken on its present character at most sites. Evidence from Danau Padang, Danau di Atas and Telago Swamp suggests that this had perhaps happened by c. 8000 years ago. Fig 8.1 summarizes the vegetational events at these sites.

The younger sequences from West Malesia do not indicate vegetation changes which may be attributable to climatic events. They do however often indicate disturbance, at various times within the last few thousand years, which may in many instances have been due to the impact of man. Man's impact on the vegetation of the area will be discussed in a later section.

The evidence from the Danau di Atas and Telago pollen sequences suggests vegetation and climatic changes which correspond with those suggested by other recently published data from Sumatra and West Java. Although these suggest that mean annual temperatures varied in the past, none provide any direct evidence for the existence of formerly drier climates.

Elsewhere in Malesia, from New Guinea, there is also palynological evidence for climatic change in the past; this was discussed in Chapter 1. It is not proposed here to compare in detail the particular changes observed at the New Guinea sites with those from West Malesia. However there are general similarities between the two areas which are worthy of comment. In the mountains of New Guinea are a number of sites but these provide little information as to the nature of environmental

Fig. 8.1
Sumatra and West Java: a summary of Late Quaternary vegetational changes (partly after Flenley, 1984)


2000
1500
1000
500
Altitude (metres)
30 000
20 000
10 000
0
Years B. P.
base of DDA core may be 39 000 yrs. old
lower montane forest I or II
upper montane forest possibly also close to DDA site
lower montane forest I/II transition
lower montane forest I/sub-montane forest transition
?
+FC ?
+ ? FC
+FC
+FC
+?FC
FC
TELAGO 1550 m.a.s.l.
DANAU DI ATAS 1535 "
PEA SIM-SIM 1450 "
TAO SIPINGGAN 1445 "
SUMATRA
SITU BAYONGBONG : WEST JAVA 1250 m.a.s.l.
DANAU PADANG : SUMATRA 950 m.a.s.l.
Upper montane forest
Lower montane forest II
I/II transition
Lower montane forest I
Sub-montane forest
Reworked sediments in the DDA core
FC Forest clearance

conditions prior to c. 27000 years B.P. Information from high altitude sites, at 2500 m a.s.l. and above (eg. Walker and Flenley, 1979) suggest that from c. 27000 to c. 25500 years ago temperatures similar to today's prevailed, but these fell after c. 25500 years B.P. The coldest period in New Guinea seems to have been from c. 18500 to c. 16000 years B.P. when mean annual temperatures appear to have been up to 10°C colder than present, at 2500 m a.s.l., although at lower altitudes the cooling was less than this. This approximately coincides with the period of greatest altitudinal depression of vegetation in West Malesia, which started c. 18000 years B.P. Evidence for climatic amelioration starts at different times at different sites in New Guinea; at some there is evidence as early as 16000 years B.P. (eg. Walker and Flenley, 1979), but sometimes it is later than this. There is also some evidence of a period of milder conditions than the present, from c. 8500 to c. 5000 years B.P. Possibly the Danau di Atas area may also have experienced this, after c. 8200 years B.P., when sub-montane forest elements increased in importance, although the evidence for this is rather weak. There is no palynological evidence for significantly drier climates during any period from montane New Guinea, which is again in agreement with the Sumatran and West Javan evidence. However, there is also the possibility in New Guinea that precipitation did decrease or became more seasonal, but not sufficiently to have an effect on the vegetation of the everwet montane regions which have so far been examined.

Palynological evidence from the montane regions of tropical

Africa and South America suggests that in both areas past climates have been both colder and drier than at present. In Africa the period from c. 27000 to c. 14000 years B.P. appears to have been colder and drier than at present, with warmer and more humid conditions prevailing after c. 12000 years B.P. In South America the period from c. 21000 to c. 13000 years B.P. appears also to have been very much colder and probably drier than at present, with warmer, wetter conditions returning after c. 9500 years B.P. In South America there is some evidence to support the idea that conditions were warmer than at present from c. 7500 to c. 3000 years B.P. Most of this evidence, from both continents, is from sites above 2000 m a.s.l. Lowland areas also appear to have experienced climatic change during the last c. 30000 years. However, in these areas moisture rather than temperature appears to have been important. Both continents appear to have experienced dry and humid phases, with a change from drier to more humid climate c. 12000 - 10000 years ago.

On the basis of palynological evidence, the montane areas of Malesia appear to have experienced climatic changes of a slightly different nature from those in the two other tropical regions. Evidence of a cooler phase c. 25000 to c. 13000 years ago is in broad agreement in the three regions, but in the montane areas of Malesia there is as yet no palynological evidence which demands the existence of a formerly drier climate.

8.8 The impact of man on the vegetation of the Danau di Atas region, and elsewhere in West Malesia

The pollen assemblages recovered from both the DDA and Telago cores do not provide any firm evidence of the early presence of man in the area. However there are pollen features in both sections which suggest possible disturbance of the vegetation.

The increase in pollen of Macaranga comp. in the zones DDA-V and DDA-VI, and TEL-III suggests that Macaranga spp. increased in importance in the vegetation of the area at this time. Macaranga spp. are important pioneer species in the forests of South-East Asia especially below 1000 m a.s.l. but also at higher altitudes (Whitmore, 1975), therefore this possibly indicates an increase in the amount of seral vegetation in the area. How extensive this could have been is difficult to assess, as Macaranga spp. may tend to be over-represented in the pollen rain (Morley, 1976). The increase in pollen of Macaranga comp. takes place at the base of zone DDA-V which has an estimated age of c. 8200 years B.P. In the Telago sequence the increase occurs only in zone TEL-III, and this cannot be dated. Since Macaranga comp. does show an increase in the later part of both sequences, it is possible that seral vegetation did become more important regionally during the period.

There are a number of factors which could result in an increase in seral vegetation, and human disturbance of the forest vegetation is one of these. It is therefore possible that man had begun to affect the vegetation of the area at some time after c. 8200 years B.P. However other factors could result in increased seral vegetation; these include tectonic disturbance, landslides and volcanism. It seems unlikely, though, that any of these would cause the increased importance of seral vegetation over such a long time span, several thousand years, unless the events were repeated. No volcanic ash was observed in the sediment, as might have been expected had volcanic activity been pronounced. Intermittent human disturbance is thus perhaps the most likely explanation.

The samples examined from the top of the cores at both sites reflect the present, open, nature of the vegetation. However the penultimate samples examined in each core do not reflect this. It appears that widespread, devastating human interference with the vegetation, which has resulted in the present characteristics of the area, has been a relatively recent phenomenon. Perhaps this has occurred only within the last few hundred years, associated with increasing human populations and a settled way of life.

One other feature is recognized which is possibly also related to the activities of man. This is the disappearance of wood from the sediment profile at both sites, and present absence of swamp forest in the area. There is nothing to suggest that the present swamps are incapable of bearing some type of swamp forest vegetation, and the sediments of both suggest that they bore some type of swamp forest in the past. Elsewhere in Sumatra swamp forest does occur, for example at Danau Padang (Morley, 1976) and Danau Bento (Morley _et_ _al_., 1973). Moreover tree stumps occur on the Danau di Atas Swamp, and one of these was sprouting leaves at the time that field work was carried out. The absence of swamp forest at present therefore appears to be a result of man's activities, such as wood cutting, rice cultivation, and grazing by domestic animals. The question remains as to whether the initial disappearance of swamp forest vegetation in the area was a direct result of man's activities, or whether this was caused by some other factor, but man's activities have since prevented re-establishment of the forest. The swamp forest at Danau di Atas appears to have declined at some time after c. 7500 years B.P. The event at Telago Swamp cannot be dated but was possibly more recent than this, as it occurs above 1.65 m depth in a core of total length 10.10 m and basal age 9105 ± 200 years B.P.

There is no archaeological evidence from the Danau di Atas region to indicate the long term presence of man in this area, although evidence does exist for the Toba region (van Heekeren, 1972; Schnitger, 1938), and the Kerinci valley (van der Hoop, 1940). Possibly the absence of such evidence from the Danau di Atas region relates to the relative lack of archaeological work carried out in the area. However palynological evidence suggesting possible human disturbance of the vegetation pre-dates the archaeological evidence in both of the other areas.

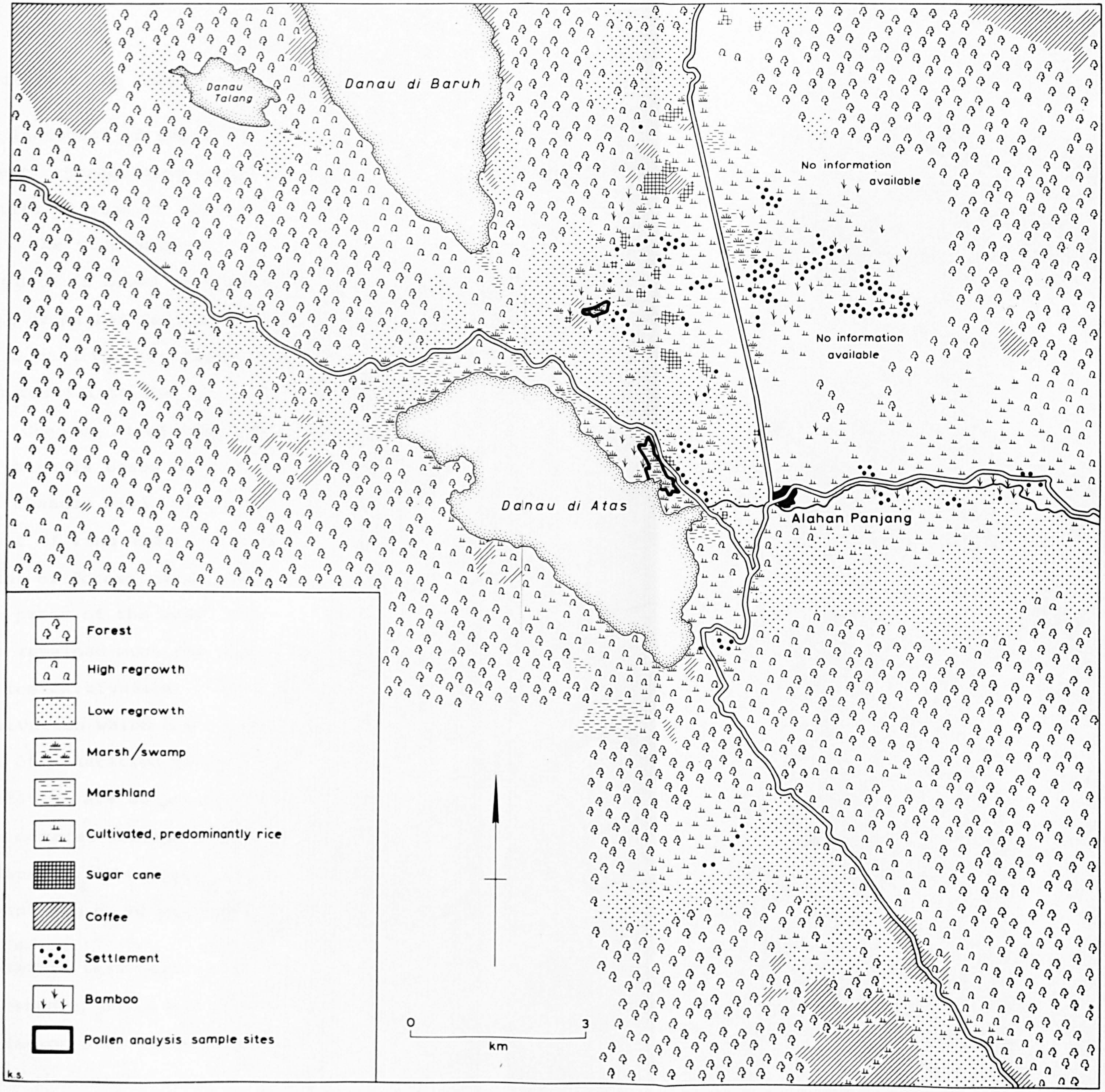
Some forest clearance seems to have occurred by c. 4000 years B.P. at Danau Padang (Morley, 1982), where it was followed by regrowth. Maloney (1980) suggests that forest clearance had certainly begun by c. 7500 years B.P. and possibly earlier, in the Toba Highlands. As yet no pollen which can be conclusively assigned to cultivars has been recorded from such old deposits in Sumatra, so the exact nature of man's effect on the vegetation cannot be ascertained.

Evidence provided by hominid remains suggests that primitive man was present in central Java at a very early stage. Hominid remains include those recovered from deposits at Trinil and Sangiran which date to the Middle Pleistocene; some may be of Early Pleistocene age (Day, 1977). Pollen evidence which might indicate the presence of man during the more recent period is, perhaps surprisingly, rather lacking. However there are changes in the pollen assemblages at Situ Bayongbong (Stuijts, 1984) c. 7890 years B.P. and Situ Gunung (van Zeist _et al_., 1979) c. 5000 years B.P. which might indicate human disturbance of the montane vegetation.

Although palynological evidence therefore exists from West Malesia which suggests human interference with the vegetation, locally, possibly as early as 8000 years ago, there is little to indicate the specific type of activity which occurred. There is certainly as yet no convincing palynological evidence of cultivation in the area so long ago. However, many cultivars do not have distinct pollen types, for example, as yet it is not possible to distinguish pollen of rice (_Oryza sativa_) from that of other grasses. Other cultivars may be from families which produce relatively little pollen while root crops may be harvested before they have chance to flower (van Zeist, 1984). As a result pollen of cultivars may be indistinguishable, or

Fig. 8.2
Distribution of major vegetational types in the Danau di Atas region, mid 1890's A.D.

Based on 1:20000 maps of the area, produced by the Batavia Topographic Bureau, 1893-1896


Danau Talang
Danau di Baruh
No information available
No information available
Danau di Atas
Alahan Panjang
Forest
High regrowth
Low regrowth
Marsh/swamp
Marshland
Cultivated, predominantly rice
Sugar cane
Coffee
Settlement
Bamboo
Pollen analysis sample sites
0
3
km
k.s.

unlikely to be found in deposits.

The landscape of the Danau di Atas region, with its mixture of forest, regenerating vegetation and cultivation was broadly similar to that at present by the mid 1890's A.D., about 90 years ago. The vegetation of the area at that time is shown in Fig. 8.2 which is based on maps from that period. Then, the area north of Alahan Panjang was, as now, largely cultivated for rice, and many of the settlements of that time still exist today. The main roads into the area were also in existence by the mid 1890's A.D. Changes since that time can be seen by reference to Fig. 4.1 which is based on air photographs of the area taken in 1970-71. Changes have taken place particularly with regard to the amount of land under cultivation, which has increased, and the amount of forest cover, which has been considerably reduced in some parts of the area. However the uses of the cultivated land have remained much the same over this period, with a predominance of rice cultivation. One of the few changes as regards cultivation which has taken place is an apparent reduction in the area of plantation crops, notably coffee. Areas of regenerating vegetation are at present very extensive within the region, but also covered considerable areas in the mid 1890's A.D. The landscape of the region was therefore one substantially altered by man even c. 90 years ago.

Earlier in this section it was mentioned that widespread human disturbance, which had resulted in the present open nature of the vegetation over considerable areas, appeared to be a relatively recent phenomenon. The pollen assemblage from the sample 0.55 m in the DDA core, having an estimated age of c. 1800 years B.P., indicated that the vegetation of the area consisted of apparently little disturbed forests, perhaps with limited areas of seral vegetation which could have been due to man's activities. The sample from 1.20 m in the Telago core also indicated the presence of this type of vegetation, although unfortunately it could not be dated. Man therefore seems to have had a major effect on the vegetation of this region only in the period post-dating c. 1800 years B.P. This may have been gradual at first, perhaps accelerating only within the last few hundred years.

Since the air photographs were taken in 1970-71 the major land use changes in the area seem principally to have affected the forest vegetation. In 1979, when field work was carried out, the forest area seemed to be reduced in extent compared with that indicated in 1970-71. This was particularly noticeable where the photographs showed forest adjacent to the roads, a feature largely absent in the area by 1979. During 1979 the forests were being affected by timber removal, although no clear felling specifically for timber was observed. There was also encroachment by fields and gardens. New gardens, sometimes entirely surrounded by forest, which had been recently cleared and burned, were commonly observed along the edges of the remaining forest. Plate 13 shows one of these, in which a crop of tobacco was being cultivated. It was also noted, during 1979, that considerable areas of the forest remaining were degraded due to selective timber removal. Only those at higher altitudes, above c. 1600 m, and at considerable distances from human settlement appeared to have escaped this type of human interference, along with some small forest patches at lower altitudes. The removal of selected species seems to reduce the diversity of the forest trees in an area quite markedly, as was shown by the Simpson's index of diversity for forest plots 1 and 2 (Table 4.6) which were both disturbed sites.

One question, which could now be asked, is how much forest remains in the region at present, and how much of this remains only slightly affected or unaffected by man. It is easy to foresee that in a relatively short time span, the encroachment of open land on the forest vegetation could result in a totally unforested environment in this part of Sumatra, particularly if the rate of forest removal accelerates, as it appears to be doing at present.

8.9 Some plant geographical considerations

A number of other points have become apparent on the basis of the results of this study.

Although there have been migrations of plants within the Danau di Atas area during the period covered by this study, the species composition of the vegetation as a whole does not appear to have altered significantly during at least the last 31000 years, therefore most plants have been in the area for a considerable time. The pollen produced by the vegetation during this time has largely been identifiable to generic or family level. Where pollen could only be identified to family level, identification problems were usually a result of similarity of pollen produced by different genera and species in the group. In the case of the relatively few unidentifiable pollen types the problem was that no match could be found in the modern pollen reference collection. This was probably because the latter does not include pollen of all species which could occur in the area, rather than that no modern source of this pollen exists. There appear therefore to have been no evolutionary changes in the flora during at least the last c. 31000 years. However evolutionary changes to whole floras appear to be very slow, as is illustrated by palynological studies of a Holocene peat from Sarawak and a 7 million year old Miocene coal from Brunei (Anderson and Muller, 1975). These showed that floristic compositions of the mixed swamp forests of both were closely comparable despite the great difference in age. In the light of these results it is perhaps rather unlikely that evolutionary change would have affected these montane floras over such a geologically short period.

The pollen assemblages from the Danau di Atas area indicate that the montane taxa have migrated in a vertical direction during this period in response to changing climatic conditions. It therefore seems likely that similar plant migrations would have happened in the period prior to c. 31000 years B.P. should climates have altered sufficiently, as indeed they appear to have done elsewhere. The migrations in the Danau di Atas area have been in response to wide ranging climatic changes, as similar plant behaviour has been observed elsewhere in montane Malesia, and other tropical montane areas, at approximately similar times. The vegetation zones of the Sumatran mountains have not been static in the past, and are unlikely to be so in the future.

The origin of the Malesian mountain floras have been considered by van Steenis (1934-36). One of the biogeographical problems posed by these floras is that of disjunction. Similar floras may exist on distinctly separate mountain peaks, especially at higher altitudes, and above the forest limit. The high, individual volcanic peaks of Java represent this situation extremely well, but the same is also true in Sumatra. These mountain floras also bear similarities with mountain floras outside the region, for example in the Himalayas. The question arises as to how these distributions arose. Van Steenis (1964) proposed three migration tracks to explain the routes taken by these species into Malesia. One of these, from the Himalayan region was through Sumatra. Originally it was thought that migration had occurred along some continuous mountain ranges which had subsequently disappeared, but the idea was rejected on the basis of lack of geological evidence for the existence of these. More recently the idea of the isolated high mountain areas acting as stepping stones for plant dispersal was also considered. However the evidence of depressed vegetation zones during the Late Quaternary period, suggested by recent palynological studies throughout Malesia does go a long way towards explaining many of the disjunct plant distributions observed at high altitudes. Clearly when vegetation zones were depressed the high altitude vegetation types would have been more extensive than at present. Some formerly isolated patches of high altitude vegetation would thus have been brought into contact, while others would have been brought much closer together, allowing the high altitude species to spread into new areas. As vegetation zones rose with climatic amelioration the populations would have again become isolated. Since it is likely that there were a number of vegetation movements during the Quaternary period, then there would have been repeated opportunities for the upland taxa to spread, although at present they are restricted to high altitude areas of fairly limited extent.

CHAPTER 9

CONCLUSIONS

It is proposed in this chapter to recap the aims of this study and to summarize the results which were obtained. In addition possible future approaches and work are considered.

The region around Danau di Atas was chosen for palynological investigation because it lay in an area of middle altitudes, and suitable polliniferous sediments were available for study. Previously, palynological work in the tropics had been concentrated at high altitude sites, mostly above 2000 m a.s.l., although some had been carried out in lowland areas, generally below c. 1100 m a.s.l. Results from these studies indicated that the lowland sites had experienced drier climates at some times during the Late Quaternary, while results from high altitude sites showed that climates had been much cooler in the past. Outside Malesia there was also some evidence to suggest drier phases in these montane areas. The question arose as to whether the middle altitudes had also experienced climatic change in the past, and if so had it been predominantly concerned with temperature, or moisture, or both. Polak (1933) initially noted the existence of polleniferous deposits in the Danau di Atas area. Subsequently Morley, Flenley and Kardin investigated a number of sites during 1972 (as described in Morley _et al_., 1973) and collected some material. Further cores were collected by Flenley in 1976 and 1977; these and some material collected in 1972 were available for palynological analysis in this study.

In order to aid the interpretation of the results from the fossil sequences, a study of the present vegetation of the area, using plots, and its pollen rain, was carried out in 1979. This provided some information as to species composition of the forest and non-forest vegetation of the area, which was supplemented also from the available literature.

The forests of the area are of lower montane type, dominated by one family, the Fagaceae, which is represented by many species of several genera. Other families of importance in these forests include Myrtaceae, Lauraceae and Theaceae, but many other groups are also represented. From the study of forest vegetation, and the information in the literature, it is clear that certain taxa are restricted in their altitudinal range. These include *Dacrycarpus imbricatus*, *Symingtonia populnea*, *Weinmannia blumei*, *Claoxylon longifolium* and *Linociera* spp. In contrast, many other species are wide ranging.

The non-forest vegetation of the area includes cultivated land, swamp and regrowth communities. Gramineae and Cyperaceae dominate in the herbaceous swamp vegetation. No swamp forest was observed within the area in 1979, although it certainly occurred there in the past. The regrowth communities are quite varied in nature, from very low, mostly herbaceous regrowth to high, largely woody vegetation. Many species are involved, *Imperata cylindrica*, *Pteridium aquilinum* and *Eupatorium inulifolium* being commonly found in regrowth having a low appearance. The higher, more woody regrowth includes taxa such as *Rhodoleia championi*, *Wendlandia glabrata*, *Rhododendron* sp. and *Vaccinium* sp.

A survey of ricefield and dry land gardens was carried out. Many of the taxa occurring as weeds in these are also commonly found in the swamp and regrowth communities, respectively, and may be considered as primary colonisers of highly disturbed ground.

The pollen deposited in surface samples and moss polsters collected from many of the vegetation plots was also examined. In addition, material was available from a variety of altitudes on G. Kerinci. These studies provided several types of information. Firstly they allowed an assessment to be made of which species are over- or under-represented in the pollen rain, and also those which are not represented at all. The latter may be due to low pollen production by the taxon, poor pollen preservation or allied factors, but may also occur if the taxon produces indistinct pollen which cannot be determined. The information thus obtained could then be used in assessing the likely importance of a taxon in the vegetation on the basis of its representation in fossil pollen assemblages.

The second type of information provided by these studies related to the nature of pollen dispersal and deposition in the area. An assessment could be made as to how much was from a local, intermediate or regional source. At all sites a large proportion of the pollen deposited is local in origin. In the non-forest sites, for example, the local component is generally contributing at least 50% TDLP. However at these sites there is also a significant regional component and this generally contributes

10-27% TDLP. The source of this may at times be several km away from the deposition site. Results from G. Kerinci also show that most pollen is deposited reasonably close to its source, such that it is generally deposited within the vegetation type from which it originates. Some movement away from source areas occurs on this mountain, being predominantly in an uphill direction. The information as to the nature of pollen dispersal and deposition in the Danau di Atas region provided by these studies could also be used in the interpretation of fossil pollen assemblages. The modern pollen studies also demonstrated that for forest vegetation it is principally the canopy reaching taxa which contribute to the regional pollen rain, in this area. Understory taxa may contribute some pollen at deposition sites within forest, but even here the canopy reaching taxa contribute the bulk of the pollen deposited.

Two cores from the area were analysed palynologically. The Danau di Atas (DDA) core from 1535 m a.s.l. is 16.50 m long, and the section 15.60 m to 15.70 m provided a ^{14}C age of 31450 + 2990 -2180 years B.P. Possibly the base of this core is c. 39000 years old. This sequence is quite well radiocarbon dated which has enabled pollen influx to be calculated for the samples examined. The Telago core from 1550 m a.s.l. was examined only briefly. Although 10.10 m long this proved to be relatively young, having a basal age of 9105 ± 200 years B.P.

The pollen assemblages of both cores showed a number of changes, so for convenience of description both sequences were zoned.

Pollen assemblages were interpreted with the aid of the information obtained from the modern pollen rain and vegetation studies carried out in the area, supplemented by information available in literature eg. Morley (1976), Flora Malesiana, and Flora of Java (Backer and Bakhuizen van den Brink, 1963-67).

The vegetation of the Danau di Atas region was not static during the period covered by the study; there were changes in the hydroseral and dry land vegetation. Hydroseral changes may have been related to infilling of the two sediment basins and appear to have been independent at the two sites. Changes in the dry land vegetation have mostly been of regional extent, and have principally taken the form of vertical migrations of the altitudinal vegetation zones, apparently in response to climatic change. More recently there have been changes which indicate that the vegetation has been disturbed, probably by man.

The dry land vegetation changes which have occurred in the area are summarized below, along with the implications of these in terms of depression of the vegetation and past climates.

From pre-31000 to c. 17900 years B.P. lower montane forests predominated in the region. These were dominated by Fagaceae, but gymnosperms may have also been important, at least locally. The exact nature of the forests in the vicinity of the Danau di Atas site is not clear, but they may have included some lower montane II type forest, but could also have been of lower montane forest I affinity. Some altitudinal depression of the vegetation is suggested at this time but the extent of this is difficult to assess. However if there was some lower montane forest II around the site then a depression of at least 265 m had taken place. This would suggest mean annual temperatures at least 1.6°C cooler than at present, based on current lapse rates of 0.6°C/100 m.

