THE IMPACT OF MAN ON THE VEGETATION OF THE MT HAGEN REGION, NEW GUINEA

by

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Thesis submitted for the degree of Doctor of Philosophy at the Australian National University.

May 1970.

Except where otherwise acknowledged
in the text, this thesis represents
the original research of the author.

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ACKNOWLEDGEMENTS

I wish to express my sincere thanks to Professor D. Walker, for his supervision and encouragement throughout the project. Mr D.E. Yen, who initially suggested the study, and Professor J. Golson, who made available the archaeological data, have also given encouragement and valuable advice on many aspects. Thanks are due also to Dr R.D. Hoogland and Mr R. Pullen, who identified the plant specimens, Messrs R.J. Lampert and W.A. Ambrose, for reports on the archaeological sites and for the photographs reproduced as Plate 32, Messrs K. Ingle and J.C. Saunders for the fossil wood identifications and Dr B. Ruxton and Mr J.M.A. Chappell, for the volcanic ash and clay analyses respectively. Mrs K. Evans and Mrs M. Ramsey assisted with laboratory work, Mrs E. Trickett and Mrs D. Lockie with the photographs and Miss W. Mumford, Mr J. Heyward and Mr M. Pancino with the diagrams. I wish to thank also Mr I.V. Manton and Mr G. Detmers, for permission to work on their Mt Hagen properties, Mr J.S. Womersley and the staff of the Lae herbarium, Mr R. Carne, Mr G. Hoy and Mr J. Lowien for help and discussion during the field work, and my field assistants, Rumbarg, Pete, Puri, Anis, Tiria and Ninitopa, who made the collection of the ecological data possible and helped in all other aspects of the field work.

The whole project has been financially supported by the Australian National University.

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CHAPTER 1

INTRODUCTION

Vegetation changes now being reported in pollen analytical studies from many tropical and subtropical areas are considered predominantly in terms of climate change, little attention being paid to the history of human influences on the vegetation there, despite the evidences provided by archaeology and ecological studies. The European situation has been used as a theoretical basis for correlation of climatic changes on a world wide scale, while the available evidence, especially from British diagrams, of human influences more often than not overriding those of climate, has hardly been considered.

The present study was undertaken to fill a gap in this knowledge and to try to show that the palynological method could provide objective evidence of human influence on vegetation in a tropical region, readily distinguishable from climatic influences. The investigation involved stratigraphic and palynological studies of lake and swamp sites in a highland region of New Guinea together with a local survey of present day vegetation and modern pollen rain. Combined with radiocarbon dating and archaeological correlations the study allows some conclusions to be drawn about early human influences in the area, as well as their relation to possible vegetation changes induced by climate or other factors.

The influence of primitive man on the vegetation of the tropics, in particular with respect to the development of grasslands and savannahs there, is a large and controversial subject. Many opinions have been expressed but few detailed and critical studies have been carried out.

Grasslands occur throughout the tropical world and in very many cases there is dispute as to whether they are man-induced or natural in origin. Thus in Africa, Stamp (1964) states that most if not all of the tropical grasslands are man-induced while Michelmore (1939) considers they are natural, in Ceylon differing opinions for both grasslands and savannahs are held by Holmes (1951) and de Rosayro (1963), in South America by Richards (1952), Beard (1953) and De La Rue (1958). For Indonesia Dimly (1963) states that an estimated 17 million hectares of grassland are all man-induced, for India Whyte (1957) expresses the same opinion, as does Quisumbing (1963) for the Philippines. For the Pacific Islands in general Fosberg (1962) considers that the middle and low altitude grasslands result from, or have been vastly expanded by, man's activities, while De