From c. 17900 to c. 12900 years B.P. lower montane forests predominated in the area. These were Fagaceous with abundant gymnosperms, possibly very similar to the present lower montane forest II. Upper montane forests also occurred in the area during this period and may at times have been widespread, although the evidence does not suggest that they ever surrounded the Danau di Atas site. The depression of vegetation zones suggested by the presence of lower montane forest with abundant gymnosperms around the site is in the range 265-865 m. The presence of upper montane forest in the area suggests that the actual maximum depression was closer to the upper limit, 865 m, than to the lower one. During this period mean annual temperatures were in the range of 1.6-5.2°C cooler than at present, and probably lay closer to the maximum rather than the minimum value.

From c. 12900 to c. 11750 years B.P. gymnosperms declined in the vegetation of the area. This is interpreted as a retreat of lower montane forest II from the area around the site, to slightly higher altitudes. Throughout much of this period the site, at 1535 m a.s.l., may have lain close to or within the transition of lower montane forests I and II. This suggests a vegetation depression of the order of 265 m and mean annual temperatures may have been about 1.6°C cooler than present.

From c. 11750 to c. 8200 years B.P. gymnosperms appear to have been of little importance in the vegetation of the region. Fagaceous forests of lower montane forest I type appear to have surrounded the Danau di Atas site during the period, and also surrounded Telago at 1550 m a.s.l. when deposition started at this site. The maximum depression of vegetation at Danau di Atas at the start of the period was 265 m, and at Telago by c. 9100 years B.P. was 250 m. However the true depression of vegetation may have been less than this, and mean annual temperatures therefore appear to have been no more than 1.6°C cooler than present values during this period. By the end of the period temperatures may have been similar to todays.

From c. 8200 to c. 5400 years B.P. forests similar to the present lower montane forest I surrounded both sites. Sub-montane forests were also closer to these than during any of the preceding periods. The forest vegetation of the area appears therefore to have had a composition similar to that of the forest remaining in the area at present. Vegetation zones seem to have been at approximately similar levels to those present today, although they could have possibly lain either slightly higher or slightly lower. Mean annual temperatures thus appear to have been similar to today's levels and it seems unlikely that they were more than c. 0.5°C warmer or cooler. At some time after c. 8200 years B.P. there may have been an increase in seral vegetation in the region, notably Macaranga spp., which could be related to human disturbance of the forests.

After c. 5400 years B.P. forests of lower montane forest I type appear to have surrounded both sites. Mean annual temperatures during this period were probably more or less similar to those at present. There are some indications that seral vegetation existed in the region throughout the period, but only the pollen assemblages from the surface samples of the two cores reflect the presence of large areas of non-forest vegetation. Widespread forest clearance, for agriculture, appears therefore to have been a relatively recent phenomenon.

Evidence from palynological studies in the Danau di Atas region suggests that climates have varied in the past. They appear to have been cooler during the period from pre-31000 years B.P. until some time after c. 11750 years B.P., and appear to have been at their coldest at some time during the period c. 17900 to c. 12900 years B.P. Mean annual temperatures have however been similar to present values during at least the last c. 8200 years. There is no palynological evidence from this region to suggest that the climate was formerly drier than at present. However there could have been a decrease in the precipitation which the area receives, without there being any recognizable effect on the vegetation of the area, since its present climate is extremely wet. Walker and Flenley (1979) have suggested that a 30% increase or decrease in precipitation could be tolerated by the present vegetation of this region.

The evidence of vegetation change from this region is similar to that described from middle altitude sites in the Toba region of

Sumatra (Maloney, 1980) and West Java (Stuijts, 1984). All show considerable depression of altitudinal vegetation zones during the period c. 18500 to c. 12000 years B.P. At all sites there is subsequently an upward migration of the vegetation, so that the sites become surrounded by forests similar to those found in the areas at present. Stuijts (1984) considers variation in mean annual temperature to have been the causal factor in West Java, although Maloney (1980) is wary of interpreting the vegetation shifts observed in the Toba region purely in terms of temperature changes.

There are several directions which could be taken by any future work in this field.

The DDA core is relatively well dated but due to lack of time available the spacing of samples is fairly large. Further sampling of this core, particularly over the basal section and the uppermost section might clarify, respectively, the nature of vegetation and climate prior to c. 17900 years B.P., and the point when man started to influence the vegetation in a major way. Closer sampling might also provide more accurate information as to the timing of vegetation events. The Telago core would be far less useful in these respects since it is insufficiently dated and further dates cannot be obtained.

More extensive vegetation studies in this part of Sumatra might reveal more indicator species, either of climatic or other conditions, which again would possibly improve the interpretation of fossil assemblages from this area.

The question of whether climates were drier during the Quaternary in this region may perhaps not be answerable on the basis of palynological studies in this area of Sumatra, which is presently extremely wet, since the vegetation may be able to tolerate a reduction in precipitation without showing any effect. Perhaps the answer to this question will be found elsewhere in Malesia where present climates are drier and more seasonal than those in Sumatra, and where the vegetation may thus be more sensitive to small changes in precipitation. Areas such as East Java and Sulawesi might prove suitable in this respect, if suitable polliniferous deposits can be found.

PLATE 1

View of the forest interior of plot 4.

PLATE 2

View of the forest interior in the vicinity of plot 24.

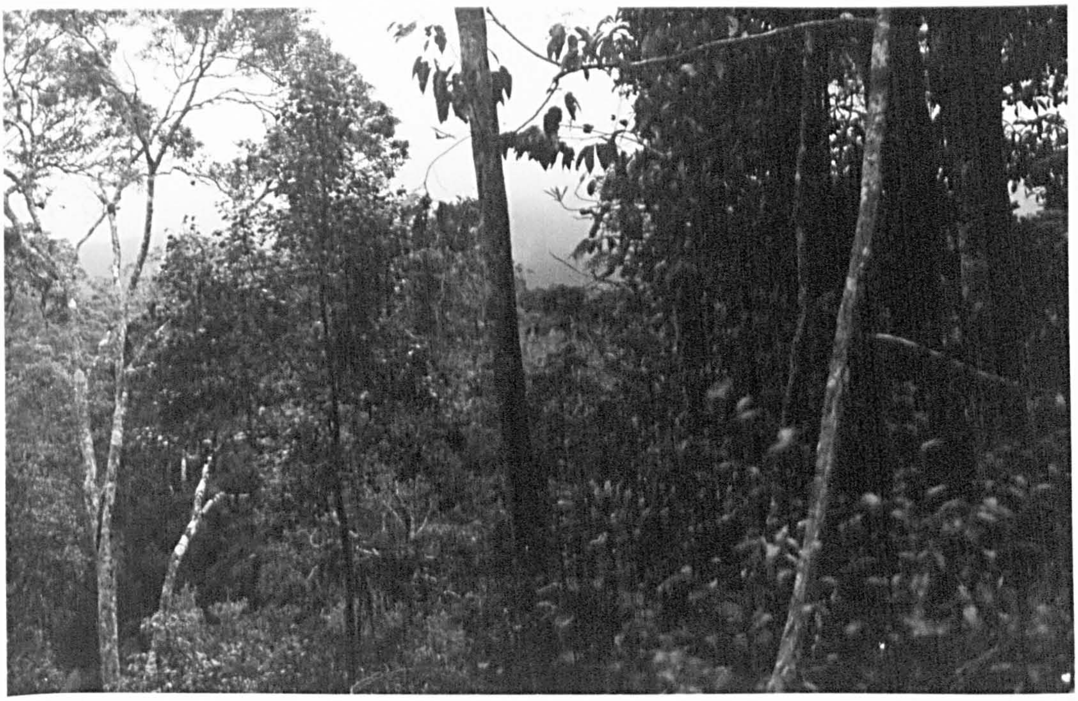


PLATE 3

View of the forest near plot 20.

PLATE 4

Vegetation in the vicinity of plot 15.

PLATE 5

Vegetation in the vicinity of plot 16.
Note the abundance of Eupatorium inulifolium.

PLATE 6

Vegetation in the vicinity of plot 17.

PLATE 7

The vegetation at plot 19.

PLATE 8

Vegetation in the vicinity of plot 19.
The base of the shrub (centre) showed signs of having been burnt.

PLATE 9

A view of the vegetation on the Danau di Atas Swamp.

PLATE 10

A view of the vegetation on the Danau di Atas Swamp. On the left are the seasonally abandoned ricefields.

PLATE 11

The Danau di Atas Swamp, viewed from the northern end.

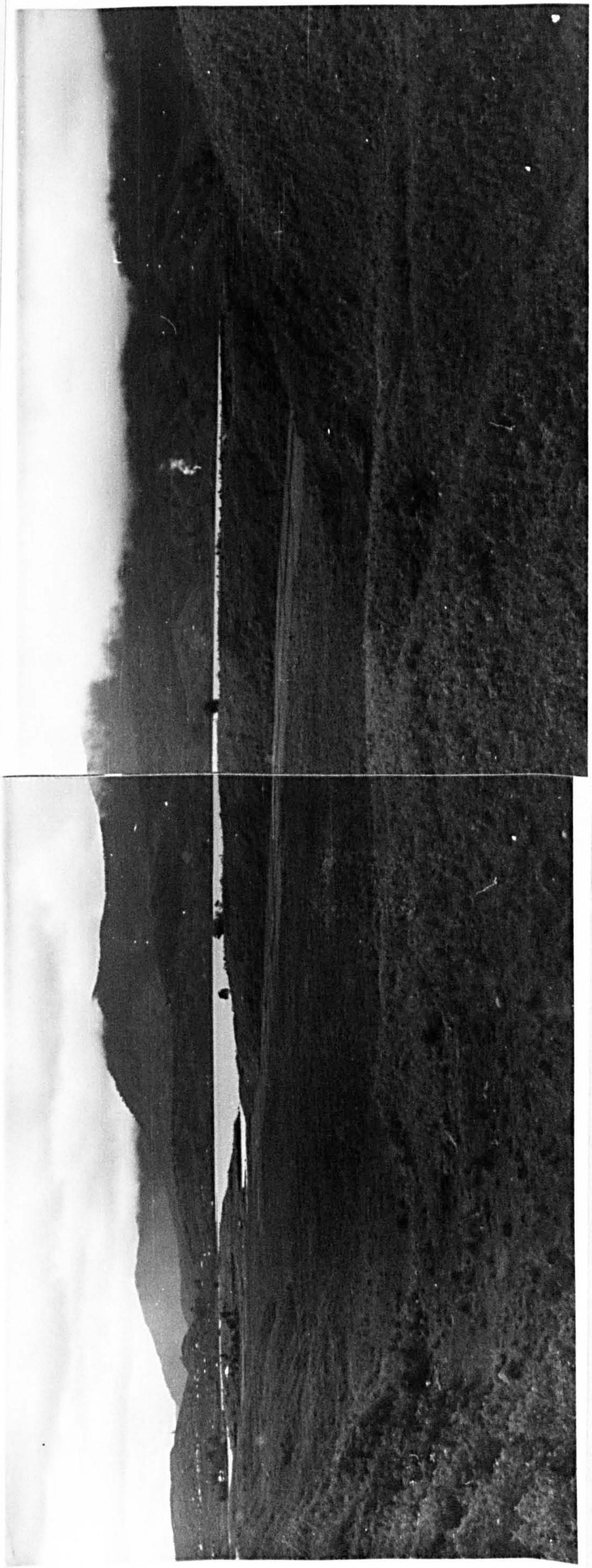


PLATE 12

The Telago Swamp.

PLATE 13

View of a recently cleared garden, with tobacco plants. This garden was still surrounded by forest.

APPENDIX 1

Plant taxa collected in the field area

Names and authorities of spermatophyte taxa are after the published sections of Flora Malesiana, series I, vols 4-9 (1954-1983). Where families have not yet been reviewed by Flora Malesiana then the names and authorities are after Flora of Java (Backer and Bakhuizen van den Brink, 1963-1968) and Index Kewensis. Pteridophyte nomenclature follows Flora of Malaya vol 11 Ferns (Holttum, 1954) and Flora Malesiana, Series II, vol 1 (1959-1978). Identifications were provided by Mr Nedi of the Herbarium Bogoriense, Bogor and occasionally these could not be traced in the literature. Here the nomenclature is that given by Bogor, preceded by a question mark.

Spermatophyte taxa

Family	Name and authorities	Collection Number
Acanthaceae	Gendarussa vulgaris NEES	195
Alangiaceae	Alangium rotundifolium (HASSK.)BLOEMB.	52,58
Amaranthaceae	Amaranthus hybridus LINNE	193
Anonaceae	Goniothalamus sp.	84
Araceae	Homalomena cordata SCHOTT	219
Araliaceae	Schefflera sp.	77
	Schefflera sp.	232
	Schefflera sp.	243
Aquifoliaceae	Ilex cymosa BL.	3,62
Balsaminaceae	Impatiens javensis (BL.)STEUD.	149
Burmanniaceae	Burmannia disticha LINNE	108
Caprifoliaceae	Viburnum beccarii GAMBLE	278
	Viburnum coriaceum BL.	281
	Viburnum sp.	289
Caryophyllaceae	Drymaria cordata (L.)WILLD. ex R.&S.	136
Combretaceae	Terminalia sp.	276
Commelinaceae	Murdannia nudiflora (L.)BRENAN	175
Compositae	Ageratum conyzoides L.	141
	Anaphallis longifolia (BL.)DC.	196
	Bidens pilosa L.	171
	Blumea lacera (BURM. f.)DC.	179
	Emelia sonchifolia (L.)DC. ex WIGHT	185
	Enydra fluctuans LOUR.	156
	Erigeron sumatrenis RETZ.	172
	Eupatorium inulifolium H.B.K.	168
	Spilanthes iabadicensis A.H. MOORE	140
	Tithonia diversifolia (HEMSLEY) A. GRAY	191
	Vernonia arborea BUCH.-HAM.	32
	Vernonia arborea BUCH.-HAM. var. javanica (DC.)CLARKE.	25
Cunoniaceae	Weinmannia blumei PLANCH.	24,101
Cyperaceae	Carex cruciata WAHLENB	212
	1.Carex cf. dimorpholepis STEUD.	144
	Cyperus brevifolius (ROTTB.)HASSK.	300

	Cyperus cyperoides (L.)O.KUNTZE	178
	2.Cyperus cf. flavidus RETZ.	116,117
	Cyperus javanicus HOUTT.	299
	Cyperus kyllingia ENDL.	143
	Eleocharis dulcis (BURM.f.)HENSCHEL	147
	Eleocharis retroflexa (POIR.)URB.	145
	Eleocharis tetraquetra NEES	146
	Fimbristylis aphylla STEUD.	157
	Fimbristylis dichotoma (L.)VAHL.	154,220
	Fimristylis polytrichoides (RETZ.)R.BR.	253
	Fuirena sp.	114
	Lipocarpha chinensis (OSB.)KERN.	115
	Machaerina rubiginosa (SPRENG.)KOYAMA	113
	Rhynchospora rugosa (VAHL)GALE	107,164
	Scirpus juncoides ROXB.	119
	Scirpus mucronatus LINNE	105
Elaeagnaceae	Elaeagnus latifolia L.	207
Elaeocarpaceae	Elaeocarpus glaber BL.	81
	Elaeocarpus ovalis MIQ.	42,266
	Elaeocarpus punctatus WALL.	75
	Elaeocarpus sp.	267
	Sloanea sigun (BL.)K.SCHUM.	4,262
Ericaceae	Rhododendron sp.	229
	Vaccinium sp.	230
	Vaccinium sp.	284
Eriocaulaceae	Eriocaulon brownianum MART.	103
	Eriocaulon heterolepis STEUD. var. nigricans KOERN.	134
Euphorbiaceae	Aleurites moluccana (L.)WILLD.	240
	Breynia microphylla (KURZ ex T.&B.)M.A.	201
	Claoxylon longifolium (BL.)ENDL. ex HASSK.	2
	Drypetes sp.	45
	Glochidion sp.	155
	Glochidion sp.	274
	Macaranga tanarius (L.)M.A.	53
	Macaranga triloba (REINW. ex BL.)M.A.	271
	Macaranga sp.	15
	Omalanthus populneus (GEISEL)PAX	210,288
Fagaceae	Castanopsis lucida (NEES)SOEPADMO	50,265
	Castanopsis malaccensis GAMBLE	286
	Lithocarpus javensis BL.	65
	Lithocarpus elegans (BL.)HATUS ex SOEPADMO	72
	Lithocarpus sp.	5
	Lithocarpus sp.	17
	Lithocarpus sp.	18
	Lithocarpus sp.	41
	Lithocarpus sp.	82
	Lithocarpus sp.	88
	Lithocarpus sp.	89
	Lithocarpus sp.	255
	Lithocarpus sp.	277
	Quercus lineata BL.	28,86,261
Flacourtiaceae	Flacourtia rukam ZOLL. & MOR.	14
Gramineae	Arthraxon hispida (THUNB.)MERR. ssp.?langsdorfii	166

	Axonopus compressus (SWARTZ)BEAUV.	150
	Brachiaria sp.	250
	Chrysopogon aciculatus (RETZ.)TRIN.	184
	Coelachne infirma BUESE	142,297
	Cymbopogon sp.	159
	Digitaria violascens LINK	161
	Eleusine indica (L.)GAERTN.	190
	Eragrostis unioloides (RETZ.)NEES ex STEUD.	254
	Hymenachne sp.	111
	Imperata cylindrica (L.)RAEUSCH.	163
	Isachne albens TRIN.	211
	Isachne globosa (THUNB.)O.K.	128
	Leersia hexandra SWARTZ	110,251
	Oplismenus compositus (L.)BEAUV.	192,227
	Oryza sativa L.	118
	Panicum repens L.	106,252
	Paspalum orbiculare FORST.f.	112
	Pogonatherum saccharoideum BEAUV.	169
	Schizachyrium brevifolium (SWARTZ)NEES	183
	Setaria geniculata SIEBER ex KUNTH	222
	Setaria palmifolia (WILLD.)STAPF	214
	Sporobolus berteroanus TRIN.	160
	Themeda villosa (POIR.)DURAND & JACKS.	187
Guttiferae	Cratoxylum arborescens (VAHL)BLUME	273
	Garcinia lateriflora BL.	46
	Garcinia sp.	256
	Hypericum japonicum THUNB. ex MURRAY	135
Haloragaceae	Laurembergia coccinea (BL.)KAN.	138
Hamamelidaceae	Rhodoleia championi HOOK. f	96,244
	Symingtonia populnea (R.BR. ex GRIFF.)STEEN.	95
Icacinaceae	Platea excelsa BL. var. riedeliana (BECC.)SLEUM.	26,76
Juglandaceae	Engelhardtia spicata LECHEN ex BL.	283
Juncaceae	Juncus prismatocarpus R. BR. var. leschenaultii (GAY)BUCHENAU	120
Labiatae	Basilicum polystachyon (L.)MOENCH	180
Lauraceae	Actinodaphne sp.	36
	Actinodaphne sp.	263
	Beilschmiedia sp.	6
	Cinnamomum sp.	27
	Cinnamomum sp.	272
	Cryptocarya sp.	39
	Cryptocarya sp.	40
	Cryptocarya sp.	48
	Cryptocarya sp.	70
	Cryptocarya sp.	264
	Endiandra sp.	44
	Endiandra sp.	49
	Endiandra sp.	102
	Lindera novoguineensis KOSTERM.	13,54,55,69
	Litsea sp.	8
	Litsea sp.	71
	Litsea sp.	100
	Neolitsea sp.	98
Leguminosae/ Caesalpinoideae	Cassia floribunda CAV.	204

/Mimosoideae	Albizia lophantha (WILLD.)BTH.	248
/Papilionatae	Crotalaria chinensis L.	165
	Crotalaria sp.	186
	Desmodium repandum (VAHL)DC.	194
	Desmodium triflorum (L.)DC.	223
Lentibulariaceae	Utricularia bifida LINNE	109
Liliaceae	Dianella ensifolia (L.)DC.	215
	Disporum cantoniense (LOUR.)MERR.	209
Loganiaceae	Fagraea sp.	35
Loranthaceae	Helixanthera parasitica LOUR.	285
Lythraceae	Cuphea balsamona CHAM. & SCHLECHT.	189
Malvaceae	3.Urena lobata L.	176
Melastomataceae	Medinilla sp.	67
	Melastoma affine D. DON	173
	Pternandra sp.	268
Meliaceae	Dysoxylum sp.	66
	Dysoxylum sp.	74
Moraceae	Ficus deltoidea JACK var.lutescens (DES. f.)CORNER	294
	Ficus ribes REINW. ex BL.	217
Myrsinaceae	Ardisia javanica DC.	246
	Ardisia sp.	9
Myrtaceae	Eugenia sp.	16
	Eugenia sp.	20
	Eugenia sp.	23
	Eugenia sp.	57
	Eugenia sp.	73
	Eugenia sp.	78
	Eugenia sp.	87
	Eugenia sp.	90
	Eugenia sp.	91
	Eugenia sp.	152
	Eugenia sp.	260
	Rhodomyrtus tomentosa (W.AIT.)HASSK	238
	4.Syzygium racemosum (BL.)DC.	59,245
	Tristania bakhuizenii BACK. ex AMSH	33
Oleaceae	Linociera oxycarpa LINGELSH.	22
	Olea javanica (BL.)KNOBL. var. ?lanciflora K.&V.	68
Orchidaceae	Arundina graminifolia (D.DON)HOCHR.	233
	Coelogyne sp.	131
	Microstylis sp.	202
	Microstylis sp.	216
	Phaius tankervilliae (W.AIT.)BL.	206
	Spiranthes sinensis (PERS.)AMES	148,174
Oxalidaceae	Oxalis corniculata LINNE	198
	Oxalis corymbosa DC.	302
Pandanaceae	Pandanus sp.	295
Passifloraceae	Passiflora edulis SIMS	213
Plantaginaceae	Plantago major L.	188
Podocarpaceae	Podocarpus (sect. Dacrycarpus ENDL.) D. imbricatus (BL.)DE LAUBENF.	247
Polygalaceae	Polygala paniculata L.	139
Polygonaceae	Polygonum cespitosum BL.	205
Potamogetonaceae	Potamogeton malaianus MIQ.	296
	Potamogeton oblongus VIV.	249
Rhizophoraceae	Carallia brachiata (LOUR.)MERR .	79

	Gynotroches axillaris BL.	63
Rosaceae	Prunus arborea (BL.)KALKMAN	1,85
	Pyrus granulosa BERTOL.	290
	Rubus alceaefolius POIR.	197
Rubiaceae	Borreria alata (AUBL.)DC.	170,301
	Borreria laevis (LAMK)GRISEB.	224
	Galium innocuum MIQ.	130
	Hedyotis verticillata (L.)LAMK	182
	?Oldenlandia agrostemmoides KAR. & HAT.	123
	Psychotria divergens BL.	280
	Tarenna fragrans (BL.)K.&V.	30,153,242
	5.Timonius cf. sericeus	56
	Wendlandia glabrata DC.	228
Rutaceae	Tetractomia holtumi RIDL.	83,93
	Tetractomia obovata MERR.	29,34
Sapindaceae	Dodonaea viscosa JACQ.	241
	Mischocarpus sundaicus BL.	269
Saurauiaceae	Saurauia vulcani KTH.	208
Saxifragaceae	Hydrangea sp.	239
Scrophulariaceae	Lindernia anagallis (BURM. f)PENNELL	137
Solanaceae	Solanum melongena L.	200
	Solanum nigrum L.	162
Staphyleaceae	Turpinia sphaerocarpa HASSK.	7
Styracaceae	Styrax paralleloneurum PERK.	21,258
Symplocaceae	Symplocos cf. ?baratogi	43
	Symplocos cochinchinensis (LOUR.)S.MOORE ssp.laurina (RETZ) NOOT var. laurina	234
	Symplocos fasciculata ZOLL.	10
	6.Symplocos henscheli (MOR.)BTH ex CLARKE var maingayi?	259
	Symplocos laeteviridis STAPF var. laeteviridis	279
	Symplocos sp.	31
	Symplocos sp.	97
Taxaceae	Taxus baccata L.	291
Theaceae	Adinandra villosa CHOISY	292
	Adinandra sp.	37
	Adinandra sp.	38
	Eurya sp.	231
	Eurya sp.	293
	Haemocharis sp.	287
	Schima wallichii (DC.)KORTH. ssp.noronhae (REINW. ex BL.) BLOEMBERGEN	51,282
	Schima sp.	94
	Ternstroemia patens (KTH.)CHOISY	47,64,80
Umbelliferae	Centella asiatica (L.)URB.	129
	Hydrocotyle sibthorpioides LAMK	121
Urticaceae	Gonostegia hirta (BL.)MIQ.	167
Verbenaceae	Lantana camara L.	181
	Vitex trifolia L. var. ?heterophylla	237
Violaceae	Viola pilosa BLUME	122
Xyridaceae	Xyris capensis THUNB. var. schoenoides (MART) NILSSON	104

Pteridophyte taxa

Azollaceae	Azolla pinata R.BR.	127
Cyatheaceae	Cyathea sp.	19
Dennstaedtiaceae	subf. Davallioideae	
	Humata sp.	203
	7.subf. Lindsayoideae	
	Schizoloma ensifolium (SW.)J.SM.	151
	subf. Oleandroideae	
	Nephrolepis cordifolia (L.)PR.	126
	subf. Pteridioideae Pteridium aquilinum (L.)KUHN.	158
Equisetaceae	Equisetum debile VAUCH.	225
Gleicheniaceae	Dicranopteris curranii COPEL.	124
Lycopodiaceae	Lycopodium ?casuarinoides SPRENG.	235
	Lycopodium cernuum L.	133
	Lycopodium clavatum L.	236
Ophioglossaceae	Botrychium ?ternatum SW.	177
Polypodiaceae	Microsorium nigrescens (BL.)COPEL	218
	Pyrrosia ?winkleri	226
Schizaeaceae	Lygodium microphyllum (CAV.)R.BR.	127
Thelypteridaceae	8.?Chaistella arida CHING.	132
	Cyclosorus sp.	125
	Cyclosorus sp.	199

Notes

1. *Carex* cf. *dimorpholepis* STEUD.

Flora Malesiana states that the collections of *C. dimorpholepis* in Leiden herbarium probably did not originate in the Malayan archipelago. *C. dimorpholepis* is known from India, Upper Burma, and China to Korea and Japan. Although collection number 144 compares with this taxon its actual identity remains uncertain.

2. *Cyperus* cf. *flavidus* RETZ.

Bogor gave this identification as *C.* cf. *globosus* ALL. Flora Malesiana now gives *C. globosus* ALL as *C. flavidus* RETZ. The identification has therefore been changed to *C.* cf. *flavidus* RETZ.

3. *Urena* *lobata* L.

Bogor gave the full identification of this as *U. lobata* L. ssp. *vimenea* (CAV)BORSS. f. *vimenea*. Borssum Waalkes (*Blumea* 14, 1-213, 1966-67) gives two subspecies for *U. lobata* L. each with two varieties as shown below.

i) *U. lobata* L. ssp. *lobata* var. *lobata*
ii) *U. lobata* L. ssp. *lobata* var. *vimenea* (CAV.)GURKE
iii) *U. lobata* L. ssp. *sinuata* (L.)BORSS. var. *sinuata*
iv) *U. lobata* L. ssp. *sinuata* (L.)BORSS. var. *glauca* (BL.)BORSS.

The subspecies and variety of collection number 176 therefore remains unclear.

4. *Syzygium racemosum* (BL.)DC.

This was formerly *Eugenia jamboloides* K.&V.

5. *Timonius* cf. *sericeus*

No authorities are given by Bogor for this identification. However *T. sericeus* (DES. f.)K.SCH. is now *T. timon* (SPRENG.)MERR.

6. *Symplocos henscheli* (MOR.)BTH. ex CLARKE var. *maingayi*?

Bogor gave this identification as *S. henscheli* (MOR) CLARKE ssp. *henscheli* var. *maingayi* (BTH.)CLARKE, a combination not given in Flora Malesiana. The latter gives only two varieties *henscheli* and *maingayi* and no subspecies. The actual identity of collection number 259 in terms of varieties is not clear but var. *maingayi* is possibly the most likely.

7. *Schizoloma ensifolium* (SW.)J.SM.

In Flora Malesiana series II this is given as

Lindsaea group
Lindsaea subgenus *Lindsaea* section *Schizoloma*
Lindsaea ensifolia SWARTZ.

8. ?*Chaistella arida* CHING.

This identification as given by Bogor could not be traced. Possibly due to a typing error. The collection may actually have been *Cyclosorus aridus* (DON) CHING (not yet confirmed).

APPENDIX 2

Preparation methods for pollen samples

A. Preparation of fossil pollen samples using addition of tablets containing Lycopodium clavatum L. spores.

1. The surface of the core was scraped horizontally to remove possible contaminants. A 1 cm thick slice of material was then removed from the core (either in the field or the laboratory) at the depth to be sampled. 1 cm^3 of this material was then removed for processing using a cork borer of 1 cm^2 cross-sectional area (No. 6) or by cutting a cube of 1 cm dimensions.

2. The sample for preparation was then placed on a weighed watchglass, and weighed, before being dried overnight at 105°C. It was then reweighed to determine the initial dry weight of the sample.

3. The dry sample was then placed in a polypropylene centrifuge tube and a number of tablets containing L. clavatum spores were added. The number of tablets and their batch number was recorded.

4. Approximately 5 ml of 10% potassium hydroxide solution was added to the tube, which was placed in a 'dri-block' tube heater at 100°C for 10 minutes. The KOH solution helps to deflocculate the fossil sample. The sample was stirred well to disperse the contained pollen and spores evenly throughout.

5. Coarse organic fragments were then removed by sieving, and washing the fragments with distilled water to remove as much adherent pollen as possible.

6. The liquid containing the pollen was then centrifuged in large (100 ml) centrifuge tubes for 3 minutes at 2500 r.p.m. The supernatant liquid was then decanted and the sample transferred to a 15 ml centrifuge tube.

7. The sample was washed in distilled water, stirred, centrifuged, and supernatant decanted.

8. The sample was washed in 10% acetic acid, stirred, centrifuged and the supernatant decanted.

9. The sample was washed in glacial acetic acid, stirred, centrifuged and the supernatant decanted.

10. Approximately 2.5 ml of a mixture of 9 parts acetic anhydride to 2 parts of concentrated sulphuric acid was added carefully to the sample. It was then heated in a 'dri-block' heater for approximately 4 minutes at 100°C. An equivalent volume of glacial acetic acid was then added to stop the reaction, stirred, centrifuged and the supernatant decanted.

11. The sample was washed in 10% acetic acid, stirred, centrifuged and the supernatant decanted.

12. The sample was washed in distilled water, stirred, centrifuged and supernatant decanted.

13. If silica was present in the sample, it was then treated with hydrofluoric acid. It was washed with 5% hydrochloric acid, and stirred until all effervescence ceased, centrifuged and the supernatant decanted. The tube was then placed in a fume cupboard and approximately 5 ml of 40% hydrofluoric acid was added. The tube was then sealed with a rubber cap, and left overnight. Then the cap was removed and the contents heated to 100°C for 30 minutes in a 'dri-block' heater. The cap was then replaced, and the tube centrifuged. The supernatant was decanted into the fume cupboard sink into a stream of running water. The sample was washed with hot 5% hydrochloric acid, stirred, centrifuged and supernatant decanted, and then washed in distilled water, stirred, centrifuged and supernatant decanted.

14. The sample was washed in 80% ethyl alcohol, stirred, centrifuged and the supernatant decanted.

15. The sample was washed in 100% ethyl alcohol, stirred, centrifuged and the supernatant decanted.

16. The sample was washed in a 50:50 mixture of ethyl alcohol and tertiary butyl alcohol (TBA). The latter solidifies at cool temperatures and in a cool laboratory may have to be placed, in its container, into warm water to bring it back into a liquid state. The sample was stirred, centrifuged and supernatant decanted.

17. The sample was washed in approximately 1 ml of TBA and

transferred to a small labelled sample tube, stirred, centrifuged and supernatant decanted.

18. A small amount of TBA was added to the sample, plus 1-2 ml of silicone oil (AK 2000), stirred and centrifuged. At this point the organic sediment would be at the base of the tube.

19. The sample tube was placed in a warm oven overnight to allow the TBA to evaporate. The sample was then ready for mounting, or could be capped and stored.

20. Four microscope slides and four square, grade 0, coverslips were placed on a slide warmer, along with a beaker of molten paraffin wax.

21. The pollen sample was stirred thoroughly with a glass rod.

22. A small drop of fresh silicone oil was placed in the centre of each slide, to each a small quantity of the sample was added, and the two were mixed.

23. The coverslip was applied to each sample, which would spread out gradually. Slides were sealed with molten paraffin wax, which was run under the edge of the coverslip and solidified when removed from the heat. Any further leaks of sample could be sealed with clear nail varnish.

24. Each of the slides was labelled and was then ready for counting.

B. Preparation of fossil pollen samples using the weighing technique.

Preparation of the samples proceeded as in Section A except that tablets were not added at stage 3. At stage 17 the sample was transferred to a weighed sample tube before centrifuging. The TBA and silicone oil was added to the residue as in stage 18. The sample tube with the sample was weighed again after stage 19, when the TBA had evaporated, and from this the total weight of the prepared sample could be calculated.

Slide preparation was modified so that the weight of sample on each could be measured, as follows.

1. A glass rod, plus the sample and sample tube were weighed. The sample was then thoroughly mixed using the glass rod.

2. Four slides and four coverslips were placed on a slide warmer.

3. Using the glass rod a quantity of sample was placed on each slide. Coverslips were applied and the slides sealed using molten paraffin wax as described previously.

4. The glass rod, sample and sample tube were reweighed in order to determine the weight of sample transferred to the slides.

For making estimates of absolute pollen frequencies in the sample it was necessary to know also the area of sample on each slide and the proportion of this which had been examined microscopically.

The initial slide preparations proved to be too dense to examine satisfactorily. As the sample tubes were too small to allow dilution of the sample simply by adding additional silicone oil, and transferal of the entire sample to a larger tube would have been difficult to accomplish, the samples were diluted as follows:

1. The prepared sample was stirred thoroughly for at least 10 minutes.
2. A proportion was transferred to a second weighed sample tube and reweighed so that the amount transferred was known.
3. Silicone oil was added to the second sample tube to dilute the sample, and the whole was reweighed. This provided the total weight of the diluted sample which was then used in slide preparation.

C. Preparation of surface sediment pollen samples

Moss polsters and other surface samples collected in the field area were prepared according to the technique outlined in Section A, with the modifications described below.

Where samples comprised moss polsters or other bulky fibrous material they were first broken down by treatment in an Atcomix blending machine. To do this the whole sample was placed in the container, covered with distilled water and run at half speed for 30 seconds. The sample was transferred to large (100 ml) centrifuge tubes and centrifuged for 3 minutes at 2500 r.p.m.

The supernatant was decanted and the residue was treated with 10% potassium hydroxide solution and heated to 100°C for 10 minutes. Subsequent procedure was as outlined in Section A from stage 5 on.

Smaller soil and surface mud samples were prepared as for stage 4 on, with the addition of 10% potassium hydroxide solution to the sample, but omitting the addition of tablets.

For a number of the surface samples it was necessary to include an oxidation treatment in the preparation procedure. This was done after stage 10 as in Section A.

After treatment with the acetolysis mixture (stage 10) the sample was washed with glacial acetic acid, stirred, centrifuged and the supernatant decanted. In a fume cupboard, 1 ml of concentrated hydrochloric acid was added to the sample, and stirred. Then 2 drops of saturated sodium chlorate solution were added carefully, the sample was stirred gently until effervescense stopped. If effervescense was slight, more drops were added, to a maximum of 6. After 45 seconds the sample was centrifuged, and supernatant decanted. The sample was then washed in distilled water and preparation continued as from stage 12.

The Gunung Kerinci samples were prepared by D. Moser at the Australian National University, Canberra, following standard preparation techniques. Saffranin staining was also used in the preparation of these samples.

D. Preparation of reference pollen

A large collection of reference pollen slides was available at Hull, however some plant material collected in the field was also prepared. Anthers were removed from other flower structures and prepared as in Section A, starting with the addition of 10% potassium hydroxide solution at stage 4, omitting the addition of tablets. The anthers were crushed well with the glass stirring rod and sieving (stage 5) was not normally necessary.

APPENDIX 3

Calculation of absolute pollen frequencies and pollen influx

A. By the addition of *Lycopodium clavatum* L. spores in tablet form.

1. Pollen influx

In order to calculate pollen influx it is necessary to know the number of pollen grains in each cm^3 of sediment (a measure of pollen concentration), and the sediment accumulation rate.

Pollen concentration is obtained using the following formula:

$$\text{Pollen concentration (grains cm}^{-3}\text{)} = \frac{\text{No. of grains counted}}{\text{No. 'exotics' counted}} \times \text{Total no. of 'exotics' added.}$$

since the amount of sample processed was $1cm^3$.

In this case the 'exotics' are the added *Lycopodium clavatum* spores.

Pollen influx is then calculated using the formula below :

$$\text{Pollen influx (grains cm}^{-2}\text{ yr}^{-1}\text{)} = \text{Pollen concentration (grains cm}^{-3}\text{)} \times \text{Sediment accumulation rate (cm yr}^{-1}\text{)}$$

2. Absolute pollen frequency as grains g^{-1}

To calculate absolute pollen frequency as grains g^{-1} sediment, a value is first calculated for each sample which represents the dry weight of sediment which was actually examined microscopically. This value is obtained from the following formula:

$$\text{Weight of sample examined microscopically (g)} = \frac{\text{No. of 'exotics' counted}}{\text{Total no. of 'exotics' added}} \times \text{Dry weight of sediment processed (g)}$$

The concentration of naturally occurring grains is then calculated using the formula below:

$$\text{Absolute pollen frequency (grains g}^{-1}\text{)} = \frac{\text{No. of grains counted}}{\text{Weight of sample examined microscopically (g)}}$$

B. Using the weighing technique

1. Pollen Influx

Where the weighing technique is used, and 1cm^3 of sample is processed, pollen concentration as grains cm^{-3} is calculated from:

$$\text{Pollen concentration (grains cm}^{-3}\text{)} = \frac{Pt \times Wt}{Ws} \times \text{Percentage area of slides counted}$$

Where:

Pt = Total pollen counted

Wt = Total weight of sample after preparation (g)

Ws = Total weight of prepared sample on the slides (g)

Since the original sample prepared was too dense for satisfactory microscopic examination, a dilution had to be carried out in order to produce useable slides. The following modified formula was then used to calculate pollen concentration.

$$\text{Pollen concentration (grains cm}^{-3}\text{)} = \frac{A \times Pt \times Wt}{B \times Wsd} \times \text{Percentage area of slides counted}$$

Where:

A = Total weight of diluted sample (g)

B = Weight of the prepared sample transferred prior to dilution (g)

Wsd = Weight of diluted sample A on the slides (g)

Pollen influx can then be calculated as:

$$\underset{(\text{grains cm}^{-2}\ \text{yr}^{-1})}{\text{Pollen influx}} = \underset{(\text{grains cm}^{-3})}{\text{Pollen concentration}} \times \underset{(\text{cm yr}^{-1})}{\text{Sediment accum. rate}}$$

2. Absolute pollen frequency as grains g^{-1}.

To calculate absolute pollen frequencies as grains g^{-1} sediment, the initial dry weight of the sample prepared needs to be included in the formula. This becomes:

$$\underset{\text{freq. (grains g}^{-1})}{\text{Absolute pollen}} = \frac{Pt \times Wt}{Ws \times Sw} \times \text{Percentage area of slides counted}$$

Where:

Sw = Dry weight of initial sample (g)

This formula was modified to allow for the dilution of the final sample, as shown below.

$$\underset{\text{frequency (grains g}^{-1})}{\text{Absolute pollen}} = \frac{A \times Pt \times Wt}{B \times Wsd \times Sw} \times \text{Percentage area of slides counted}$$

C. Number of *Lycopodium clavatum* spores added and counted in fossil pollen samples, and initial dry weight of sample prepared.

1. Danau di Atas

Depth (m)	Number of *L.clavatum* spores added and standard deviation (Ns / $\sqrt{N}$)	Number of *L. clavatum* spores counted	Dry weight of sample processed (g)
0	25000 ± 707	448	0.098
0.55	25000 ± 707	34	0.142
1.10	25000 ± 707	7	0.360
1.60	50000 ± 1000	37	0.237
2.75	25000 ± 707	56	0.126
3.70	25000 ± 707	245	0.099
4.70	25000 ± 707	77	0.125
5.60	21700 ± 283	70	0.136
5.70	25000 ± 707	139	0.300
6.10	25000 ± 707	225	0.154
6.20	25000 ± 707	80	0.261
6.60	21700 ± 283	62	0.358
7.10	25000 ± 707	74	0.171
7.60	21700 ± 283	150	0.123
8.10	25000 ± 707	193	0.139
8.60	21700 ± 283	52	0.259
9.10	25000 ± 707	106	0.185
9.60	21700 ± 283	29	0.255
10.20	25000 ± 707	111	0.144
10.70	21700 ± 283	103	0.175
11.20	25000 ± 707	79	0.219
11.70	21700 ± 283	48	0.328
12.20	25000 ± 707	135	0.167
12.60	21700 ± 283	57	0.220
13.10	25000 ± 707	59	0.323
13.60	21700 ± 283	47	0.123
14.10	25000 ± 707	55	0.719
14.60	21700 ± 283	33	0.293
15.25	25000 ± 707	116	0.238
15.75	21700 ± 283	24	0.653
16.10	21700 ± 283	38	0.337
16.30	25000 ± 707	193	0.117

2. Telago

Depth (m)	Number of *L. clavatum* spores added and standard deviation (Ns/$\sqrt{N}$)	Number of *L. clavatum* spores counted	Dry weight of sample processed (g)
0	25000 ± 707	744	0.828
1.20	25000 ± 707	58	0.267
2.10	25000 ± 707	45	0.209
3.10	25000 ± 707	7	0.396
4.10	25000 ± 707	40	0.208
5.10	25000 ± 707	39	0.492
6.10	25000 ± 707	35	0.546
7.10	25000 ± 707	46	0.644
8.10	25000 ± 707	60	0.635
9.10	25000 ± 707	41	0.543
10.10	25000 ± 707	70	0.709

D. Weight details for samples prepared using the weighing technique.

Danau di Atas

Depth (m)	Dry weight of sample processed (g)	Total sample weight after preparation (g)	Weight of sample transferred prior to dilution (g)
2.20	0.206	3.623	0.364
3.20	0.170	3.389	0.489
4.20	0.195	3.611	0.312
5.20	0.217	3.940	0.314

Depth (m)	Total weight of diluted sample (g)	Weight of diluted sample on 4 slides (g)	Area of slide examined microscopically (%)
2.20	1.926	0.024	54.5
3.20	1.340	0.042	60.0
4.20	1.062	0.030	44.5
5.20	1.271	0.044	50.0

APPENDIX 4

Photographs of selected pollen taxa

Plate I

1-3. Altingia comp. DDA 0.55 m. Diameter 26μm
1 - Medium focus 2 - Intermediate focus 3 - High focus

4. Linociera malabarica. Reference slide. Lt 20μm
Medium focus

5-6. Helicia comp. Telago 1.20 m. Lt 25μm
5 - High focus, oblique polar view 6 - Medium focus, oblique polar view

7-8. Helicia javanica sim. Telago 9.10 m. Lt 21μm
7 - High focus, polar view 8 - Medium focus, polar view

9-11 Randia comp. Telago 2.10 m. Lt 15μm
9 - Intermediate focus, equatorial view 10 - Medium focus, equatorial view 11 - High focus, equatorial view

12-15. Dodonaea Plot 20. Lt 24μm
12 - High focus, equatorial view 13 - High focus, equatorial view 14 - Medium focus, equatorial view
15 - Low focus, equatorial view

16-19. Araliaceae comp. DDA 3.70 m. Lt 22μm
16 - High focus, polar view 17 - Medium focus, polar view
18 - Medium focus, equatorial view 19 - High focus, equatorial view

20-22. Alangium sim. Plot 24. Lt 50μm
20 - Intermediate focus, polar view 21 - High focus, polar view 22 - Medium focus, polar view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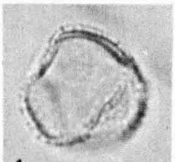
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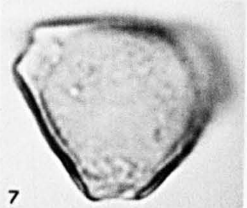
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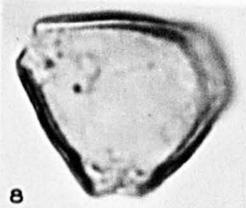
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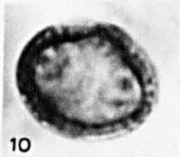
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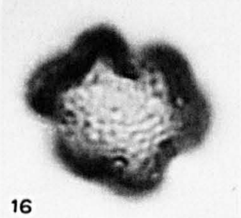
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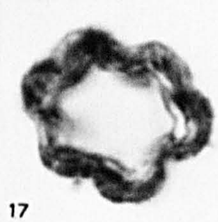
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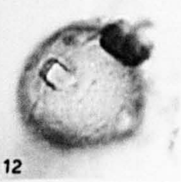
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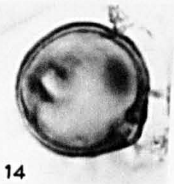
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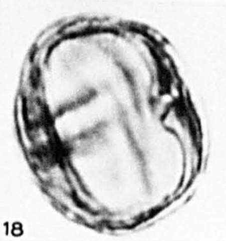
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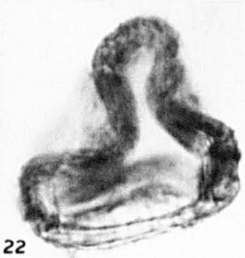
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Plate II

1-2. Compositae type 3 (Tubuliflorae). G. Kerinci 2085 m. Lt 30µm
1 - Medium focus, equatorial view 2 - High focus, equatorial view

3. Compositae type 2 (Tubuliflorae). Plot 6. Lt 16µm
Medium focus, polar view

4-6. Compositae type 5 (Tubuliflorae). G. Kerinci 3010 m. Lt 25µm
4 - Medium focus, equatorial view 5 - Intermediate focus, equatorial view 6 - High focus, equatorial view

7-10. Compositae type 4 (Tubuliflorae). G. Kerinci 2395 m. Lt 30µm
7 - Medium focus, equatorial view 8 - Low focus, equatorial view 9 - High focus, equatorial view
10 - Medium focus, oblique

11-13. Compositae type 6 (Tubuliflorae). Plot 5. Lt 26µm
11 - Medium focus, polar view 12 - Intermediate focus, polar view 13 - High focus, polar view

14-15. Compositae type 7 (Tubuliflorae). Plot 13. Lt 26µm
14 - Medium focus, equatorial view 15 - High focus, equatorial view

16-18. *Hedyotis vestita*. Reference slide. Lt 25µm
16 - High focus, equatorial view 17 - Medium focus, equatorial view 18 - Low focus, equatorial view

19-20. *Oldenlandia uncinella*. Reference slide. Lt 38µm
19 - High focus, equatorial view 20 - Medium focus, equatorial view

21-22. *Lonicera*. DDA 9.60 m. Lg 52µm
21 - High focus, polar view 22 - Medium focus, polar view

23-24. *Gentiana*. G. Kerinci 3175 m. Lt 40µm
23 - High focus, equatorial view 24 - Medium focus, equatorial view

25-27. *Gentiana*. G. Kerinci 3315 m. Lt 32µm
25 - High focus, equatorial view 26 - Medium focus, equatorial view 27 - High focus, equatorial view

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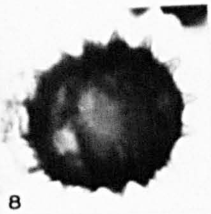

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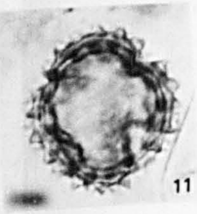

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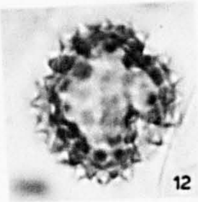

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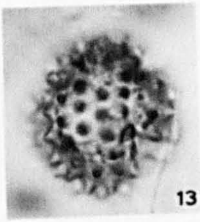

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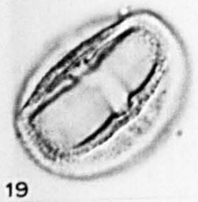

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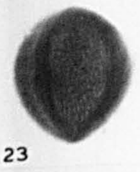

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Plate III

1-2. *Schefflera* comp. 1. Telago 9.10 m. Lt 26µm
1 - Medium focus, equatorial view 2 - Low focus, equatorial view

3-4. *Schefflera* comp. 2. G. Kerinci 2700 m. Lt 24µm
3 - Medium focus, equatorial view 4 - High focus, equatorial view

5-6. *Schefflera* comp. 3. G. Kerinci 2085 m. Lt 20µm
5 - High focus, equatorial view 6 - Medium focus, equatorial view

7. *Gouania javanica*. Reference slide. Lt 19µm
Medium focus, polar view

8-10. Indeterminate 18. DDA 4.70 m. Lt 27µm
8 - High focus, equatorial view 9 - Medium focus, equatorial view 10 - Intermediate focus, equatorial view

11-13. Indeterminate 79. Telago 9.10 m. Lg 23µm
11 - High focus, polar view 12 - Medium focus, polar view
13 - Intermediate focus, polar view

14-15. Compositae type 1 (Tubuliflorae). DDA 0m. Lg 18µm
14 - Medium focus, polar view 15 - High focus, polar view

16-17. *Elaeagnus* comp. DDA 5.60 m. Lg 26µm
16 - Medium focus, oblique polar view 17 - High focus, oblique polar view

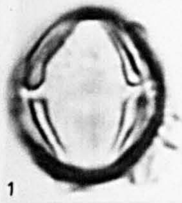
18-19. *Viburnum* comp. 1. DDA 1.10m. Lg 25µm
18 - High focus, polar view 19 - Medium focus, polar view

20-22. *Utricularia*. Plot 6. Lg 28µm
20 - High focus, polar view 21 - Medium focus, polar view
22 - Low focus, polar view

23-25. *Lycopodium* comp. DDA 8.10 m. 30µm
23 - High focus 24 - Medium focus 25 - Low focus

26-27. *Humata pulchia*. Reference slide. 50µm
26 - Low focus 27 - High focus

28. *Microsorium nigrescens*. Reference slide 60µm
Medium focus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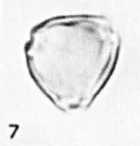
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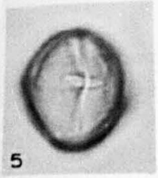
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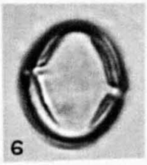
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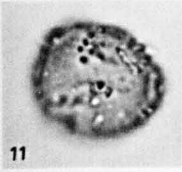
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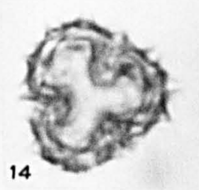
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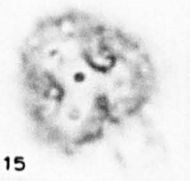
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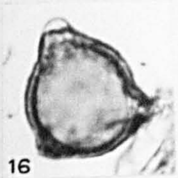
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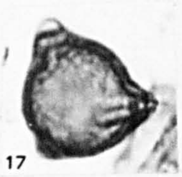
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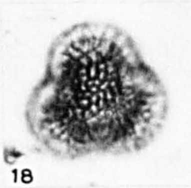
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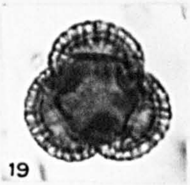
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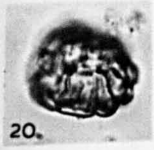
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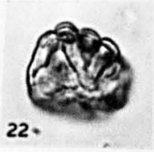
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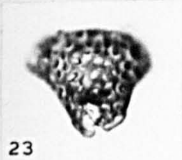
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APPENDIX 5

Palynomorph types encountered, their level of identification, and possible source taxa

The most likely sources are given for the palynomorph types. Where no sources are listed then the most probable source is considered to be the species, genus or family named in the determination. However possible sources are not suggested for the pteridophyte taxa. This is because the reference collection for this group lacked examples of many genera which can occur in Sumatra.

Palynomorph type	Possible sources
Dacrycarpus	This is referred to in some accounts as *Podocarpus imbricatus* and has *D. imbricatus* as its source
Dacrydium	
Pinus	Probably *P. merkusii*
Podocarpus	*P. neriifolius*, *P. amarus*
Adinandra comp.	*Adinandra*, *Ternstroemia*, possibly other Theaceae
Alangium rotundifolium	
Altingia comp.	*Altingia excelsa* is the most probable source of this, although some other taxa eg. some Caryophyllaceae may possess similar pollen
Arenga	
Engelhardtia comp.	eg. *E. serrata*, *E. spicata*
Helicia comp.	Some other Proteaceae may also have pollen of this type
Helicia javanica sim.	Other *Helicia* and Proteaceae may have similar pollen
Ilex cymosa	
Lithocarpus/ *Castanopsis* comp.	Many species of *Lithocarpus* and *Castanopsis* have pollen of this type
Longetia	eg. *L. nitida*, *L. malayana*
Macropanax comp.	Other Araliaceae
Mastixia comp.	Other Cornaceae and Bignoniaceae
Oroxylon sim.	Other Bignoniaceae
PALMAE comp.	
Polyosma comp.	
Pometia	
Quercus comp.	Many species of *Quercus* have pollen of this type
Randia comp.	Comparable with *R. cochinchinensis*
Schima	
Shorea comp.	Other Dipterocarpaceae
Styrax	eg. *Styrax paralleloneurum*
Symingtonia	Probably *Symingtonia populnea*
Symplocos comp.	Matches many species of *Symplocos*
Vernonia arborea sim.	Compositae, Tubuliflorae, comparable with *V. arborea*
Wendlandia comp.	*Wendlandia* and possibly other Rubiaceae

Alangium sim.	Unlike *A. rotundifolium*
Antidesma comp.	*Antidesma* and probably some other genera
Ardisia comp.	*Ardisia* and other genera. Some *Ardisia* grains may be classed under 'tricolporate, psilate 10-12μm' and '12-15μm'
Celtis comp.	
Claoxylon comp.	Probably *Claoxylon* but other Euphorbiaceae may also have pollen of this type
Claoxylon longifolium	
Daphniphyllum comp.	As *D. gracile*. Other genera may have pollen of this type
Dillenia comp.	eg. *Dillenia excelsa*, (*D. exima*)
Dodonaea	
Elaeocarpus comp.	*Elaeocarpus angustifolius*, *E. paniculatus* have grains of this type as do some *Saurauia* spp. and other genera
Evodia comp.	*E. latifolia*, other *Evodia* spp., other Rutaceae
Fagraea comp.	
Garcinia	
Ilex comp.	Prolate grains of *Ilex*
Lasianthus comp.	
LAURACEAE	
Linociera comp.	Resembles *L. microphylla*, *L. axillaris*, other pollen types such as *Nauclea*, *Uncaria* are not dissimilar
Linociera malabrica sim.	
Macaranga comp. small.	Small more or less psilate grains as found in eg. *M. tanarius*, *M. triloba*
Macaranga comp. large.	Larger (16μm) scabrate grains as found in eg. *M. javanica*, *M. denticulata*
Mallotus comp.	eg. *M. paniculatus*. Similar pollen is found in some *Macaranga* spp.
Medinilla comp.	Matches well with *Medinilla* but may include other Melastomataceae
MELIACEAE/SAPOTACEAE comp.	Pollen type with characteristics of these families
Memecylon comp.	*Memecylon*, *edinilla*, possibly other Melastomataceae
Myrsine comp.	*M. affinis* is identical
MYRTACEAE type 1	Less than 14μm, apocolpium present. Most like *Eugenia*, *Syzygium*. *Tristania*, *Callistemon* and *Melaleuca* also have comparable pollen
MYRTACEAE type 2	Less than 14μm, apocolpium slitlike. As in *Syzygium*, but type found also in *Melaleuca* and *Leptospermum*
MYRTACEAE type 3	Less than 14μm, no apocolpium. Occasionally grains of Myrtaceae occur in this form
MYRTACEAE type 4	14-20μm, apocolpium present. As in *Eugenia*, *Syzygium*, *Decaspermum*. Also found in *Melaleuca* and *Rhodamnia*
MYRTACEAE type 5	14-20μm, apocolpium slitlike. As in *Melaleuca*

MYRTACEAE type 6	Larger than 20μm, distinct apocolpium. As in *Eugenia* and *Melaleuca*
Neonauclea comp.	*Neonauclea* and others eg *Uncaria*, *Nauclea*
Picrasma javanica sim.	
Polyalthia sim.	
SANTALACEAE comp.	Like *Santalum*
Symplocos sessilifolia sim.	
Tarenna fragrans	
Trema comp.	
Weinmannia comp.	Like *W. blumei*
ARALIACEAE comp.	No definite match was found for this pollen type, but its characteristics suggest Araliaceae
Psychotria comp.	Possibly also other Rubiaceae
Zanthoxylum comp.	Possibly *Z. myriacanthum*, but other Rutaceae possible
Daphne comp.	Compares well with *Daphne* and *Drapetes*
Elaeagnus comp.	Comparable with *E. latifolia*
LORANTHACEAE	
Schefflera aromatica sim.	
Schefflera comp. 1)	Resemble various *Schefflera* sp. in the reference collection for which no specific name is available
Schefflera comp. 2)	
Schefflera comp. 3)	
Strobilanthes	
Croton comp.	*Croton*, and possibly other Euphorbiaceae
ACANTHACEAE comp.	
Begonia comp.	*Begonia* but possibly other taxa have pollen of this type
GESNERIACEAE comp.	
Eurya comp.	*Eurya* and possibly other Theaceae. Some grains of this type may be included in 'tricolporate psilate 10-12μm' & '12-15μm'
Glochidion comp.	Most likely *Glochidion* sp.
Melastoma comp.	*Melastoma*, other Melastomataceae eg. *Astromia*, *Pternandra*, Combretaceae eg. *Terminalia*
Myrica comp.	Might possibly include some grains of *Casuarina*
Rhododendron comp.	Includes *Rhododendron*, *Gaultheria* and some *Vaccinium*
Vaccinium comp.	Principally *Vaccinium*
Viburnum comp. 1	Similar to some *Viburnum* pollen although no definite match was found.
Viburnum comp. 2	*Viburnum* and *Ligustrum* (Oleaceae) have pollen of this type
RHAMNACEAE comp.	Also some Sapindaceae
Gouania comp.	Possibly other Rhamnaceae
Gendarussa comp.	Also referred to as *Justicia* comp. in some accounts. May include other Acanthaceae
Lonicera	
Rubus comp.	
Acalypha comp.	

MELASTOMATACEAE comp.	eg. *Melastoma*, *Osbeckia*, *Sarcopyramis*, other Melastomataceae and possibly Combretaceae
Polygala comp.	Other Polygalaceae
AMARANTHACEAE comp.	
Boea sim.	*Boea* and other Gesneriaceae
COMPOSITAE type 1 (TUBULIFLORAE)	All Compositae have similarities with a number of reference pollens. This is similar to *Erigeron*
COMPOSITAE type 2 (TUBULIFLORAE)	Not unlike *Ageratum conyzoides*, *Eupatorium inulifolium*, *Senecio sonchifolius*, *Anaphalis longifolia*
COMPOSITAE type 3 (TUBULIFLORAE)	Like some spp. of *Blumea*, but other Compositae also possible
COMPOSITAE type 4 (TUBULIFLORAE)	Not unlike some *Blumea*, but other Compositae also possible
COMPOSITAE type 5 (TUBULIFLORAE)	Similar to *Spilanthes acmella* but other Compositae also possible
COMPOSITAE type 6 (TUBULIFLORAE)	Like *Crassocephalum* but other Compositae also possible
COMPOSITAE type 7 (TUBULIFLORAE)	Like *Bidens* but other Compositae also possible
COMPOSITAE (LIGULIFLORAE)	
Crotalaria comp.	
Hedyotis comp.	As *Hedyotis macrostegia*
Hedyotis vestita sim.	
Impatiens	
Oldenlandia uncinella sim.	
Drymaria comp.	Other Caryophyllaceae may have similar pollen
Galium comp.	Other Rubiaceae may possess pollen of this type
Gentiana	
LILIACEAE comp.	
LILIACEAE/PALMAE comp.	
Plantago major	
UMBELLIFERAE comp. 1	A small pollen grain (19 x 11μm) of umbell type
UMBELLIFERAE comp. 2	Larger grain not unlike *Trachymene*
CYPERACEAE	
GRAMINEAE	
Hydrocotyle comp.	Like *Hydrocotyle*, but other Umbelliferae may be similar
Laurembergia comp.	*Laurembergia* and other Haloragidaceae
Nepenthes comp.	
MONOCOTYLEDON undifferentiated	
Burmannia	
Eriocaulon	
Utricularia	As in *U. vulgaris*, *U. exoleta*
Xyris	
Pandanus	
Tricolporate, psilate 10-12μm	Some possibilities are *Elaeocarpus grandis*, *Ardisia*, *Saurauia*, *Eurya* and others

Tricolporate, psilate 12-15μm	Some possibilities are *Elaeocarpus spaerocarpus*, *Saurauia*, *Maesa*, *Aglaia*, Flacourtiaceae and *Eurya*
Alnus	
MENISPERMACEAE comp.	
URTICACEAE/MORACEAE 2-porate	
URTICACEAE/MORACEAE 3-porate	
URTICACEAE/MORACEAE 4-porate	
Indeterminate 18	
Indeterminate 79	
Potamogeton	
Typha comp.	*Typha*, *Sparganium*
Athyrium comp.	
Lindsaya sim.	
Microlepia sim.	
Microsorium comp.	
Selaginella caulescens sim.	
Selaginella planata comp.	
Selaginella semicaudata sim.	
Selaginella comp.	
Asplenium comp. small	
Asplenium comp. large	
Blechnum comp.	
Crypsinus comp.	
Cyathea comp. psilate	
Cyathea comp. verrucate	
Cyathea comp. striate	
Cyathea comp. irregular striate	
Davallia sim.	
Humata sim.	
Hymenophyllum comp.	
DENNSTAEDTIACEAE comp.	
Filices undifferentiated	Includes many monolete spores in which the exosporium is missing
Filices undifferentiated areolate	Various sources
Lycopodium cernuum	
Lycopodium clavatum comp.	
Lycopodium phlegmaria comp.	
Lycopodium comp.	
Unclassified spores	Various sources
Dicranopteris comp.	
Gleichenia comp.	
Lygodium	
Nephrolepis comp.	
Ophioglossum comp.	
Pteridium	
Pteris comp. psilate	
Pteris comp. verrucate	
Pyrrosia sim.	
Sphenomeris comp.	
Cyclosorus comp. 1	
Cyclosorus comp. 2	

APPENDIX 6

Details of pollen counts and allocation of taxa to categories for summary diagrams

Actual pollen counts for all samples studied are listed in the following tables. For convenience each pollen or spore type has been given a code number, as listed below.

1	Dacrycarpus
2	Dacrydium
3	Pinus
4	Podocarpus
5	Adinandra comp.
6	Alangium rotundifolium
7	Altingia comp.
8	Arenga
9	Engelhardtia comp.
10	Helicia comp.
11	Helicia javanica sim.
12	Ilex cymosa
13	Lithocarpus/Castanopsis comp.
14	Longetia
15	Macropanax comp.
16	Mastixia comp.
17	Oroxylon sim.
18	Palmae comp.
19	Polyosma comp.
20	Pometia
21	Quercus comp.
22	Randia comp.
23	Schima
24	Shorea comp.
25	Styrax
26	Symingtonia
27	Symplocos comp.
28	Vernonia arborea sim.
29	Wendlandia comp.
30	Alangium sim.
31	Antidesma comp.
32	Ardisia comp.
33	Celtis comp.
34	Claoxylon comp.
35	Claoxylon longifolium
36	Daphniphyllum comp.
37	Dillenia comp.
38	Dodonaea
39	Elaeocarpus comp.
40	Evodia comp.
41	Fagraea comp.
42	Garcinia
43	Ilex comp.
44	Lasianthus comp.
45	Lauraceae
46	Linociera comp.
47	Linociera malabarica sim.
48	Macaranga comp. small
49	Macaranga comp. large
50	Mallotus comp.
51	Medinilla comp.
52	Meliaceae/Sapotaceae comp.
53	Memecylon comp.
54	Myrsine comp.
55	Myrtaceae type 1
56	Myrtaceae type 2
57	Myrtaceae type 3
58	Myrtaceae type 4
59	Myrtaceae type 5
60	Myrtaceae type 6
61	Neonauclea comp.
62	Picrasma javanica sim.
63	Polyalthia sim.
64	Santalaceae comp.
65	Symplocos sessilifolia sim.
66	Tarenna fragrans
67	Trema comp.
68	Weinmannia comp.
69	Araliaceae comp.
70	Psychotria comp.
71	Zanthoxylum comp.
72	Daphne comp.
73	Elaeagnus comp.
74	Loranthaceae
75	Schefflera aromatica sim.
76	Schefflera comp. 1
77	Schefflera comp. 2
78	Schefflera comp. 3
79	Strobilanthes
80	Croton comp.
81	Acanthaceae comp.
82	Begonia comp.
83	Gesneriaceae comp.
84	Eurya comp.
85	Glochidion comp.
86	Melastoma comp.
87	Myrica comp.
88	Rhododendron comp.
89	Vaccinium comp.
90	Viburnum comp. 1
91	Viburnum comp. 2
92	Rhamnaceae comp.

93 Gouania comp.
94 Gendarussa comp.
95 Lonicera
96 Rubus comp.
97 Acalypha comp.
98 Melastomataceae comp.
99 Polygala comp.
100 Amaranthaceae comp.
101 Boea sim.
102 Compositae type 1 (Tubuliflorae)
103 Compositae type 2 (Tubuliflorae)
104 Compositae type 3 (Tubuliflorae)
105 Compositae type 4 (Tubuliflorae)
106 Compositae type 5 (Tubuliflorae)
107 Compositae type 6 (Tubuliflorae)
108 Compositae type 7 (Tubuliflorae)
109 Compositae (Liguliflorae)
110 Crotalaria comp.
111 Hedyotis comp.
112 Hedyotis vestita sim.
113 Impatiens
114 Oldenlandia uncinella sim.
115 Drymaria comp.
116 Galium comp.
117 Gentiana
118 Liliaceae comp.
119 Liliaceae/Palmae comp.
120 Plantago major
121 Umbelliferae comp. 1
122 Umbelliferae comp. 2
123 Cyperaceae
124 Gramineae
125 Hydrocotyle comp.
126 Laurembergia comp.
127 Nepenthes comp.
128 Monocotyledon undifferentiated
129 Burmannia
130 Eriocaulon
131 Utricularia
132 Xyris
133 Pandanus
134 Tricolporate, psilate 10-12 m
135 Tricolporate, psilate 12-15 m
136 Alnus
137 Menispermaceae comp.
138 Urticaceae/Moraceae 2-porate
139 Urticaceae/Moraceae 3-porate
140 Urticaceae/Moraceae 4-porate
141 Indeterminate 18
142 Indeterminate 79
143 Potamogeton
144 Typha comp.
145 Unidentified pollen
146 Athyrium comp.
147 Lindsaya sim.
148 Microlepia sim.
149 Microsorium comp.
150 Selaginella caulescens sim.
151 Selaginella planata comp.
152 Selaginella semicaudata sim.
153 Selaginella comp.
154 Asplenium comp. small
155 Asplenium comp. large
156 Blechnum comp.
157 Crypsinus comp.
158 Cyathea comp. psilate
159 Cyathea comp. verrucate
160 Cyathea comp. striate
161 Cyathea comp. irregular striate
162 Davallia sim.
163 Humata sim.
164 Hymenophyllum comp.
165 Dennstaedtiaceae comp.
166 Filices undifferentiated
167 Filices undifferentiated areolate
168 Lycopodium cernuum
169 L. clavatum comp.
170 L. phlegmaria comp.
171 L. comp.
172 Unclassified spores
173 Dicranopteris comp.
174 Gleichenia comp.
175 Lygodium
176 Nephrolepis comp.
177 Ophioglossum comp.
178 Pteridium
179 Pteris comp. psilate
180 Pteris comp. verrucate
181 Pyrrosia sim.
182 Sphenomeris comp.
183 Cyclosorus comp. 1
184 Cyclosorus comp. 2
185 Corroded/degraded/crumpled /obscurred grains

APPENDIX 6A

Modern pollen rain, Danau di Atas area : actual pollen counts

Plot	1	2	3	4	5	6	7	8	9	12	13	14	18	19	21
1							8			1	33				39
2		1			6		3			1	88	17			68
3	1				4		1			1	70				8
4	2			1	8		2		3	1	65				67
5							1		3		8				9
6		1	1				1		3		8				10
7	1	1	3	1			5		5		12			1	18
8	1				2		1		2		9				9
9	1	1		1			2		5		7				20
10							5		1		5				16
11	1	1	1				4		3		15				23
12	1	1		2	1						9				6
13	2						6		4		8				16
16		3					3		1		11			1	18
17			1								2				2
18							3	1	1		9		1		12
19		1	1	1			18	3	3		12			1	27
20	1		1		1	1	1		37	3	39				13
24	3						1	1	3	5	24				96

Plot	22	23	25	26	27	28	29	30	31	32	33	34	38	39	40
1		1			3				1			1		2	
2					1				4					5	
3		14		1	1				7					5	
4		1	1	3	1				2					15	
5											1			2	
6											2			4	1
7				1		1			2						
8							1		1		1			1	1
9														4	
10		1			1		2								
11									2	1	2			1	
12		2					2		1					2	
13					1						1	1		6	2
16				1			3					1			
17														3	
18					1									3	
19		4					4				4			2	
20		1			2		38						53	9	
24	2	1	2		2		3	1	1	2				82	

Plot	42	43	45	46	48	49	50	51	52	53	54	55	56	57
1			2		134	4		1			4	13	2	
2		1	11	1	4	1	1	1			5	5	2	
3		2			18	1		6	2	34	3	34		2
4		2	1		8	4	1	3			1	12	1	
5					3							2		
6					2	1	1	1			1			
7		1			2			2			4	17		
8					8	3					3	6		
9					7	3		2			1	5		1
10					1	1				1	1			
11					5	3		1			1	5		
12					3	3		1				2		
13				1	14	1	1			2	4	1		
16		2			2						1	4		
17	1				1									
18	5				2							2		
19				2	1	1				2	1	3		
20				8	1						1	12		
24				2	4			13			4	6		

Plot	58	59	63	66	67	69	70	71	73	74	75	77	79	83
1	7	24			1					2				
2	2						1			1				
3	8	2								2				
4	4						1	1						
5					2									
6			1		2									
7	3				1						1			
8					1									
9					2							5		
10	1													
11					6									3
12														
13					7									
16														
17														
18	3				1				1					
19					1									
20	10			2	1	1		2						
24	1			1	3								1	

Plot	85	86	87	88	89	91	92	93	94	96	97	98	99	100	101
1								1							
2		1	1		2										2
3		1			17						2	1			
4		2		2	3			1				1			
5			1											2	
6										1					
7	1	2	4	1	2		1								
8	1		2										1		
9			1									2			
10	1		1								1		1		
11		1	2	1	1										
12		1			1										
13			4												
16			1		3				1				4		
17													3		
18			1		1								6		1
19		7	2	2		1						2			
20		1			1		8				4				3
24		1			1										

Plot	102	103	107	108	109	113	115	118	120	123	124	125	126	128	129
1	2	3								1					
2	2	5	1					1		1					
3		7			1										
4	6	14								1					
5		4	1							85	158			1	
6		3								80	130	3			1
7		1				1				42	143				1
8		5	1							71	81		2		
9		6								95	101	1	15	2	
10		7								71	156	4			
11		6								94	70	1	1		
12		9	1							121	114	2	3		
13	3	5		2						69	69				
16	21	25		13		1			1	31	12	1			
17	85	68		2						9	5				
18	22	6					2			43	65				
19		5								9	16				
20		3								2	2				
24	6		1							3	2				

Plot	130	131	132	133	134	135	137	138	139	140	141	145	147	148
1					1	7				1		4		
2					8	11	4	1	2		18	13		3
3					9	12		5	1		1	14		
4					1	15	2	1		1	7	33		
5	2		1	1	2			3	3	4		5		
6	3	3	9		2	1			12	6	1	5		2
7			2	1	3	3			3	3	1	8		
8	4	2	2			1		2	6	7		8		5
9	1		6					3	3	1		6		
10	1		13		1			3	5	2		3		7
11	2		6			5		4	6	3		18		
12	1		4		2	5			1	3		5		5
13			13	1	3	4		7	24	11		9		
16					1	4		1	7			5		
17					4			3		1		10		
18						2		2	13	2		21	7	
19						6	1	1	4	1		22		
20					11	8		10	16	8		9	5	
24					17	4		1	4			9		

Plot	149	151	154	155	157	158	159	160	161	162	163	164	165	166
1			1			1		2		10	3			11
2					3	5		9		21	1			13
3	2		13	7			1	6		1	8		1	19
4				4	1	7		23		4	4			7
5			2							1	1			15
6								1		2				25
7			1					1			3		1	36
8	1		2							3	2		1	75
9						9		1		1	2		2	43
10								1						71
11	5		6							2	4		1	82
12	1		3							2	1		2	67
13			3							1				135
16								1		6			3	99
17		1			1							1		82
18							1	2		3				238
19	35			1		6		1		11	1			210
20			2			10		9	3	2	18			33
24			4			8		3		4				51

Plot	167	168	169	170	172	173	174	175	176	178	180	182	183	185	Total Pollen & Spores
1		1	1		2					4		3	4	3	349
2				2			2			4		2	4	5	377
3	1		2	1			7			3		4	2	3	380
4		1	4		2		2			1		3	1	6	372
5		85	13		3		4			1		1	1		431
6		18	7				4			11			3		373
7		17	2	2	7		1		4	3			1		384
8		171	4		17	1				1			2		531
9		323	9	1	12		1		6	4		2	1		726
10		127	11		25		1		4	3			4		560
11		69	7		24		23	1		4		4	1	2	535
12		137	19		32		3		1	7	1	1	10		601
13		11	12				76				4			9	553
16		2	2				26			15			160	5	502
17		5	15				69						8	3	385
18			5	1		2	125						8	11	634
19		4	27	1		82	270			199	1	17		34	1071
20			3		11		25						8	13	466
24			2		2		5						1	16	409

APPENDIX 6B

Modern pollen rain, Kerinci: actual pollen counts

Sample	1	2	3	5	7	9	12	13	15	16	20	21	22	23	26
3315	5		1		9	17		4				21			2
3175	1	1			3	1		3				9			
3070					1			1		1		6	2		
3010					1			3		1	1	7			
2855								2				1		3	
2700	1					1		6				5		7	
2545						1		215				5		2	1
2395						127		15				15		1	15
2240					1	14	28	14				17		5	63
2085				6	5	13	1	27	2			25		26	34
1935				12		12		28				25		1	94

	27	32	33	34	36	39	40	41	43	46	48	49	52	53	54
3315											25	3			62
3175		43									19				38
3070		2									1				31
3010		20									12		1		76
2855		119		1							4				196
2700		34			2						12	1			120
2545						1	1		1		7	2			2
2395		2							3		4				3
2240	1							1	125		11			1	3
2085	20	1							3		10	1			3
1935		3	1			4			9	6	15	2			

	55	57	58	59	62	65	66	67	69	70	73	74	77	78	79
3315	1							18	1				1		
3175								8					1		
3070								2							
3010						1		7							
2855	1				3	14							4		
2700	3		1			35		7				3	9		
2545	1					1		2							
2395	18		2					3			1		27		
2240	13							10							1
2085	42			1	6	1		8		13	1		4	1	
1935	10	1				4	1	8		7			2		1

	85	86	87	88	89	94	97	102	103	104	105	106	112	113	117
3315			45	33	14			1				5	1		1
3175			111	35	1					2		1			2
3070			414	5											
3010			183	15	3							5			
2855			19	1					1			1			
2700	1		9		1		1							4	
2545			1	2	10										
2395			1		15	1	1				1	5			
2240												3			
2085	3		2	1	1			4	1	3					
1935		1				1			3						

	123	124	134	135	138	139	145	147	149	151	152	153	154	155	157
3315	25	1		7		4	14					1		3	
3175	6			51			12	2							
3070	2						2								
3010	7	1					11								
2855	2					1	1	1			7				
2700	1	1		26	1	2	22			1				1	2
2545			6	77		3	14		1						
2395	3	1		10		1	33		1				1		
2240		1	10	19			9						22		
2085	1	1	5	12		4	17						35		1
1935	2	1	11	19	1	1	34		1				10		

	158	159	160	162	163	165	166	167	168	169	170	172	173	174	176
3315			7		2		15		1	1		1		25	6
3175				4		1	3		10			3			
3070						2	2								
3010	2			3			3		26					2	
2855	1			2			3					1	1	11	
2700	8		32	3		3	25							120	
2545	2		1	3			2							39	
2395		3	27	5	11		42							48	
2240	3		28			1	40	39			2			25	
2085	6		2			49	159							6	
1935	1			2		9	17								

	178	180	182	183	185	Total Pollen and Spores
3315			4	2	11	400
3175					4	375
3070			2		1	477
3010					7	398
2855						401
2700					4	515
2545		1			2	406
2395		1		4	7	457
2240		1		1	3	515
2085	1			3	8	579
1935				1	9	370

APPENDIX 6C Danau di Atas: actual pollen counts

Depth (m)	1	2	3	4	5	7	8	9	12	13	14	16	17	18
0	1			1		2		2		4				1
0.55						12	3	5	1	48				
1.10				2	6	16		7	9	31				
1.60		1				15			43	61				
2.20						13		3	11	19	1			
2.75					2	17		2	3	28				
3.20						1		1	1	26				
3.70		1			1	5		1	1	19				1
4.20		1			1	1				8				
4.70		5		1	3	7		4	4	54				
5.20		1				1				4				
5.60	9	3			3	3				29				
5.70	2	9			2	8		5	1	32				
6.10	6	2				13		2	1	34				
6.20	22	17		2	2	4			3	32				
6.60	68	53		3		4			2	21				
7.10	33	15				6	1	3	1	27				
7.60	41	24	1	7	1	5		2	3	28				
8.10	36	15	1	1		1		1	3	19				4
8.60	37	38	1	3	2	3			6	18				
9.10	57	31	4	2	2	2			5	17				
9.60	35	37	2	3	1	2			3	18				
10.20	14	43			6	2			2	16				
10.70	40	25		8	2	1			4	22				
11.20	35	16		2	1	2		2	3	23				
11.70	27	31		6	4	4		1		13				
12.20	15	5			3			1	3	31				
12.60	41	30		4	3				2	27		1		
13.10	25	33		4				1	4	29				
13.60	7	20			1			4	1	44				
14.10	12	25		2					3	35				
14.60	8	32	2			2			2	39	1			
15.25	2	10			2	4			4	37			3	
15.75	5	31	4	1	4	1				34				
16.10	12	36	8		1	4		1		24				
16.30	21	15			2	1		3	6	28				

	19	21	22	23	24	26	27	28	29	31	32	33	34	36
0		6				1	1							
0.55		16				2	2	1		1		1		
1.10		27				1	1	1		5				
1.60		24				5	1		2	4				
2.20		34				5					1			
2.75		17			1	9	4	1	3		1	1	1	
3.20		12				5								
3.70		21			1		1							
4.20		2												
4.70		27				2								
5.20		3				1								
5.60		28				5	1			2	4			
5.70		33		6	2	2					5	1		
6.10		22				4	1		1					
6.20		19				14	4		1		3			
6.60		21				6				1	3			
7.10		23				3	1	2				1		
7.60		22				2	1		1					
8.10		11				6								
8.60		20				2	1							
9.10		12				3								
9.60		18				5	2		2		1	1		
10.20	1	11				4	1					2		
10.70		17				6		1						
11.20	1	11				4	3							
11.70		17				3			1					
12.20		9	1	1		4	2			1				
12.60		19				3						1		
13.10		16				6	1			1				
13.60		27			1	7								
14.10		24		1		6		1						1
14.60	1	34				7	1							
15.25		30				3	3							
15.75		38	1		3									
16.10		25				1	3				1	1		
16.30		15	1			2	2							

	37	39	40	41	43	44	46	48	49	50	51	52	53	54
0								2						
0.55		3		1			4	3			14			4
1.10		6			2		18	6			24		1	3
1.60		4	4	5			1		11		15			1
2.20		13	1				2	2	1		2			1
2.75		12			5		3	6	1		13			5
3.20		3					1	8						
3.70		2			17						3			4
4.20					1						2			
4.70		11			6			2	1		7		1	31
5.20		2												
5.60		1			5			4		1	4	1		6
5.70		10			3			1	1		7	1		19
6.10		5			15			1			17			10
6.20		14	1		6		2	2			7			5
6.60		1			2	1		2			3			13
7.10		6			8			2	2	2	12			7
7.60		2			9		1	1		1	3	1	4	10
8.10		12			6						5			10
8.60		2	1		5			5			6	2		
9.10		11			5			1		1	6			12
9.60		7			6	1	1				7			14
10.20		7			10				1		14			33
10.70		4			11		1		1		20			30
11.20		7		2	6			1		1	11		3	17
11.70		10			5		1				15			7
12.20		15			11				1		10			21
12.60		3		1	2						5			16
13.10		8			5			2		1	5			20
13.60					6						3			6
14.10		9			4		1				3		2	19
14.60					7				2		5			3
15.25		12		1	3		1				5			5
15.75		3			4						1	1		6
16.10		2			7				1		4			5
16.30	1	6	4		6		1		2		5			10

	55	56	57	58	60	62	63	64	65	66	67	69	70	71
0	3													
0.55	61	2		29		2					1		4	
1.10	49		1	19				1					2	
1.60	21			4				1				5	6	
2.20	6										1			
2.75	111			8									2	
3.20	151										1			
3.70	2	4		4							4	12		
4.20	6	1			1									
4.70	44	6		6							1			
5.20					1									
5.60	39	7		16	12							2		
5.70	7			6	3							24	2	1
6.10	51	23		10		1					2	9		
6.20	10	43		19								2	2	
6.60	4	21		2	1							3		
7.10	40	18	2	1							3		1	
7.60	25	18	2	1								3	1	1
8.10	12	45				2			2		2	5		
8.60	14	15	1									1		
9.10	17	37				1			1			6		
9.60	13	19		2								2		
10.20	27	25		2								10	1	
10.70	14	10	1				1							
11.20	12	25		2							1	3		
11.70	18	23		3		1						2		
12.20	16	37		5							1	5		
12.60	9	8	1	1	2						1			
13.10	15	24		2								7		
13.60	22	15							1		1	1		
14.10	14	19		2						3		5	1	
14.60	9	15	2	3		1				4		7	1	
15.25	19	35		2						2			1	
15.75	10	8		5										
16.10	7	24		2								2	1	
16.30	21	34		10								4	1	

	72	73	74	75	77	79	80	81	83	84	85	86	87	88	89
0												1	1		1
0.55							1		5		3	4	1		1
1.10									2		4	1	1	1	2
1.60					1				3		5			4	1
2.20			2	2									2	2	1
2.75			1								12		1		3
3.20			2												
3.70												1		3	14
4.20															
4.70						2						7	1		8
5.20															
5.60		1	2										1	3	3
5.70												1		5	14
6.10											1	10			7
6.20												6		1	9
6.60			1									10		1	2
7.10						1				1		7			7
7.60			2									2			16
8.10			1			2		1				1		1	23
8.60		1	2	1		2			2			3	1	1	10
9.10												8			8
9.60			1	1		2						5		2	8
10.20												5		1	19
10.70		1		1		1								5	16
11.20						1						3		1	14
11.70			1									7	1	1	8
12.20	1		4								1	7			7
12.60			2	1		2			1			2		1	3
13.10			1			1				1	2	1	1	1	9
13.60						1								2	6
14.10						4						3		1	9
14.60												2		4	3
15.25					1						1	3			6
15.75										2		1			12
16.10						1						1		1	4
16.30						1					1	11			7

	90	91	92	94	95	97	98	101	102	107	110	111	112	113
0									3					
0.55														
1.10	1													
1.60	1		1			1								
2.20							3							
2.75														
3.20									1					
3.70											2			2
4.20								1						
4.70														
5.20														
5.60				1		3	6	3				1		
5.70			3											1
6.10									1					3
6.20						1								
6.60														
7.10							1							
7.60								1						
8.10					1								1	
8.60		1		1			3	2				2		
9.10														
9.60					1								1	
10.20							1							
10.70														
11.20							1							
11.70								2		1				
12.20														4
12.60							2						1	2
13.10														1
13.60							3							1
14.10														1
14.60							1							
15.25					1				1					1
15.75														
16.10												2		
16.30														

	114	116	117	118	119	121	123	124	125	126	127	128	130	132	133
0							59	192	1	1				8	
0.55							16	10							
1.10							21	5					1		
1.60							15	1				1			
2.20							67	11							3
2.75							1	8							
3.20							57	10							12
3.70							4	173							3
4.20							23	3			1				
4.70					2			5					7		
5.20							5	1							1
5.60							51	28					7		
5.70							9	4						4	
6.10							1	6					4	1	
6.20							8	3						1	
6.60							14	31						1	
7.10							1	19					4		
7.60							21	7					2		
8.10							10	15							
8.60				2		1	36	17				6	2	2	
9.10							11	8		1			2		1
9.60		1					31	19					2		
10.20	1						9	6					1		
10.70							32	17				4	5		
11.20							11	26					2		
11.70			1				32	16					4		
12.20			2				15	21					9		
12.60			1				44	24		1			4		
13.10							21	24					4		
13.60							52	41							2
14.10						1	18	16					7		
14.60							39	21		1			5		2
15.25							17	28		4			8		1
15.75							50	30					2		
16.10						1	65	18					6		
16.30							7	16					5		

	134	135	137	138	139	140	141	143	144	145	146	149	150	151
0	3			1	4	1	1			9				
0.55	7	13		4	4					20				1
1.10	8	14		1	1		1			18				
1.60	4	18		1			3			31				
2.20	11	3		4						3				
2.75	15	7		4						20				
3.20	1	2								3				5
3.70		2				1				2				
4.20	1	1		3										1
4.70	18	17		2	2		10			12				
5.20	1													1
5.60	6	12		1	1		2			8				
5.70	23	11			1		9			23				
6.10	12	7		2	1		8	1		10				
6.20	14	7		3	5		6		1	21				
6.60	4	15		2			13	183	2	13				
7.10	18	10		1	3	3	2	2	2	13				
7.60	2	11		2				20	8	26		6		
8.10	15	11		10		1		3		18		1		
8.60	5	9		2				9	3	8		5	2	
9.10	18	5			1		6		7	14				
9.60	8	11		4	4	1	1	5	4	12				
10.20	14	8	6			1				15				1
10.70	1	6			3				2	19	1			2
11.20	23	5			2		3		1	18				
11.70	11	6		2	3		1	21	3	12		3		
12.20	18	12	1	3	1		2	2		17				
12.60	1	12	1	2			1	7	1	24				1
13.10	17	9						1		19				
13.60	7	10		2			2			10				1
14.10	12	24					1		1	21				
14.60	10	14		4						31				
15.25	13	11					3			21				
15.75	5	18		4						22		4		
16.10		21		1	1		5			17		7		
16.30	14	6		5	12		5		3	9				

	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166
0															3
0.55							3	1			12	4		5	90
1.10							3				1			10	102
1.60		1									12	2		9	98
2.20							4								45
2.75											1			2	12
3.20	1										7				10
3.70															4
4.20															3
4.70															
5.20											1				2
5.60			3			1	6				6	7			102
5.70											1			1	5
6.10															
6.20															1
6.60			1	1										1	28
7.10														1	7
7.60	2			2				2			7	1			78
8.10			3											5	31
8.60			2				4					6		2	66
9.10											1			5	10
9.60							3				6			4	88
10.20							1	1			2	2		7	13
10.70				1							7			1	58
11.20		2									1				2
11.70							6		1		1				106
12.20															2
12.60			12				4					1		1	107
13.10			1				3				1				147
13.60			1				6			1		2	3		120
14.10		1					13				8				232
14.60					1		5				10			2	66
15.25															4
15.75							7	1			2		1	3	99
16.10							6	1				2	1	2	87
16.30											2				4

	167	168	169	170	171	172	173	174	176	178	179	180	181	182
0		93	19			4								
0.55	1	1						1	11				5	6
1.10	9	3		1		4			9	1				21
1.60		1		2		2		1	14					25
2.20	28	1						1		4				
2.75		4		1										1
3.20							1		1					
3.70			2											
4.20														
4.70			1			1								
5.20		1	1							1	1	1		
5.60		5				2		3	2	1				11
5.70				2					2					
6.10						1								
6.20				1		2								
6.60		1	1							2			2	
7.10						1								
7.60			1			3		1	2	2	1			
8.10					1						3	2		
8.60				5		2			2					1
9.10						1	1		1	5				
9.60		2		2			2			3				
10.20		2				1		2						
10.70							6			1		2		9
11.20							1							
11.70	1									5				
12.20								1						
12.60	2								4	1	3			5
13.10				1				1	9		2			2
13.60	14	34				30				4		37		
14.10		19		2		2	1		2	2		16		
14.60		9				1	2	8	2			1		2
15.25		108								1				
15.75		59							3	2	9	2		
16.10	10	11				4				1	12	6		
16.30		5								2				

	183	184	185	Total Pollen and Spores
0			9	438
0.55			4	454
1.10		1	1	486
1.60			5	497
2.20	1		16	330
2.75		1	17	367
3.20			12	335
3.70	1	1	16	335
4.20			6	67
4.70			19	337
5.20			5	35
5.60	1		6	481
5.70			18	330
6.10			23	329
6.20			15	341
6.60			3	356
7.10			12	336
7.60	1		7	456
8.10			19	378
8.60			2	417
9.10			10	357
9.60			11	442
10.20			9	360
10.70			4	424
11.20			15	326
11.70			11	459
12.20			15	343
12.60			3	465
13.10			16	515
13.60	2		11	574
14.10	1		19	629
14.60			6	440
15.25			19	436
15.75			4	502
16.10			8	474
16.30			16	332

APPENDIX 6D

Telago: actual pollen counts

Depth (m)	1	2	3	4	5	7	8	9	10	11	12	13	19	21
0			1		1	9		6				6		11
1.20					2	3		6	1		5	28		30
2.10					2	12		4			1	41		30
3.10					2	13		5			8	25		58
4.10	2	2			4	2		1				20		14
5.10	1				6			5		1	6	52		32
6.10	1				6			1				41		32
7.10	1	1		2	3		1	2			3	28		22
8.10	4		1		1			3			2	30	2	24
9.10	5	1			2	2		4		2	5	31		34
10.10	2			2	1	1		2			1	42		26

	22	23	26	27	28	29	31	33	34	35	36	39	40	43
0			2					2						
1.20	1	1	2									12		2
2.10	1	1	1									24		8
3.10			2			2						28		4
4.10			1									16		3
5.10	1			1		3	2				2	19		
6.10				1	1	3	1					23	1	7
7.10	1	2			2							9		
8.10			2	4	3					2		14	1	
9.10	1		3	1	1				1			16	1	1
10.10			3	3	12			1				12		

	46	47	48	50	51	52	53	54	55	56	58	59	60	61
0			5	3					2					
1.20	3		14		6		2		63	3	4		6	2
2.10		4	13	1	11		2	3	67		10		1	
3.10	7		1		2	1		4	75		1			
4.10	16	8	1		4		1		110		2			
5.10	7		2		4			2	23	1	5			
6.10	4		2		7				35	4				
7.10		1	2					2	19	2				
8.10		6			6				11					
9.10	1	2			2		3	2	22	1	2	1	1	
10.10	1	1	1		3			1	12		3			

	67	68	70	71	74	76	77	79	82	84	85	86	87	88
0	6						1						5	61
1.20							4					1		
2.10		1	2									1		
3.10										1	3			
4.10						1	1				1		1	
5.10			2					1	1			4		
6.10							1							
7.10												1		
8.10			3					1				2	1	
9.10	1			2	1	3	1		2				1	
10.10			1									2		

	89	92	97	98	101	102	103	104	106	107	108	113	114	116
0	3					26			2			1		
1.20				1	1			5	11				1	1
2.10	3										3			
3.10			2		1									
4.10	6		2											
5.10		3		1										
6.10		1	1				1							
7.10						2								
8.10	1									2		6	2	
9.10	1												2	
10.10	1												1	1

	118	119	122	123	124	125	126	130	132	133	134	135	136	138
0				42	41		5		24		1	4	1	2
1.20				23	13						8	11		
2.10				9	8						19	4		3
3.10				17	4						13	15		
4.10				5	38						19	6		
5.10				13	31			1		23	12	25		1
6.10				18	36	1				3	16	27		
7.10			2	17	117					24	22	9		
8.10		1	3	13	41			2		55	19	12		
9.10			1	12	90				3	16	20	13		
10.10	1			65	23	1				1	17	26		

	139	140	141	142	145	146	149	153	154	157	158	159	162	163	165
0	2	5			13			1					3		
1.20	6	1	4		14						4		7		8
2.10	6	1	1		12									11	5
3.10					16		3		1		1				2
4.10	5	1			15								4		7
5.10	3		2		12	1					8	2	13		11
6.10	1				24								5	5	1
7.10			1	1	10	3						2	7		
8.10	5		2	1	13	3		2	1			3	25	7	
9.10	3		1	3	19						18	1	13	9	
10.10	6	1		1	32	1			1	3		6	10	16	17

	166	167	168	169	170	172	173	174	176	177	178	179	180	182	183
0	12		5	35		3		3							
1.20	132				3			7						1	2
2.10	162					3		5	17	1	2				
3.10	174	3	3			1								4	2
4.10	107				1	1			8	1					7
5.10	159		4			5		1			2		1		13
6.10	113		2			2		18			3		1		3
7.10	180		3		3	1	8	20					1	2	1
8.10	195				6	36	11				6		3		13
9.10	122	1	1			8						3		8	
10.10	329				4	22		3		1	6	1			8

	184	185	Total Pollen and Spores
0		11	364
1.20		12	477
2.10	1	17	535
3.10		14	518
4.10	6	9	459
5.10	120	14	664
6.10	1	26	480
7.10	183	11	734
8.10	124	17	753
9.10	1	16	544
10.10	13	12	763

APPENDIX 6E

Allocation of arboreal pollen taxa to altitudinal forest groups

Taxa have been allocated to groups on the basis of the altitudinal ranges of their source taxa.

Arboreal taxa

Arboreal taxa were those listed at the beginning of the Appendix and having the following code numbers

1-69	(inclusive)	*Dacrycarpus* to Araliaceae comp.
75-78	(inclusive)	*Schefflera aromatica* sim. to *Schefflera* comp. 3
80		*Croton* comp.
84		*Eurya* comp.
85		*Glochidion* comp.
87-89	(inclusive)	*Myrica* comp. to *Vaccinium* comp.
98		Melastomataceae comp.

More or less confined to sub-montane forest

Celtis comp.
Madhuca comp.*
Fagraea comp.
Linociera comp.
L. malabarica sim.
Trema comp.

Sub-montane forest and lower montane forest I

Macropanax comp.
Pometia
Randia comp.
Claoxylon comp.
C. longifolium
Aglaia comp.*
Meliosma comp.*
Nauclea comp.*

Lower montane forest I only

Altingia comp.
Euonymus comp.*

Lower montane forest I and II

Podocarpus
Engelhardtia comp.
Polyosma comp.
Symplocos sessilifolia sim.
Weinmannia comp.

More or less confined to lower montane forest II

Dacrycarpus
Symingtonia

Commonest in ericoid forest and _Gleichenia_ scrub

Myrsine comp.
Vaccinium comp.

Commonest in ericaceous scrub

Rhododendron comp.
Myrica comp.

Common to all lower montane forest types

All other arboreal taxa were allocated to this group.

* These taxa were not recorded in any samples examined by the present author but were present in the surface samples from G. Kerinci studied by Morley (1976) and which have been included in the summary diagrams in Section 5.6 (Fig 5.6 and 5.7).

APPENDIX 6F

Allocation of dry land pollen taxa to source habitat groups

Taxa have been allocated to groups on the basis of habitat preferences of their source taxa.

The taxa which make up the dry land pollen are those listed at the beginning of the Appendix and having the following code numbers.

1-132	(inclusive)	*Dacrycarpus* to *Xyris*
137-140	(inclusive)	Menispermaceae comp. to Urticaceae/Moraceae 4-porate

Forest, secondary forest or non-forest

Oroxylon sim.
Vernonia arborea sim.
Macaranga comp. small
Macaranga comp. large
Mallotus comp.
Trema comp.
Eurya comp.
Glochidion comp.
Melastoma comp.
Myrica comp.
Rhododendron comp.
Vaccinium comp.
Viburnum comp. 1
Viburnum comp. 2
Rhamnaceae comp.
Gouania comp.
Gendarussa comp.
Lonicera
Rubus comp.
Acalypha comp.
Melastomataceae comp.
Polygala comp.
Amaranthaceae comp.
Boea sim.
Compositae types 1-7 (Tubuliflorae)
Compositae (Liguliflorae)
Crotalaria comp.
Hedyotis comp.
Hedyotis vestita sim.
Impatiens
Oldenlandia uncinella sim.

Non-forest only

Drymaria comp.
Galium comp.
Gentiana
Liliaceae comp.

Liliaceae/Palmae comp.
Plantago major
Umbelliferae comp. 1 and 2

Non forest and swamp

Cyperaceae
Gramineae
Hydrocotyle comp.
Laurembergia comp.
Nepenthes comp.
Monocotyledon undifferentiated

Swamp only

Burmannia
Eriocaulon
Utricularia
Xyris

Various

Menispermaceae comp.
Urticaceae/Moraceae 2-, 3- and 4-porate

Forest

All remaining pollen taxa were allocated to the forest category.

APPENDIX 7

Results of POLZON analysis of the DDA and Telago pollen data

Results provided by the POLZON analysis are shown in diagrammatic form in the following figures.

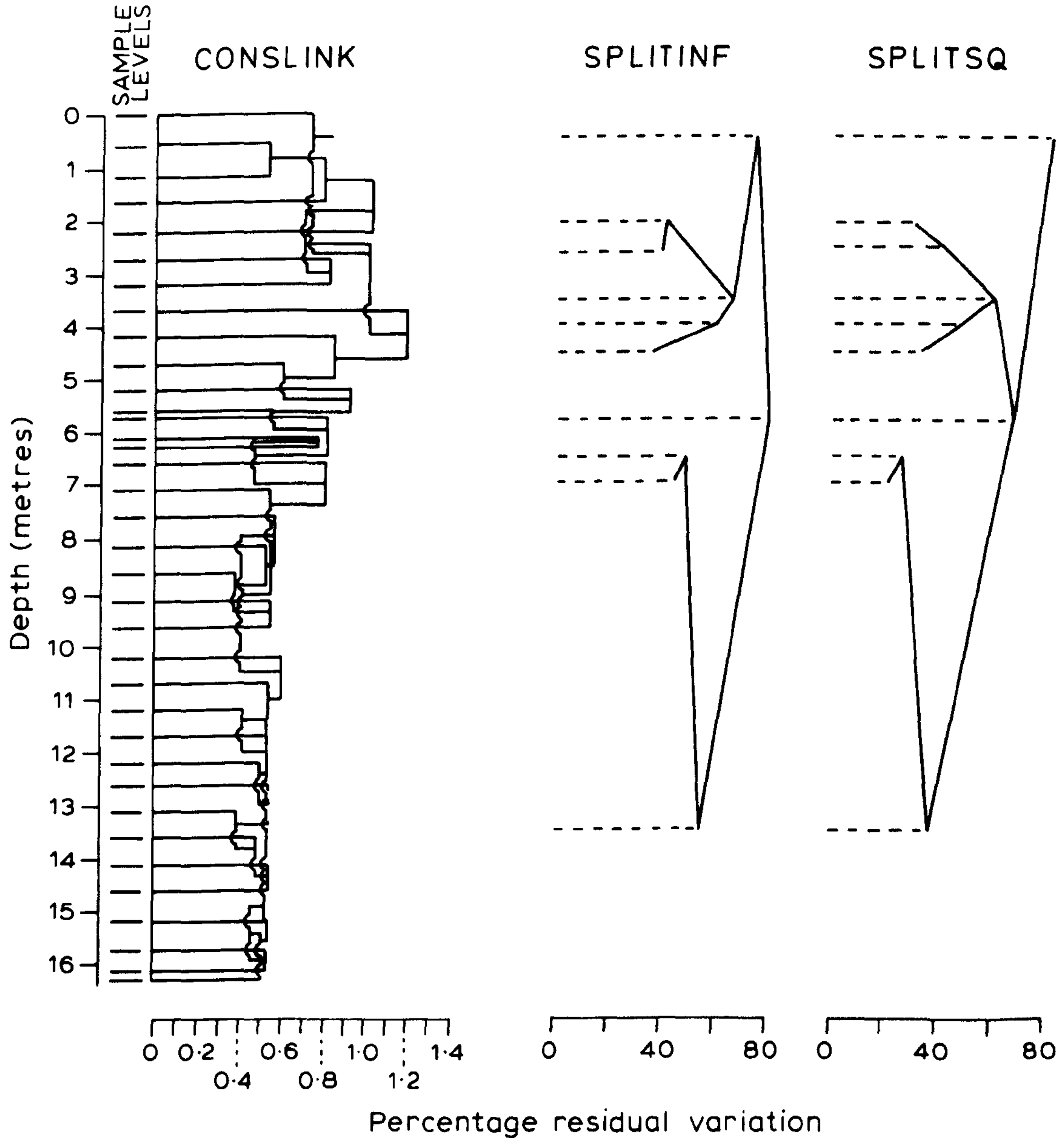
A. Danau di Atas

Figs A1 - A4 show the results of POLZON analysis on the four different data sets from the DDA sequence. Major problems occurred with the CONSLINK procedure for all data sets. Because of changes in the information content after grouping of samples, subsequent amalgamations were often at lower levels of variance than earlier ones. The overall effect of this was to make it very difficult to distinguish distinct groupings of samples, especially in the lower part of the sequence. SPLITINF and SPLITSQ procedures did produce interpretable results, but unfortunately the boundaries suggested were often between whole series of consecutive samples. This was not particularly useful to the subsequent interpretation of the data, and may have been the result of variation inherent in the data, as discussed in Section 6.4b. Because of this the analyses were not used to zone the DDA pollen data.

B. Telago

Figs A5 - A8 show the results of POLZON analysis on four data sets from the Telago sequence. In contrast with the DDA analyses, no particular problems occurred in these, and the results were used in subsequent zonation, as described in section 7.4b.

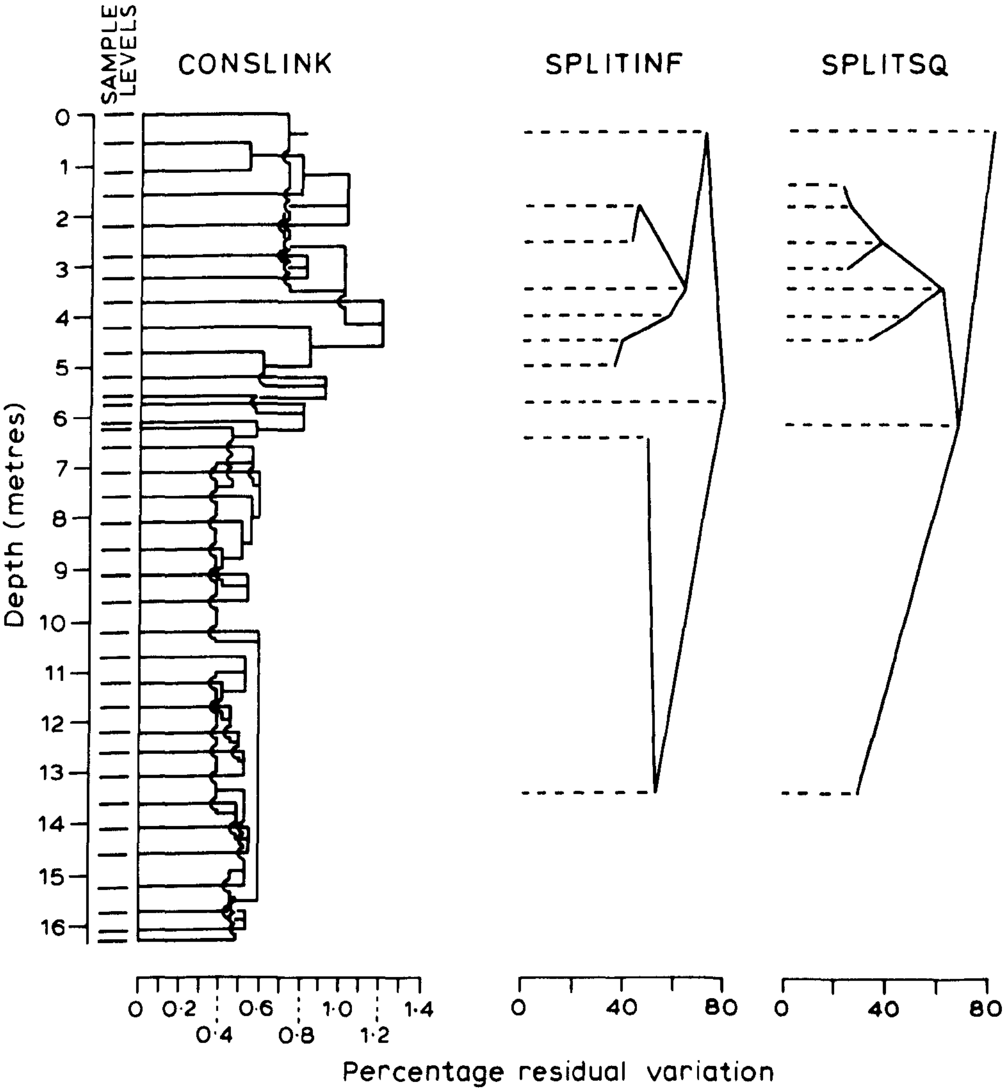
FIG. A1



DDA, Results of POLZON

(i) All dry land and aquatic pollen excluding spores and unknown grains

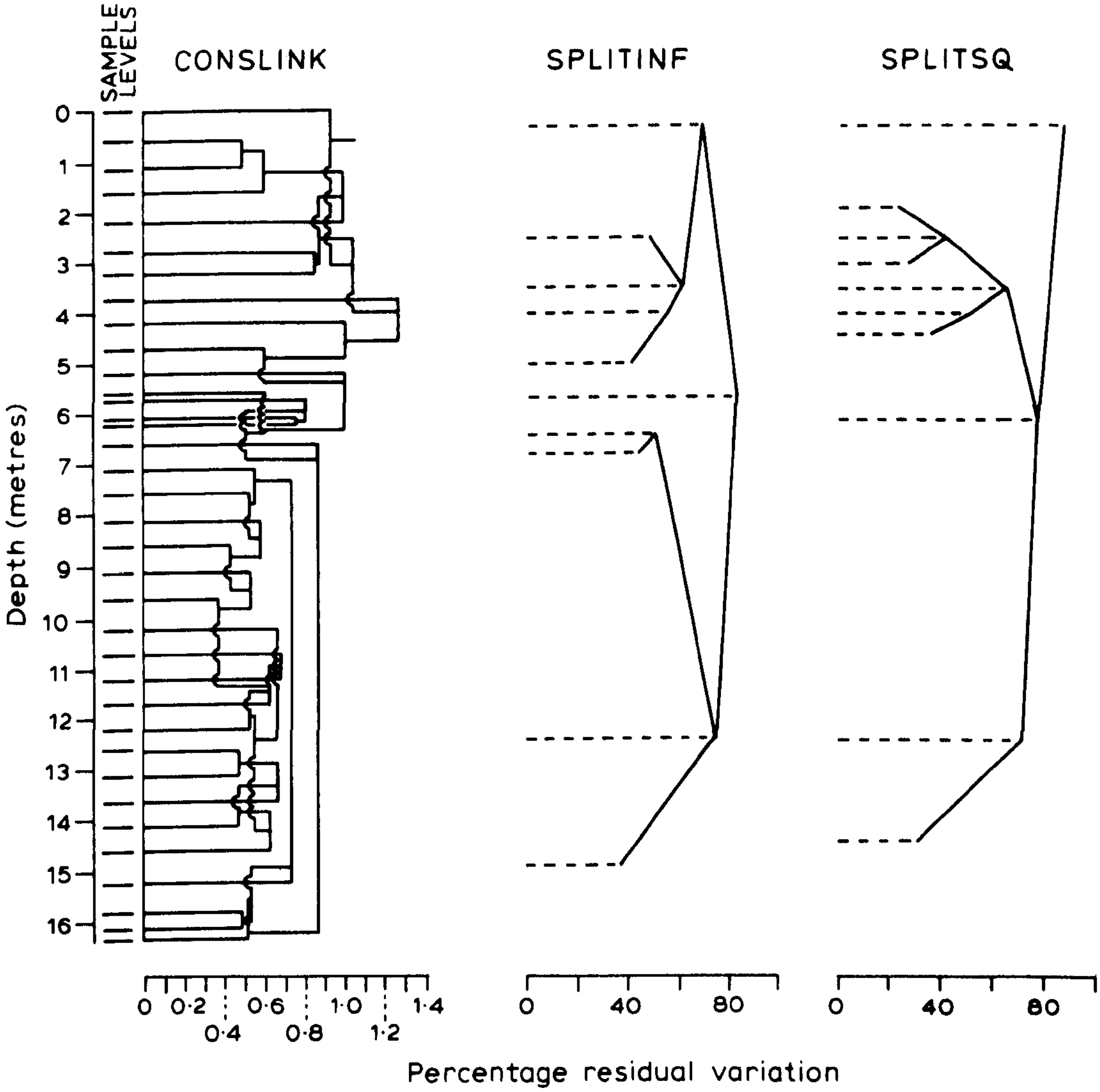
FIG. A2



DDA, Results of POLZON

(ii) Dry land pollen only, excluding unknown grains

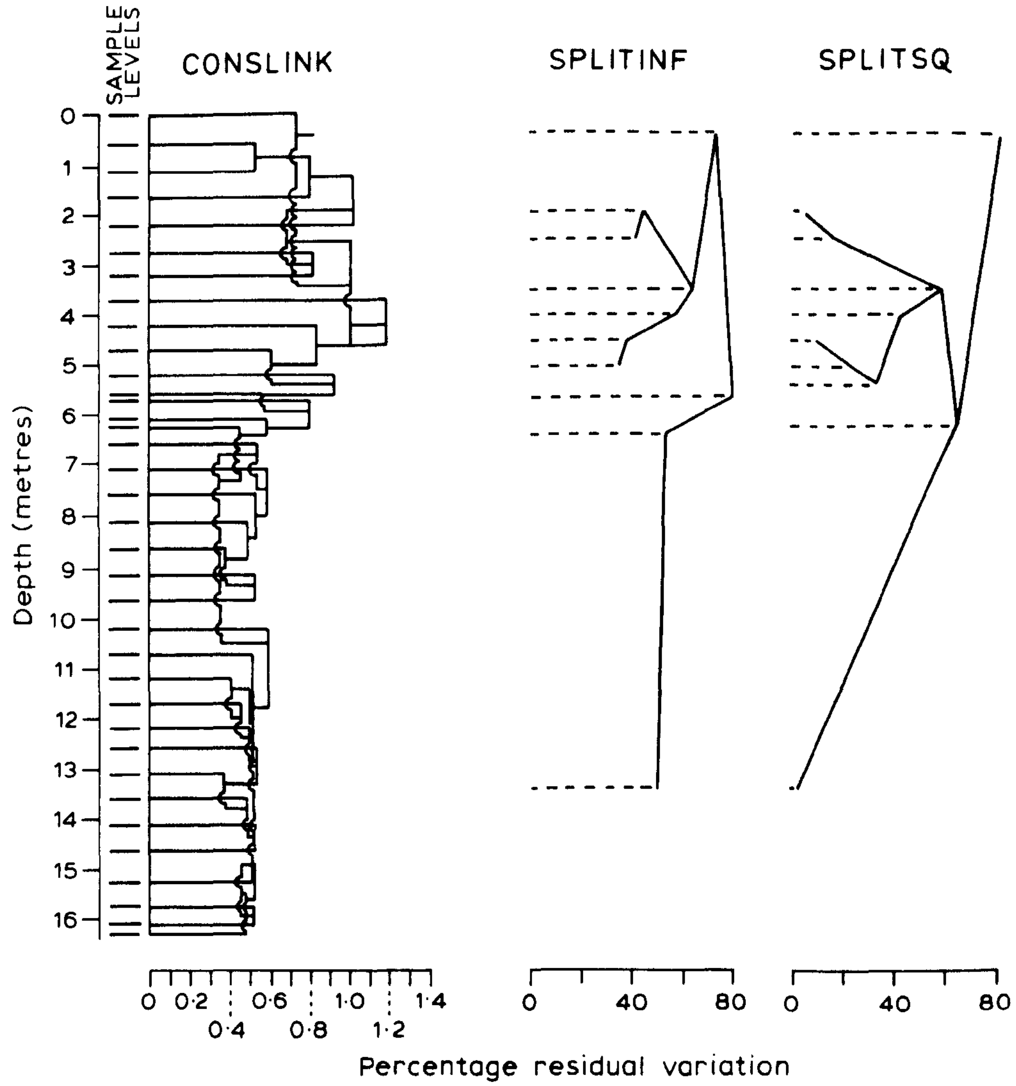
FIG. A3



DDA, Results of POLZON

(iii) All pollen and spores occurring as greater than 0·5 percent T. D. L. P. in any sample

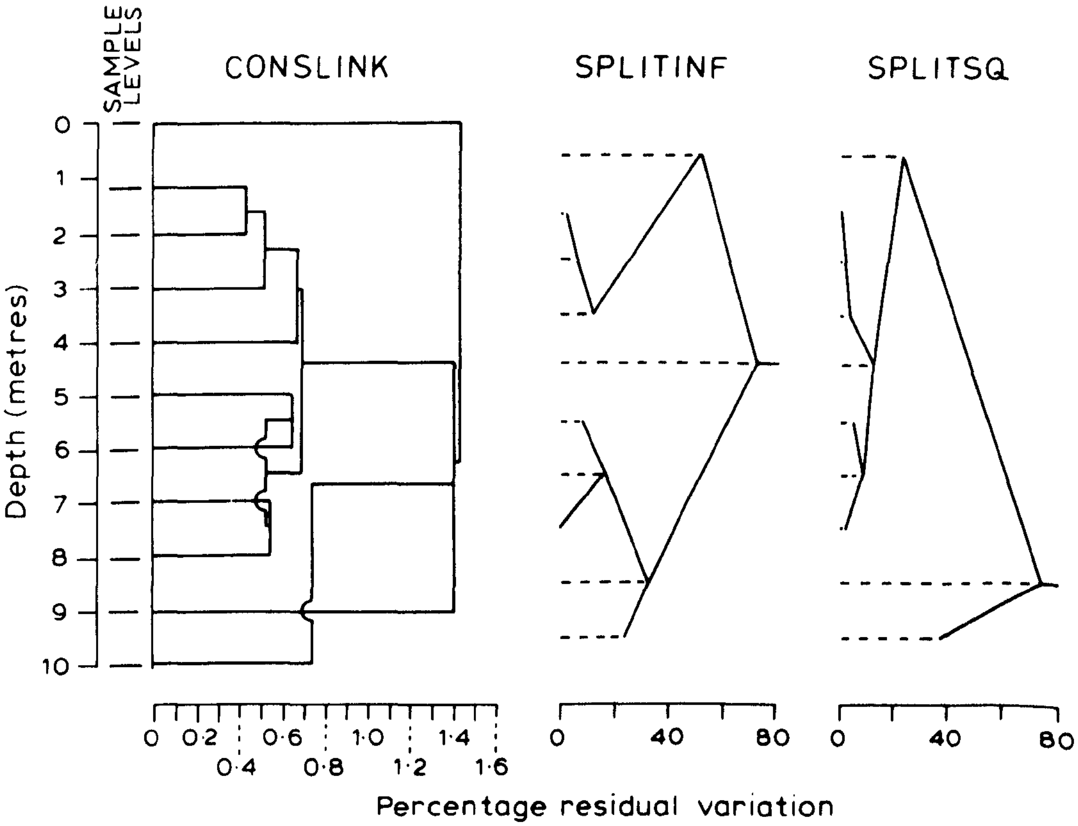
FIG. A4



DDA, Results of POLZON

(iv) Dry land pollen only occurring as greater than 0·5 percent T.D.L.P. in any sample

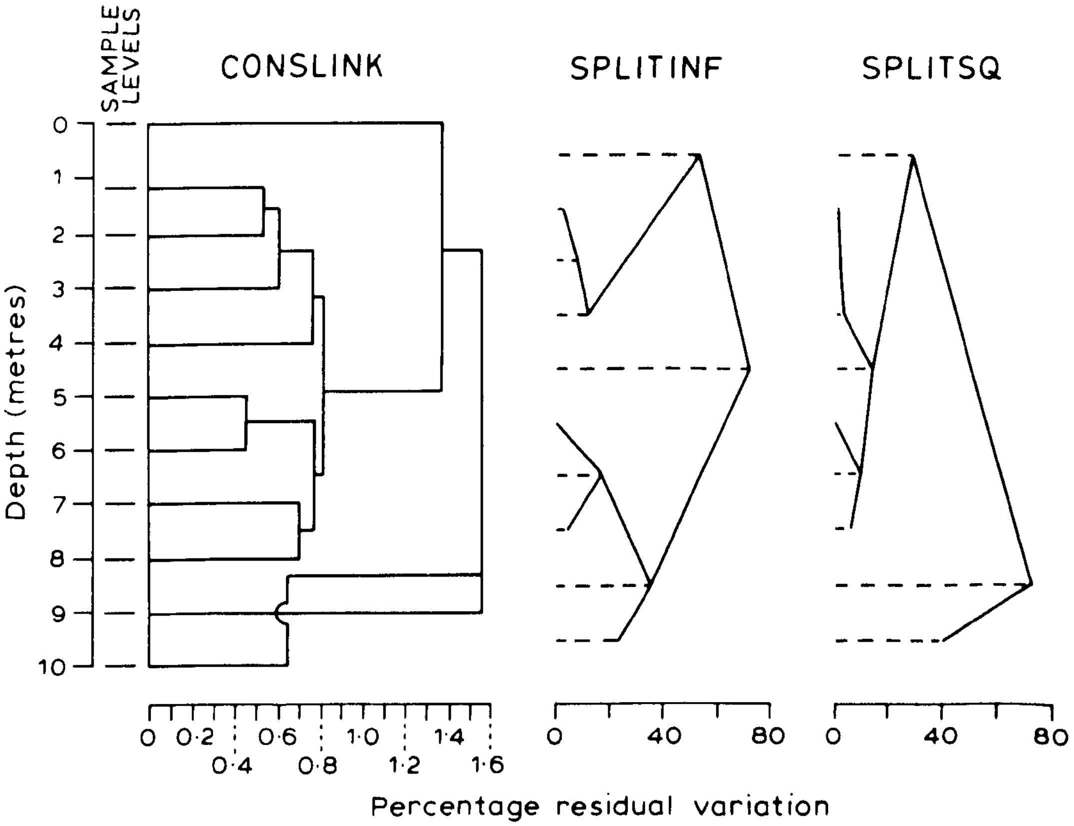
FIG. A5



TELAGO, Results of POLZON

(i) All pollen and spores

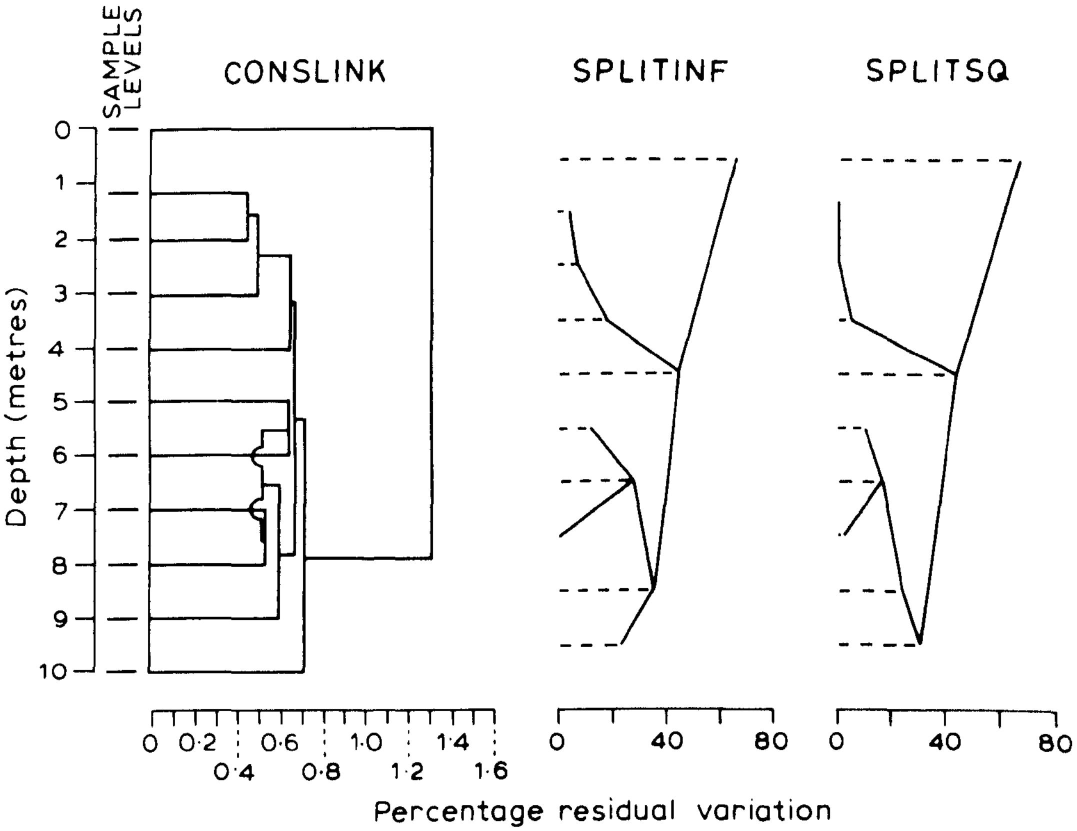
FIG. A6



TELAGO, Results of POLZON

(ii) Dry land pollen only, excluding unknown types.

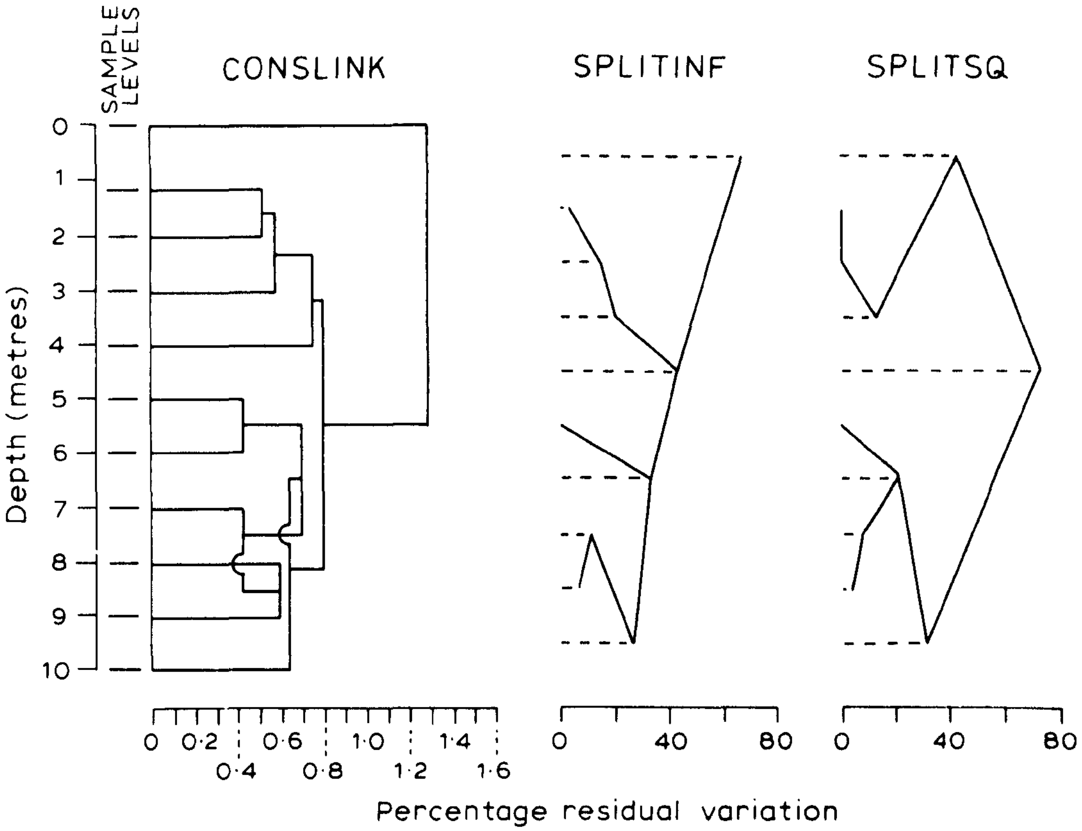
FIG. A7



TELAGO, Results of POLZON

(iii) All pollen and spores occurring as greater than 0·5 percent T.D.L.P. in any sample

FIG. A8



TELAGO, Results of POLZON

(iv) Dry land pollen only occurring as greater than 0·5 percent T.D.L.P. in any sample

BIBLIOGRAPHY

ANDERSEN, S.T. (1974). Wind conditions and pollen deposition in a mixed deciduous forest. I. Wind conditions and pollen dispersal. Grana, 14, 57-63.

ANDERSON, J.A.R. and MULLER, J. (1975). Palynological study of a Holocene peat and a Miocene coal deposit from N.W. Borneo. Rev. Palaeobot. Palynol., 19, 291-351.

ASHTON, P.S. (1964). Ecological studies in the mixed Dipterocarp forests of Brunei State. Oxf. For. Mem., 25, 1-75.

ASHTON, P.S. (1965). Some problems arising in the sampling of mixed rain forest communities for floristic studies. Symposium on ecological research in humid tropics vegetation, Kuching, Sarawak, 1963, 235-240, UNESCO.

ASSEMIEN, P., FILLERON, J.C., MARTIN, L. and TASTET, J.P. (1970). Le Quaternaire de la zone littorale de Cote d'Ivoire. Bull. ASEQUA, 25, 65-78.

BACKER, C.A. (1954). Myricaceae. Flora Malesiana, I, 4, 276-279.

BACKER, C.A. and BAKHUIZEN van den BRINK, R.C. (1963-68). Flora of Java, 3 volumes, vol 1,1963; vol 2, 1965; vol 3,1967., NVP Noordhoff, Groningen.

BAKKER, E.M. van ZINDEREN (1962). A Late-Glacial and Post-Glacial climatic correlation between East Africa and Europe. Nature, 194, 201-203.

BAKKER, E.M. van ZINDEREN (1964). A pollen diagram from equatorial Africa, Cherangani, Kenya. Geologie Mijnb., 43, 123-128.

BAKKER, E.M. van ZINDEREN and COETZEE, J.A. (1972). A re-appraisal of Late-Quaternary climatic evidence from tropical Africa. Palaeoecol. of Africa, 7, 151-181.

BALL, D.F. (1964). Loss-on-ignition as an estimate of organic matter and organic carbon in non-calcareous soils. J. Soil Sci., 15, 84-92.

BARTLETT, A.S. and BARGHOORN, E.S. (1973). Phytogeographic history of the Isthmus of Panama during the past 12000 years. (A history of vegetation, climate and sea-level change). In Vegetation and Vegetational History of Northern Latin America, a Symposium. (ed. A. Graham), 203-299, Elsevier, Amsterdam & New York.

BEEK, C.G.G. van (1982). A Geomorphological and Pedological study *of the Gunung Leuser National Park, North Sumatera, Indonesia*. Wageningen Agricultural University, Wageningen.

BENNINGHOFF, W.S. (1962). Calculation of pollen and spore density in sediments by addition of exotic pollen in known quantities. *Pollen Spores* 4, 332-333.

BENNINGHOFF, W.S. and KAPP, R.O. (1962). Suggested notations to indicate identification status of fossil pollen. *Pollen Spores*, 4, 332.

BIRKS, H.J.B. (1973). Modern pollen rain studies in some arctic and alpine environments. In *Quaternary Plant Ecology* (ed. H.J.B. Birks and R.G. West), 143-168, Blackwell, Oxford.

BIRKS, H.J.B. (1974). Numerical zonations of Flandrian pollen data. *New Phytol*., 73, 351-358.

BIRKS, H.J.B., WEBB, T. and BERTI, A.A. (1975). Numerical analysis of pollen samples from central Canada: a comparison of methods. *Rev*. *Palaeobot*. *Palynol*., 20, 133-169.

BLASCO, F. and THANIKAIMONI, G. (1974). Late Quaternary vegetational history of southern region. In *Aspects and Appraisal of Indian Palaeobotany* (ed. K.R. Surange, R.N. Lakhanpal and D.C. Bharadwaj), 632-643, Birbal Sahni Institute of Palaeobotany, Lucknow.

BOEREMA, J. (1931). Regenval in Nederlandsch - Indie, Verhandelingen 24, Deel II. *Kon*. *Mag*. *en* *Met*. *Obs*. *te* *Batavia*.

BONNEFILLE, R. (1973). Nouvelles recherches en Ethiopie. *Le Quaternaire*, *Geodynamique*, *stratigraphie et environment*. Travaux Francais Recents, 182-187, Comite National Francais de L'INQUA.

BONNY, A.P. (1972). A method for determining absolute pollen frequencies in lake sediments *New Phytol*., 71, 391-405.

BRAAK, C. (1928). The climate of the Netherlands Indies. *Proc. Royal Magn*. *Meteorol*. *Observ*. *Batavia*, 8, 272 pp.

BRADSHAW, R.H.W. (1981). Modern pollen representation factors for woods in south-east England. *J*. *Ecol*., 69, 45-70.

BRAUN-BLANQUET, J. (1932). *Plant Sociology*. McGraw-Hill, New

York, 439 pp.

CARATINI, C. BLASCO, F. and THANIKAIMONI, G. (1973). Relation between the pollen spectra and the vegetation of a south Indian mangrove. Pollen spores, 15, 281-292.

CASELDINE, C.J. and GORDON, A.D. (1978). Numerical analysis of surface pollen spectra from Bankhead Moss, Fife. New Phytol., 80, 435-453.

CLAPHAM, A.R. (1932). The form of the observational unit in quantitative ecology. J. Ecol., 20, 192-197.

CLARK, J.D. and BAKKER, E.M. van ZINDEREN (1964). Prehistoric culture and Pleistocene vegetation at the Kalambo Falls, Northern Rhodesia. Nature, 201, 971-975.

CLIMAP Project Members (1976). The surface of the Ice-Age Earth. Science, 191, 1131-1137.

COETZEE, J.A. (1964). Evidence for a considerable depression of the vegetation belts during the Upper Pleistocene on East African mountains. Nature, 204, 564-566.

COETZEE, J.A. (1967). Pollen analytical studies in East and Southern Africa. Palaeoecol. of Africa, 3, 1-146.

COLINVAUX, P.A. (1972). Climate and the Galapagos Islands. Nature, 240, 17-20.

CONANT, D.S. (1978). A radioisotope technique to measure spore dispersal of the tree fern Cyathea arborea sm. Pollen Spores, 20, 583-593.

COTTAM, G. and CURTIS, J.T. (1949). A method for making rapid surveys of woodlands by means of pairs of randomly selected trees. Ecology, 30, 101-104.

COTTAM, G. and CURTIS, J.T. (1956). The use of distance measures in phytosociological sampling. Ecology, 37, 451-460.

DAVIS, M.B. (1963). On the theory of pollen analysis. Am. J. Sci., 261, 897-912.

DAVIS, M.B. (1965). A method for determination of absolute pollen frequency. In Handbook of Paleontological Techniques (ed. B. Kummel and D.M. Raup), 674-686, Freeman, San Francisco and London.

DAVIS, M.B. (1968). Pollen grains in lake sediments: redeposition caused by seasonal water circulation. Science, 162, 796-799.

DAVIS, M.B., BRUBAKER, L.B. and WEBB, T. (1973). Calibration of absolute pollen influx. In Quaternary Plant Ecology (ed. H.J.B. Birks and R.G. West), 9-25, Blackwell, Oxford.

DAVIS, M.B. and GOODLETT, J.C. (1960). Comparison of the present vegetation with pollen spectra in surface samples from Brownington Pond, Vermont. Ecology, 41, 346-357.

DAVIS, R.B. (1974). Stratigraphic effects of tubificids in profundal lake sediments. Limnol. Ocean., 19, 466-488.

DAY, M.H. (1977). Guide to Fossil Man, 3rd Edition. Cassell, London. 346 pp.

FAEGRI, K. (1966). Some problems of representivity in pollen analysis. Palaeobotanist, 15, 135-140.

FAEGRI, K. and IVERSEN, J. (1975). Textbook of Pollen analysis. Blackwell, Oxford. 295pp.

FITCH, T.J. (1972). Plate convergence, transcurrent faults and internal deformation adjacent to Southeast Asia and the Western Pacific. J. Geophysical Res., 77, 4432-4460.

FLENLEY, J.R. (1969). The vegetation of the Wabag Region, New Guinea Highlands: a numerical study. J. Ecol., 57, 465-490.

FLENLEY, J.R. (1973). The use of modern pollen rain samples in the study of the vegetational history of tropical regions. In Quaternary Plant Ecology (ed. H.J.B. Birks and R.G. West), 131-141, Blackwell, Oxford.

FLENLEY, J.R. (1984). Late Quaternary changes of vegetation and climate in the Malesian mountains. Erdwissenschaftliche Forschung, 18, 261-267.

FLENLEY, J.R. and MORLEY, R.J. (1978). A minimum age for the deglaciation of Mt Kinabalu, East Malaysia. Mod. Quaternary Res. SE Asia, 4, 57-61.

FLENLEY, J.R. and RICHARDS, K. (Eds) (1982). The Krakatoa Centenary Expedition Final Report. University of Hull, Dept of Geography, Miscellaneous Series No. 25, Hull, England, 196 pp.

FONTANEL, J. and CHANTEFORT, A. (1978). Bioclimats du Monde Indonesian (Bioclimates of the Indonesian Archipelago). Institut Francais de Pondichery. Travaux de la section scientifique et technique, 16, 106 pp.

GAUCH, H.G., WHITTAKER, R.H. and WENTWORTH, T.R. (1977). A comparative study of reciprocal averaging and other ordination techniques. J. Ecol., 65, 157-174

GEEL, B. van and HAMMEN, T. van der (1973). Upper Quaternary vegetation and climatic sequence of the Fuquene area (Eastern cordillera, Colombia). Palaeogeogr. Palaeoclimatol. Palaeoecol., 14, 9-92.

GONZALEZ, E., HAMMEN T. van der and FLINT, R.F. (1966). Late Quaternary glacial and vegetational sequence in Valle de Lagunillas, Sierra Nevada del Cocuy, Colombia. Leid. geol. Meded., 32, 157-182.

GOOD, R. (1947). The geography of flowering plants, 1st Edition. Longman, London, 403 pp.

GOODALL, D.W. (1952). Quantitative aspects of plant distribution. Biol. Rev., 27, 194-245.

GORDON, A.D. and BIRKS, H.J.B. (1974). Numerical methods in Quaternary palaeoecology. II. Comparison of pollen diagrams. New Phytol., 73, 221-249.

GRABANDT, R.A.J. (1980). Pollen rain in relation to arboreal vegetation in the Colombian Cordillera Oriental. Rev. Palaeobot. Palynol., 29, 65-147.

GREIG-SMITH, P. (1983). Quantitative Plant Ecology, 3rd Edition. Blackwell, Oxford.

GRUBB, P.J. (1974). Factors controlling the distribution of forest types on tropical mountains, new facts and a new perspective. Altitudinal zonation of forests in Malesia, Transactions of the Third Aberdeen-Hull Symposium on Malesian Ecology, Hull 1973 (ed. J.R. Flenley), 13-46, University of Hull, Dept of Geography, Miscellaneous Series No. 16, Hull, England.

GRUBB, P.J., LLOYD, J.R., PENNINGTON, T.D. and WHITMORE, T.C. (1963). A comparison of montane and lowland rain forest in Ecuador. I. The forest structure, physiognomy and floristics. J. Ecol., 51, 567-601.

HAMILTON, A.C. (1972). The interpretation of pollen diagrams from Highland Uganda. Palaeoecol. of Africa, 7, 45-149.

HAMMEN, T. van der (1963). A palynological study of the Quaternary of British Guiana. Leid. geol. Meded., 29, 125-180.

HAMMEN, T. van der (1972). Changes in vegetation and climate in the Amazon Basin and surrounding areas during the Pleistocene. Geologie Mijnb., 51, 641-643.

HAMMEN, T. van der (1974). The Pleistocene changes of vegetation and climate in tropical South America. *J. Biogeogr*, 1, 3-26.

HAMMEN, T. van der (1978). Stratigraphy and environments of the Upper Quaternary of the El Abra corridor and rock shelters (Colombia). *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 25, 111-162.

HAMMEN, T. van der, BARELDS, J., JONG, H. de and VEER, A.A. de (1981). Glacial sequence and environmental history in the Sierra Nevada del Cocuy (Colombia). *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 32, 247-340.

HAMMEN, T. van der and GONZALEZ, E. (1960). Upper Pleistocene and Holocene climate and vegetation of the 'Sabana de Bogota', (Colombia, South America). *Leid. geol. Meded.*, 25, 261-315.

HAMMEN, T. van der and GONZALEZ, E. (1965a). A pollen diagram from 'Laguna de la Herrera' (Sabana de Bogota). *Leid. geol. Meded.*, 32, 183-191.

HAMMEN, T. van der and GONZALEZ, E. (1965b). A Late-glacial and Holocene pollen diagram from Cienaga del Visitador (Dept. Boyaca, Colombia). *Leid. geol. Meded*, 32, 193-201.

HASTENRATH, S. (1968). Certain aspects of the three-dimensional distribution of climate and vegetation belts in the mountains of Central America and Southern Mexico. *Colloquium geogr.*, 9, 122-130.

HAVINGA, A.J. (1967). Palynology and pollen preservation. *Rev. Palaeobot. Palynol.*, 2, 81-98.

HEEKEREN, H.R., van, (1972). *The Stone Age of Indonesia*. Nijhoff, The Hague.

HEIDE, K.M. and BRADSHAW, R.H.W. (1982). The pollen-tree relationship within forests of Wisconsin and Upper Michigan, USA. *Rev. Palaeobot. Palynol.*, 36, 1-23.

HENDERSON, M.R. (1954). *Malayan wild flowers* (2 volumes). Caxton, Kuala Lumpur.

HICKS, S. (1975). Variations in pollen frequency in a bog at Kangerjoki, N.E. Finland during the Flandrian. *Comment. Biol.*, 80, 28pp.

HICKS, S. (1977). Modern pollen rain in Finnish Lapland investigated by analysis of surface moss samples. *New Phytol.*, 78, 715-734.

HILL, M.O. (1973). Reciprocal averaging: an eigenvector method of ordination. *J. Ecol.*, 61, 237-249.

HILL, M.O. (1979). *DECORANA - a FORTRAN program for detrended correspondence analysis and reciprocal averaging*. Ecology and Systematics, Cornell University, Ithaca, New York.

HOLTTUM, R.E. (1954). *Flora of Malaya. Volume II Ferns* Government Printer, Singapore. 643 pp.

HOOGHIEMSTRA, H. (1984). *Vegetational and climatic history of the High Plain of Bogota, Colombia: a continuous record of the last 3.5 million years*. Cramer, Liechtenstein.

HOOP, A.N.J. Th. a Th. van der (1940). A prehistoric site near the Lake of Kerinchi (Sumatra). *Proc. 3rd Congr. Prehistorians of the Far East, 1938, Singapore* (ed. F.N. Chasen and M.W.F. Tweedie) 200-204.

HOPE, G.S. (1976). The vegetational history of Mt Wilhelm , Papua New Guinea. *J. Ecol.*, 64, 627-661.

HOPE, G.S. (1983). The vegetational changes of the last 20000 years at Telefomin, Papua New Guinea. *Singapore J. Trop. Geogr.*, 4, 25-33.

HOPE, G.S. and PETERSON, J.A. (1975). Glaciation and vegetation in the high New Guinea Mountains. *R. Soc. N. Z. Bull.*, 13, 155-162.

HOPKINS, B. (1957). The concept of minimal area. *J. Ecol.*, 45, 441-449.

JACOBS, M. (1958). Contribution to the botany of Mount Kerintji and adjacent area in West Central Sumatra - 1. *Annales Bogorienses*, 3, 45-104.

JANSSEN, C.R. (1967). A comparison between the recent regional pollen rain and the sub-recent vegetation in four major vegetation types in Minnesota (USA). *Rev. Palaeobot. Palynol.*, 2, 331-342.

JORGENSEN, S. (1967). A method of absolute pollen counting. *New Phytol.*, 66, 489-493.

KENDALL, R.L. (1969). An ecological history of the Lake Victoria Basin. *Ecol. Monogr.*, 39, 121-176.

KERSHAW, A.P. (1970). A pollen diagram from Lake Euramoo, north-east Queensland, Australia. *New Phytol.*, 69, 785-805.

KERSHAW, A.P. (1971). A pollen diagram from Quincan Crater, north-east Queensland, Australia. *New Phytol.*, 70, 669-681.

KERSHAW, A.P. (1973). The numerical analysis of modern pollen spectra from northeast Queensland rain forest. *Spec. Publ. geol. Soc. Aust.*, 4, 191-199.

KERSHAW, A.P. (1975). Stratigraphy and pollen analysis of Bromfield Swamp, north-eastern Queensland, Australia. *New Phytol.*, 75, 173-191.

KERSHAW, A.P. (1976). A Late Pleistocene and Holocene pollen diagram from Lynch's Crater, north-eastern Queensland, Australia. *New Phytol.*, 77, 469-498.

KERSHAW, A.P. (1983). A Holocene pollen diagram from Lynch's Crater, north-eastern Queensland, Australia. *New Phytol.*, 94, 669-682.

KERSHAW, A.P. and HYLAND, B.P.H. (1975). Pollen transfer and periodicity in a rain-forest situation. *Rev. Palaeobot. Palynol.*, 19, 129-138.

KOOPMANS, B.N. and STAUFFER, P.H. (1968). Glacial phenomena on Mount Kinabalu, Sabah. *Geol. Survey Malaysia (Borneo Region). Bull.*, 8, 25-35.

KOWAL, N.E. (1966). Shifting cultivation, fire, and pine forest in the Cordillera Central, Luzon, Philippines. *Ecol. Monogr.*, 36, 389-419.

KRZYWINSKI, K. (1977). Different pollen deposition mechanism in forest: a simple model. *Grana*, 16, 199-202.

LEHMAN, J.T. (1975). Reconstructing the rate of accumulation of lake sediment: the effect of sediment focusing. *Quat. Res.*, 5, 541-550.

LEZINE, A.M. (1982). Etude palynologique des sediments quaternaires du Lac Abiyata (Ethiopie). *Palaeoecol. of Africa*, 14, 93-98.

LIVINGSTONE, D.A. (1967). Postglacial vegetation of the Ruwenzori Mountains in equatorial Africa. *Ecol. Monogr.*, 37, 25-52.

LIVINGSTONE, D.A. (1971). A 22000 year pollen record from the plateau of Zambia. *Limnol. Ocean.*, 16, 349-356.

LIVINGSTONE, D.A. (1975). Late Quaternary climatic change in Africa. *Annu. Rev. Ecol. & Syst.*, 6, 249-280.

LOFFLER, E. (1972). Pleistocene glaciation in Papua and New Guinea. Z. Geomorph. Suppl., 13, 46-72.

MAHER, L.J. (1972). Absolute pollen diagram of Redrock Lake, Boulder County, Colorado. Quat. Res., 2,531-553.

MAHER, L.J. (1977). Palynological studies in the Western arm of Lake Superior. Quat. Res., 7, 14-44.

MAHER, L.J. (1981). Statistics for microfossil concentration measurements employing samples spiked with marker grains. Rev. Palaeobot. Palynol, 32, 153-191.

MALEY, J. and LIVINGSTONE, D.A. (1983). Extension d'un element montagnard dans le sud du Ghana (Afrique de l'Ouest) au Pleistocene Superieur et a l'Holocene inferieur: premieres donnees polliniques. C. R. Acad. Sc. Paris II, 296, 1287-1292.

MALONEY, B.K. (1979). Man's influence on the vegetation of North Sumatra: a palynological study. Ph. D. thesis, University of Hull, England.

MALONEY, B.K. (1980). Pollen analytical evidence for early forest clearance in North Sumatra. Nature, 287, 324-326.

MALONEY, B.K. (1981). A pollen diagram from Tao Sipinggan, a lake site in the Batak Highlands of North Sumatra, Indonesia. Mod. Quaternary Res. SE Asia, 6, 57-76.

MALONEY, B.K. (1984a). Inverted and other anomalous radiocarbon dates from Southeast Asian pollen sites: some comments. Mod. Quaternary. Res. SE Asia, 8, 43-47.

MALONEY, B.K. (1984b). A preliminary pollen diagram from Pea Sijajap, North Sumatra. Mod. Quaternary Res. SE Asia, 8, 35-42.

MARTIN, P.S. (1964). Palaeoclimatology and a tropical pollen profile. Report of the VIth International Congress on Quaternary, Warsaw, 1961. Vol ii, 319-323, Palaeoclimatological Section, Lodz.

MATTHEWS, J. (1969). The assessment of a method for the determination of absolute pollen frequencies. New Phytol., 68, 161-166.

MEYER, H.A. (1952). Structure, growth and grain in balanced uneven aged forests. J. Forest., 50, 85-92.

MORLEY, R.J. (1976). Vegetation change in West Malesia during the Late Quaternary Period. Ph.D. thesis, University of Hull, England.

MORLEY, R.J. (1981a). The palaeoecology of Tasek Bera, a lowland swamp in Pahang, West Malaysia. Singapore J. Trop. Geogr., 2, 49-56.

MORLEY, R.J. (1981b). Development and vegetation dynamics of a lowland ombrogenous peat swamp in Kalimantan Tengah, Indonesia. J. Biogeogr., 8, 383-404.

MORLEY, R.J. (1982). A palaeoecological interpretation of a 10000 year pollen record from Danau Padang, Central Sumatra, Indonesia. J. Biogeogr., 9, 151-190.

MORLEY, R.J., FLENLEY, J.R. and KARDIN, M.K. (1973). Preliminary notes on the stratigraphy and vegetation of the swamps and small lakes of the Central Sumatran Highlands. Sumatra Research Bulletin, 2, 50-60.

MORRISON, M.E.S. (1961). Pollen analysis in Uganda. Nature, 190, 483-486.

MORRISON, M.E.S. (1968). Vegetation and climate in the uplands of south-western Uganda during the later Pleistocene period. I. Muchoya Swamp, Kigezi District. J. Ecol., 56, 363-384.

MULLER, J. (1965). Palynological study of Holocene peat in Sarawak. Symposium on ecological research in humid tropics vegetation, Kuching, Sarawak, 1963, 147-156, UNESCO.

MULLER, J. (1975). Pollen analytical studies of peat and coal from northwest Borneo. Mod. Quaternary Res. SE Asia, 1, 83-86.

NOSSIN, J.J. (1964). Beach ridges on the east coast of Malaya. J. Trop. Geogr., 18, 111-117.

O'SULLIVAN, P.E. and RILEY, D.H. (1974). Multivariate numerical analysis of surface pollen spectra from a native Scots pine forest. Pollen Spores, 16, 239-264.

OWEN, R.B., BARTHELME, J.W., RENAUT, R.W. and VINCENS, A. (1982). Palaeolimnology and archaeology of Holocene deposits north-east of Lake Turkana, Kenya. Nature, 298, 523-529.

PADANG, M. NEUMANN van (1951). Catalogue of the active volcanoes of the World. 1. Indonesia. International Volcanological Association, Napoli.

PECK, R.M. (1973). Pollen budget studies in a small Yorkshire catchment. In Quaternary Plant Ecology (ed. H.J.B.

Birks and R.G.West), 43-60, Blackwell, Oxford.

PECK, R.M. (1974). A comparison of four absolute pollen preparation techniques. *New Phytol.*, 73, 567-587.

PENNINGTON, W. (1973). Absolute pollen frequencies in the sediments of lakes of different morphometry. In *Quaternary Plant Ecology* (ed. H.J.B. Birks and R.G. West), 79-104, Blackwell, Oxford.

PENNINGTON, W. and BONNY A.P. (1970). Absolute pollen diagram from the British Late-glacial. *Nature*, 226, 871-873.

PETERSON, J.A. and HOPE, G.S. (1972). Lower limit and maximum age for the last major advance of the Carstensz Glaciers, West Irian. *Nature*, 240, 36-37.

PETERSON, J.A., HOPE, G.S. and MITTON, R. (1973). Recession of snow and icefields of Irian Jaya, Republic of Indonesia. *Zeitschrift fur Gletscherkunde und Glazialgeologie*, 9, 73-87.

POHL, F. (1937). Die pollenerzeugung der windbluter. *Botanisch. Centralblatt*, 56A, 365-470.

POLAK, E. (1933). Ueber Torf und Moor in Niederlandisch Indien. *Proc. K. ned. Akad. Wet.*, 30, 1-84.

POORE, M.E.D. (1964). Integration in the plant community. *J. Ecol.*, 52 Suppl., 213-226.

POORE, M.E.D. (1968). Studies in Malaysian rain forest I. The forest on Triassic sediments in Jengka forest reserve. *J. Ecol.*, 56, 143-196.

POST, L. von (1916). Om skogstradpollen i sydsvenska torfmosselagerfoljder. *Geol. For. Stockh. Forh.*, 38, 384-394.

POWELL, J.M. (1970). *The impact of man on the vegetation of the Mt Hagan Region, New Guinea*. Ph.D. thesis, Australian National University, Canberra.

PROCTOR, M. and YEO, P. (1973). *The Pollination of Flowers*. Collins, London. 418 pp.

RICHARDS, P.W. (1952). *The Tropical Rain Forest*. Cambridge University Press, Cambridge. 450 pp.

ROSSIGNOL-STRICK, M. and DUZER, D. (1979). West African vegetation and climate since 22500 B.P. from deep-sea cores palynology. *Pollen Spores*, 21, 105-134.

ROWLEY, J.R. and ROWLEY, J. (1956). Vertical migration of spherical and asphaerical pollen in a sphagnum bog. Proc. Minnesota Acad. Sci., 24, 28-30.

RUDOLPH, K. and FIRBAS, F. (1926). Pollen analytische Untersuchung subalpiner moores des Reisengebirges. Ber. dt. bot. Ges., 44, 227-238.

RYMER, L. (1973). Modern pollen rain studies in Iceland. New Phytol., 72, 1367-1373.

SALGADO-LABOURIAU, M.L. (1979). Modern pollen deposition in the Venezuelan Andes. Grana, 18, 53-68.

SALGADO-LABOURIAU, M.L. (1980). A pollen diagram of the Pleistocene - Holocene boundary of Lake Valencia, Venezuela. Rev. Palaeobot. Palynol., 30, 297-312.

SALGADO-LABOURIAU, M.L. and SCHUBERT, C. (1976). Palynology of Holocene peat bogs from the Central Venezuelan Andes. Palaeogeogr. Palaeoclimatol. Palaeoecol., 19, 147-156.

SALGADO-LABOURIAU, M.L. and SCHUBERT, C. (1977). Pollen analysis of a peat bog from Laguna Victoria (Venezuelan Andes). Acta Cient. Venezolana, 28, 328-332.

SCHNITGER, F.M. (1938). The archaeology of Hindoo Sumatra. Int. Archiv. f. Ethnogr., 35, Suppl., 1-44.

SCHREVE-BRINKMAN, E.J. (1978). A palynological study of the upper Quaternary sequence in the El Abra Corridor and rock shelters (Colombia). Palaeogeogr. Palaeoclimatol. Palaeoecol., 25, 1-109.

SHACKLETON, N.J. (1978). Some results of the CLIMAP project. In Climatic change and variability (ed. A.B. Pittock, L.A. Frakes, D. Jenssen, J.A. Petersen and J. Zillman), 69-76, Cambridge University Press, Cambridge.

SIMKIN, T., SIEBERT, L., McCLELLAND, L., BRIDGE, D., NEWHALL, C. and LATTER, J.H. (1981). Volcanoes of the World. A regional directory, gazetteer and chronology of volcanism during the last 10000 years. Smithsonian Inst, Hutchinson, Stroudburg, Pennsylvannia.

SIMPSON, E.H. (1949). Measurement of diversity. Nature, 163,688.

SOEPADMO, E. (1973). Fagaceae. Flora Malesiana, I, 7, 265-403.

SOWUNMI, M.A. (1981a). Aspects of Late Quaternary vegetational changes in West Africa. *J. Biogeogr.*, 8, 457-474.

SOWUNMI, M.A. (1981b). Nigerian vegetational history from the Late Quaternary to the present day. *Palaeoecol. of Africa*, 13, 217-234.

STEENIS, C.G.G.J. van (1934-36). On the origin of the Malaysian mountain flora. *Bull. Jard. bot. Buitenz. Series III*; Part I, *13*, 135-262; Part II, 13, 289-417, Part III, 14, 56-72.

STEENIS, C.G.G.J. van (1938). Exploraties in de Gajo-Landen. Algemeene Resultaten der Losir-Expeditie, 1937. *Tijdschr. K. ned. aardrijksk. Genoot*, 55, 728-801.

STEENIS, C.G.G.J. van (1962). The mountain flora of the Malaysian tropics. *Endeavor*, 21, 183-193.

STEENIS, C.G.G.J. van (1964). Plant geography of the mountain flora of Mt Kinabalu. *Proc. R. Soc. B.*, 161, 7-38.

STEENIS, C.G.G.J. van (1972). *The mountain flora of Java*. E.J. Brill, Leiden, 90 pp.

STEENIS, C.G.G.J. van and SCHIPPERS-LAMMERTSE, A.F. (1965). Concise plant geography of Java. In *Flora of Java* (ed. C.A. Backer and R.C. Bakhuizen van den Brink), vol 2, 1-72, N.V.P. Noordhoff, Groningen.

STOCKMARR, J. (1971). Tablets with spores used in absolute pollen analysis. *Pollen Spores*, 13, 615-621.

STUIJTS, I. (1984). Palynological study of Situ Bayongbong, West Java. *Mod. Quaternary Res. SE Asia.*, 8, 17-27.

SUTTON, O.G. (1932). A theory of eddy diffusion in the atmosphere. *Proc. Roy. Soc. A*, 135, 143-165.

SUTTON, O.G. (1947). The theoretical distribution of airborne pollution from factory chimneys. *Quart. J. R. Met. Soc.*, 73, 426-436.

SYMINGTON, C.F. (1933). The study of secondary growth on rain forest sites in Malaya. *Malay. Forester*, 2, 107-117.

SYMINGTON, C.F. (1943). Foresters' manual of Dipterocarps. *Malayan Forest Records* No. 16, 244 pp.

TALBOT, M.R., LIVINGSTONE, D.A., PALMER, R.G., MALEY, J., MELACK, J.M., DELIBRIAS, G. and GULLIKSEN, S. (1984). Preliminary results from sediment cores from Lake Bosumtwi, Ghana. Palaeoecol. of Africa, 16, 173-192.

TAUBER, H. (1965). Differential pollen dispersal and the interpretation of pollen diagrams, with a contribution to the interpretation of the elm fall. Danm. geol. Unders. II, 89, 69 pp.

TAUBER, H. (1967a). Investigations of the mode of pollen transfer in forested areas. Rev. Palaeobot. Palynol., 3, 277-286.

TAUBER, H. (1967b). Differential pollen dispersion and filtration. In Quaternary Palaeoecology (ed. E.J. Cushing and H.E. Wright), 131-141, Yale University Press.

TAUBER, H. (1977). Investigations of aerial pollen transport in a forested area. Dansk. Botanisk. Arkiv., 32, 121 pp.

TINSLEY, H. and SMITH, R.T. (1974). Surface pollen studies across a woodland/heath transition and their application to the interpretation of pollen diagrams. New Phytol., 73, 547-565.

TJIA, H.D., FUJII, S., KIGOSHI, K., SUGIMURA, A. and ZAKARIA, T. (1972). Radiocarbon dates of elevated shorelines, Indonesia and Malaysia. Part I. Quat. Res., 2, 487-495.

TURNER, J. (1964). Surface sample analyses from Ayrshire, Scotland. Pollen Spores, 6, 583-592.

VERSTAPPEN, H. Th. (1964). The geomorphology of Sumatra. J. Trop. Geogr., 18, 184-191.

VERSTAPPEN, H. Th. (1973). A geomorphological reconnaissance of Sumatra and adjacent islands (Indonesia). Wolters-Noordhoff, Groningen. 194 pp.

WALKER, D. and FLENLEY, J.R. (1979). Late Quaternary vegetational history of the Enga District of Upland Papua New Guinea. Phil. Trans. R. Soc. B 286, 265-344.

WEST, R.G. (1977). Pleistocene Geology and Biology, 2nd edition. Longman, London, 440 pp.

WHITMORE, T.C. (1975). Tropical Rain Forests of the Far East. Oxford University Press, Oxford, 282 pp.

WHITMORE, T.C. and BURNHAM, C.P. (1969). The altitudinal sequence of forests and soils on granite near Kuala Lumpur. Malay. Nat. J., 22, 99-118.

WIJMSTRA, T.A. (1967). A pollen diagram from the upper Holocene of the Lower Magdalena Valley. Leid. geol. Meded., 39, 261-267.

WIJMSTRA, T.A. (1969). Palynology of the Alliance Well. Geologie Mijnb., 48, 125-133.

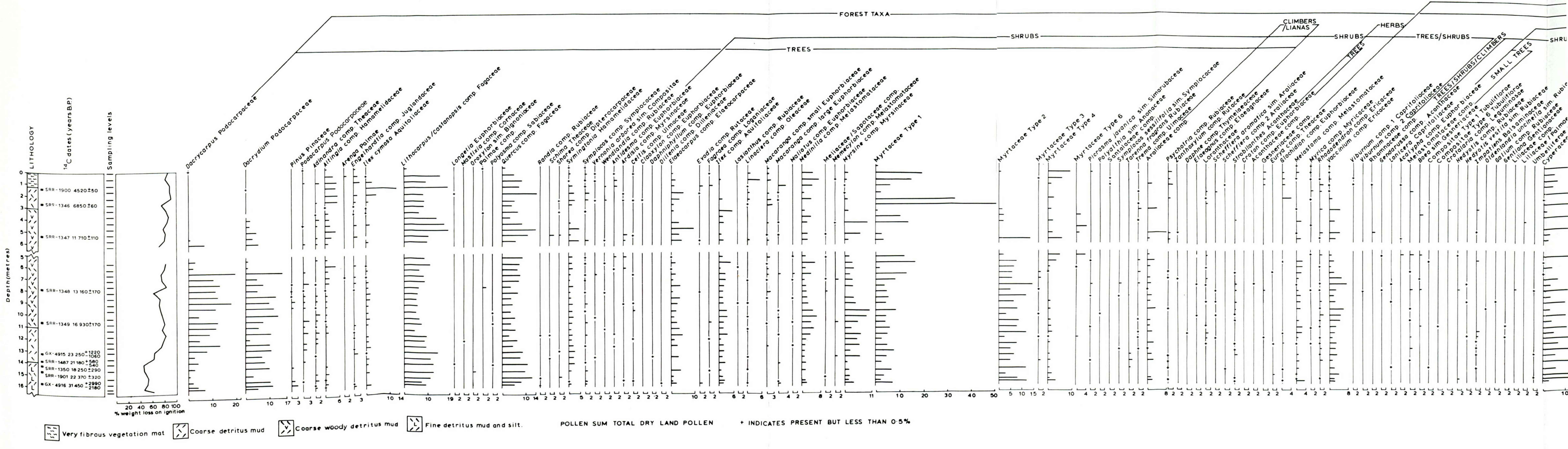
WIJMSTRA, T.A. and HAMMEN, T. van der (1966). Palynological data on the history of tropical savannas in Northern South America. Leid. geol. Meded., 38, 71-90.

WILLIAMS, P.W., McDOUGALL, I. and POWELL, J.M. (1972). Aspects of the Quaternary geology of the Tari-Koroba area, Papua. J. geol. Soc. Aust., 18, 333-347.

WYATT-SMITH, J. (1964). A preliminary vegetation map of Malaya with descriptions of the vegetation types. J. Trop. Geogr., 18, 200-213.

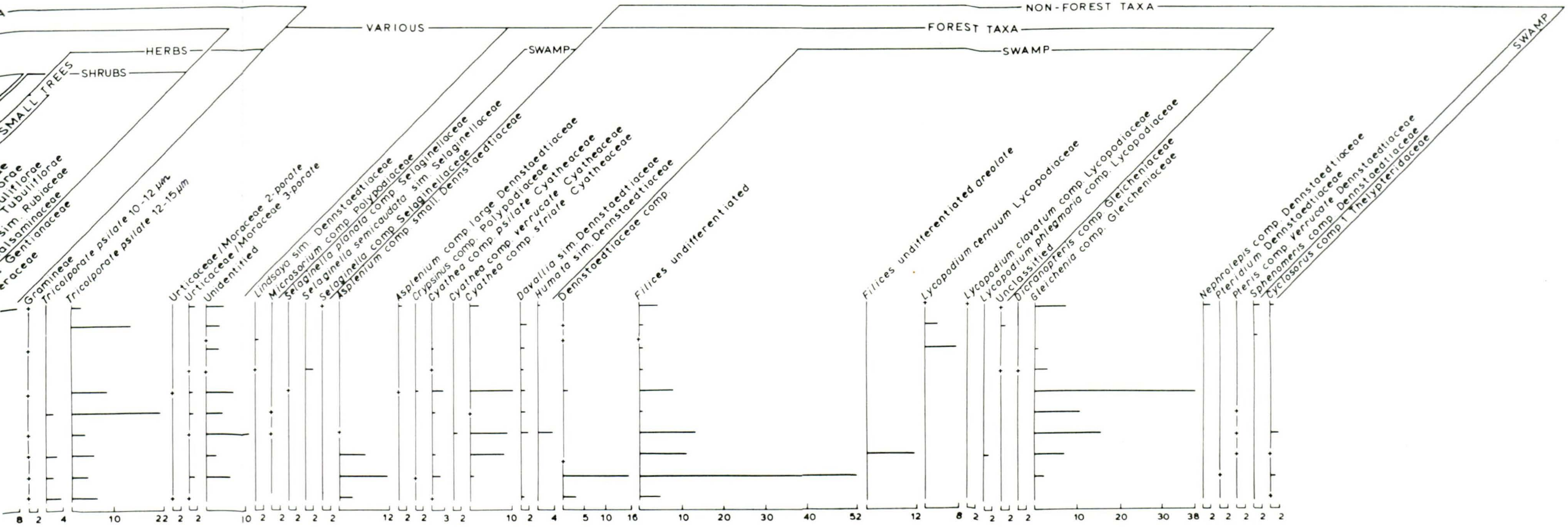
ZEIST, W. van (1984). The prospects of palynology for the study of prehistoric man in Southeast Asia. Mod. Quaternary Res. SE Asia, 8, 1-15.

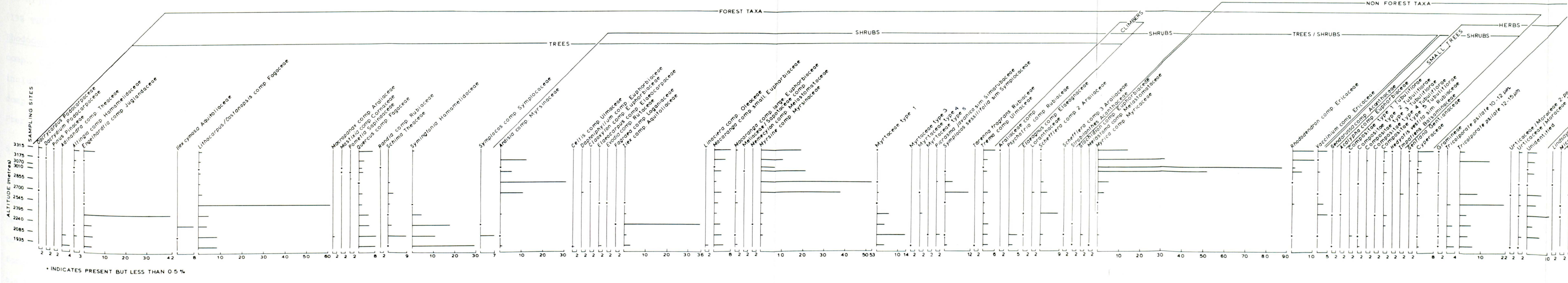
ZEIST, W. van, POLHAUPESSY, N.A. and STUIJTS, L.M. (1979). Two pollen diagrams from West Java, a preliminary report. Mod. Quaternary Res. SE Asia., 5, 43-56.



POLLEN SUM TOTAL DRY LAND POLLEN

+ INDICATES PRESENT BUT LESS THAN 0·5%


NON-FOREST TAXA
VARIOUS
FOREST TAXA
SWAMP
HERBS
SHRUBS
SMALL TREES
SWAMP
SWAMP
Gramineae
Tricolporate psilate 10-12 µm
Tricolporate psilate 12-15 µm
Urticaceae/Moraceae 2-porate
Urticaceae/Moraceae 3-porate
Unidentified
Lindsaya sim. Dennstaedtiaceae
Microsorium comp. Polypodiaceae
Selaginella planata comp. Selaginellaceae
Selaginella semicaudata sim. Selaginellaceae
Selaginella comp. Selaginellaceae
Asplenium comp small Dennstaedtiaceae
Asplenium comp large Dennstaedtiaceae
Crypsinus comp. Polypodiaceae
Cyathea comp. psilate Cyatheaceae
Cyathea comp. verrucate Cyatheaceae
Cyathea comp striate Cyatheaceae
Davallia sim. Dennstaedtiaceae
Humata sim. Dennstaedtiaceae
Dennstaedtiaceae comp
Filices undifferentiated
Filices undifferentiated areolate
Lycopodium cernuum Lycopodiaceae
Lycopodium clavatum comp. Lycopodiaceae
Lycopodium phlegmaria comp. Lycopodiaceae
Unclassified
Dicranopteris comp Gleicheniaceae
Gleichenia comp. Gleicheniaceae
Nephrolepis comp. Dennstaedtiaceae
Pteridium Dennstaedtiaceae
Pteris comp verrucate Dennstaedtiaceae
Sphenomeris comp. Dennstaedtiaceae
Cyclosorus comp 1 Thelypteridaceae
8 2 4 10 22 2 2 10 2 2 2 2 2 12 2 2 3 2 10 2 4 5 10 16 10 20 30 40 52 12 8 2 2 2 2 10 20 30 38 2 2 2 2 2



• INDICATES PRESENT BUT LESS THAN 0.5 %

NON-FOREST TAXA
SWAMP TAXA
HERBS
SHRUBS
VARIOUS
TREES/SHRUBS
SWAMP
FOREST TAXA
SWAMP
NON-FOREST TAXA
SWAMP
ositae type 2 Tubuliflorae
Compositae type 6 Tubuliflorae
Compositae type 7 Tubuliflorae
Compositae Liguliflorae
Impatiens Balsaminaceae
Drymaria comp. Caryophyllaceae
Liliaceae comp.
Plantago major Plantaginaceae
Cyperaceae
Gramineae
Hydrocotyle comp. Umbelliferae
Laurembergia comp. Haloragidaceae
Monocotyledon undifferentiated
Burmannia Burmanniaceae
Eriocaulon Eriocaulaceae
Utricularia Lentibulariaceae
Xyris Xyridaceae
Pandanus Pandanaceae
Tricolporate psilate 10-12 µm
Tricolporate psilate 12-15 µm
Menispermaceae comp.
Urticaceae/Moraceae 2-porate
Urticaceae/Moraceae 3-porate
Urticaceae / Moraceae 4-porate
Indeterminate 18
Unidentified
Lindsaya sim. Dennstaedtiaceae
Microlepia sim. Dennstaedtiaceae
Microsorium comp. Polypodiaceae
Selaginella planata comp. Selaginellaceae
Asplenium comp. small. Dennstaedtiaceae
Asplenium comp. large. Dennstaedtiaceae
Crypsinus comp. Polypodiaceae
Cyathea comp. psilate Cyatheaceae
Cyathea comp verrucate Cyatheaceae
Cyathea comp. striate Cyatheaceae
Cyathea comp. irregularly striate Cyatheaceae
Davallia sim. Dennstaedtiaceae
Humata sim. Dennstaedtiaceae
Hymenophyllum comp. Hymenophyllaceae
Dennstaedtiaceae comp. scabrate-verrucate
Filices undifferentiated
Filices undifferentiated areolate
Lycopodium cernuum Lycopodiaceae
Lycopodium clavatum comp. Lycopodiaceae
Lycopodium phlegmaria comp. Lycopodiaceae
Unclassified
Dicranopteris comp. Gleicheniaceae
Gleichenia comp. Gleicheniaceae
Lygodium Schizaeaceae
Nephrolepis comp. Dennstaedtiaceae
Pteridium Dennstaedtiaceae
Pteris comp. verrucate Dennstaedtiaceae
Sphenomeris comp. Dennstaedtiaceae
Cyclosorus comp. 1 Thelypteridaceae
10 20 30 34 2 7 2 2 2 2 2 10 20 30 40 10 20 30 40 51 2 5 2 2 2 2 5 2 5 5 2 3 8 4 6 10 13 3 3 10 20 2 5 2 2 4 2 8 2 7 6 2 2
10 20 30 40 50
25 50 75 100 125
2
10 20 30 40 50
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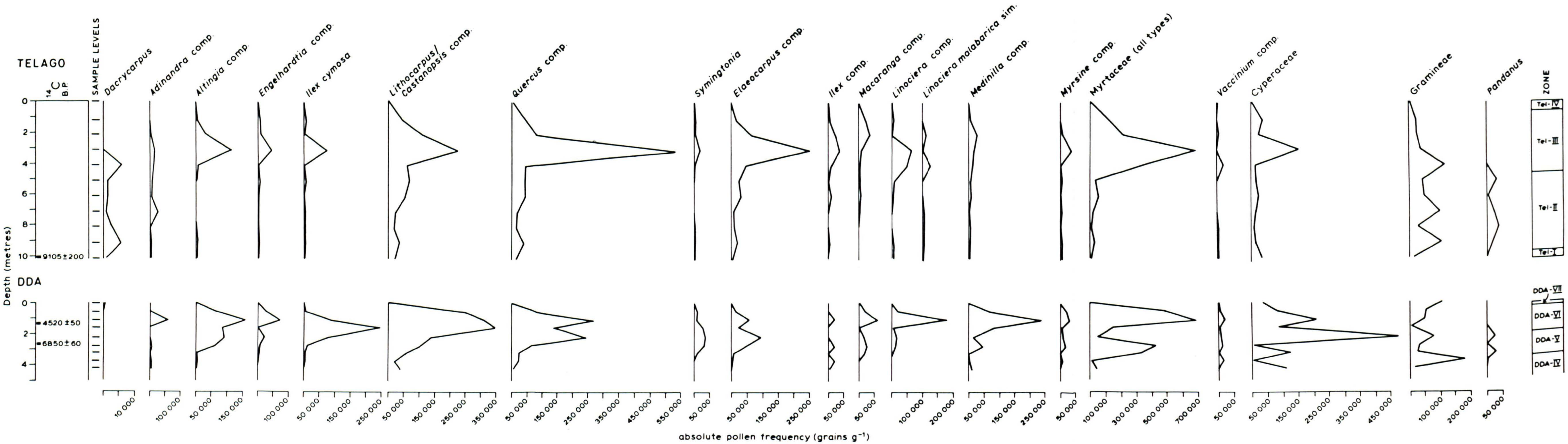
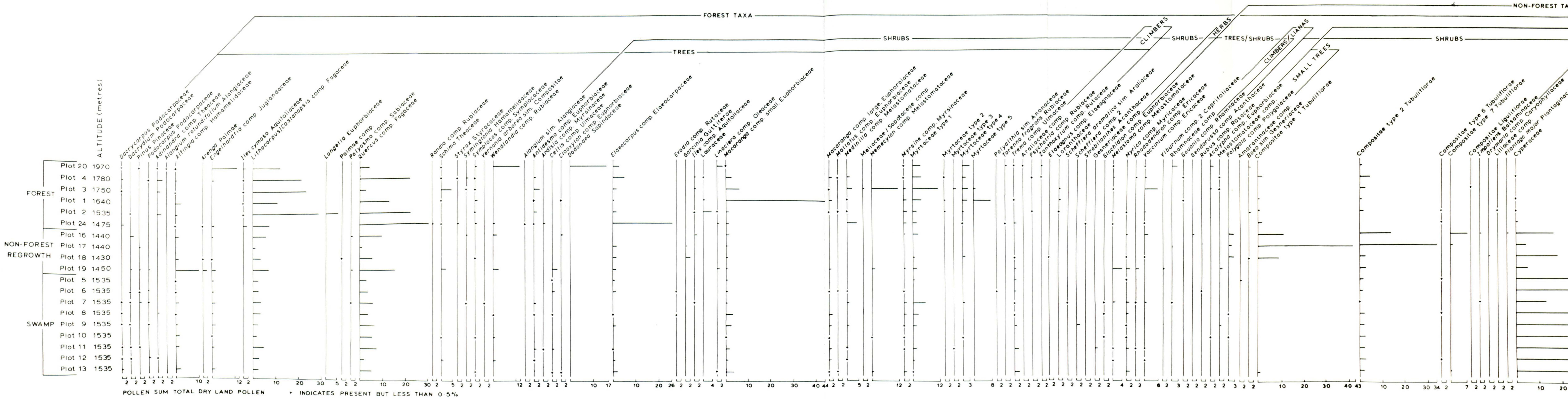
2 10
10 20 30 40
25 50 75 100


TELAGO
DDA
Depth (metres)
14C B.P.
9105±200
4520±50
6850±60
SAMPLE LEVELS
Dacrycarpus
Adinandra comp.
Altingia comp.
Engelhardtia comp.
Ilex cymosa
Lithocarpus/ Castanopsis comp.
Quercus comp.
Symingtonia
Elaeocarpus comp.
Ilex comp.
Macaranga comp.
Linociera comp.
Linociera malabarica sim.
Medinilla comp.
Myrsine comp.
Myrtaceae (all types)
Vaccinium comp.
Cyperaceae
Gramineae
Pandanus
ZONE
Tel-IV
Tel-III
Tel-II
Tel-I
DDA-VII
DDA-VI
DDA-V
DDA-IV
0
2
4
6
8
10
10 000
100 000
50 000
150 000
250 000
350 000
450 000
550 000
200 000
300 000
500 000
700 000
absolute pollen frequency (grains g⁻¹)


NON-FOREST TAXA
SWAMP TAXA
HERBS
HERBS
TREES/SHRUBS
TREES/SHRUBS/CLIMBERS
TREES
SHRUBS
SMALL TREES
VARIOUS
AQUATICS
FOREST & SWAMP TAXA
NON-FOREST TAXA
FOREST TAXA
SWAMP TAXA
SWAMP TAXA
ataceae
eae
p. Ericaceae
p. Ericaceae
num comp. 1 Caprifoliaceae
burnum comp. 2 Caprifoliaceae
Rhamnaceae comp.
Gendarussa comp. Acanthaceae
Lonicera Caprifoliaceae
Acalypha comp. Euphorbiaceae
Melastomataceae comp.
Boea sim. Gesneriaceae
Compositae Type 1 Tubuliflorae
Compositae Type 6 Tubuliflorae
Crotalaria comp. Leguminosae
Hedyotis comp. Rubiaceae
Hedyotis vestita sim. Rubiaceae
Impatiens Balsaminaceae
Oldenlandia uncinella sim. Rubiaceae
Galium comp. Rubiaceae
Gentiana Gentianaceae
Liliaceae comp.
Liliaceae / Palmae comp.
Umbelliferae comp. 1
Cyperaceae
Gramineae
Hydrocotyle comp. Umbelliferae
Laurembergia comp. Haloragidaceae
Nepenthes comp. Nepenthaceae
Monocotyledon undifferentiated
Eriocaulon Eriocaulaceae
Xyris Xyridaceae
Pandanus Pandanaceae
Tricolporate psilate 10-12 μm
Tricolporate psilate 12-15 μm
Menispermaceae comp.
Urticaceae / Moraceae 2-porate
Urticaceae / Moraceae 3-porate
Urticaceae / Moraceae 4-porate
Indeterminate 18
Unidentified
Potamogeton Potamogetonaceae
Typha comp. Typhaceae
Athyrium comp. Dennstaedtiaceae
Microsorium comp. Polypodiaceae
Selaginella caulescens sim. Selaginellaceae
Selaginella planata comp. Selaginellaceae
Selaginella semicaudata sim. Selaginellaceae
Selaginella comp. Selaginellaceae
Asplenium comp. small Dennstaedtiaceae
Asplenium comp. large Dennstaedtiaceae
Blechnum comp. Dennstaedtiaceae
Crypsinus comp. Polypodiaceae
Cyathea comp. psilate Cyatheaceae
Cyathea comp. verrucate Cyatheaceae
Cyathea comp. striate Cyatheaceae
Cyathea comp. irregular-striate Cyatheaceae
Davallia sim. Dennstaedtiaceae
Humata sim. Dennstaedtiaceae
Hymenophyllum comp. Hymenophyllaceae
Dennstaedtiaceae comp. Scabrate-verrucate
Filices undifferentiated
Filices undifferentiated areolate
Lycopodium cernuum Lycopodiaceae
Lycopodium clavatum comp. Lycopodiaceae
Lycopodium phlegmaria comp. Lycopodiaceae
Lycopodium comp. Lycopodiaceae
Unclassified
Dicranopteris comp. Gleicheniaceae
Gleichenia comp. Gleicheniaceae
Nephrolepis comp. Dennstaedtiaceae
Pteridium Dennstaedtiaceae
Pteris comp. psilate Dennstaedtiaceae
Pteris comp. verrucate Dennstaedtiaceae
Pyrrosia sim. Polypodiaceae
Sphenomeris comp. Dennstaedtiaceae
Cyclosorus comp. 1 Thelypteridaceae
Cyclosorus comp. 2 Thelypteridaceae
Zone
VII
VI
V
IV
III
II B
II A
I
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
10 20 30 40
10 20 30 40 50 60
2 2 2 2 2 3 3 5 8 8 2 6 4 2 4
10 10 20 30 40 50 60
3 2 3 2 4 2 4 2 2 2 5 2 2 2 4 3 2 4
10 20 30 40 50 60 70 75
10 12
10 20 30 35
7 2 2
10 2 3 5 4 6 10 12 2 7 2 2

POLLEN SUM TOTAL DRY LAND POLLEN

+ INDICATES PRESENT BUT LESS THAN 0.5%


FOREST TAXA
NON-FOREST TA
TREES
SHRUBS
CLIMBERS
HERBS
TREES/SHRUBS
CLIMBERS/LIANAS
SMALL TREES
ALTITUDE (metres)
FOREST
NON-FOREST REGROWTH
SWAMP
Plot 20 1970
Plot 4 1780
Plot 3 1750
Plot 1 1640
Plot 2 1535
Plot 24 1475
Plot 16 1440
Plot 17 1440
Plot 18 1430
Plot 19 1450
Plot 5 1535
Plot 6 1535
Plot 7 1535
Plot 8 1535
Plot 9 1535
Plot 10 1535
Plot 11 1535
Plot 12 1535
Plot 13 1535
Dacrycarpus Podocarpaceae
Dacrydium Podocarpaceae
Pinus Pinaceae
Podocarpus Podocarpaceae
Adinandra comp Theaceae
Alangium rotundifolium Alangiaceae
Altingia comp Hamamelidaceae
Arenga Palmae
Engelhardtia comp Juglandaceae
Ilex cymosa Aquifoliaceae
Lithocarpus/Castanopsis comp Fagaceae
Longetia Euphorbiaceae
Palmae comp
Polyosma comp Sabiaceae
Quercus comp Fagaceae
Randia comp Rubiaceae
Schima Theaceae
Styrax Styracaceae
Symingtonia Hamamelidaceae
Symplocos comp Symplocaceae
Vernonia arborea sim Compositae
Wendlandia comp Rubiaceae
Alangium sim Alangiaceae
Antidesma comp Euphorbiaceae
Ardisia comp Myrsinaceae
Celtis comp Ulmaceae
Claoxylon comp Euphorbiaceae
Dodonaea Sapindaceae
Elaeocarpus comp Elaeocarpaceae
Evodia comp Rutaceae
Garcinia Guttiferae
Ilex comp Aquifoliaceae
Lauraceae
Linociera comp Oleaceae
Macaranga comp small Euphorbiaceae
Macaranga comp large Euphorbiaceae
Mallotus comp Euphorbiaceae
Medinilla comp Melastomataceae
Meliaceae/Sapotaceae comp
Memecylon comp Melastomataceae
Myrsine comp Myrsinaceae
Myrtaceae type 1
Myrtaceae type 2
Myrtaceae type 3
Myrtaceae type 4
Myrtaceae type 5
Polyalthia sim Anonaceae
Tarenna fragrans Rubiaceae
Trema comp Ulmaceae
Araliaceae comp
Psychotria comp Rubiaceae
Zanthoxylum comp Rutaceae
Elaeagnus comp Elaeagnaceae
Loranthaceae
Schefflera aromatica sim Araliaceae
Schefflera comp 2
Strobilanthes Acanthaceae
Gesneriaceae comp
Glochidion comp Euphorbiaceae
Melastoma comp Melastomataceae
Myrica comp Myricaceae
Rhododendron comp Ericaceae
Vaccinium comp Ericaceae
Viburnum comp 2 Caprifoliaceae
Rhamnaceae comp
Gouania comp Rhamnaceae
Gendarussa comp Acanthaceae
Rubus comp Rosaceae
Acalypha comp Euphorbiaceae
Melastomataceae comp
Polygala comp Polygalaceae
Amaranthaceae comp
Boea sim Gesneriaceae
Compositae type 1 Tubuliflorae
Compositae type 2 Tubuliflorae
Compositae type 6 Tubuliflorae
Compositae type 7 Tubuliflorae
Compositae Liguliflorae
Impatiens Balsaminaceae
Drymaria comp Caryophyllaceae
Liliaceae comp
Plantago major Plantaginaceae
Cyperaceae
POLLEN SUM TOTAL DRY LAND POLLEN
• INDICATES PRESENT BUT LESS THAN 0·5%
2
10
12
20
26
30
34
40
43
44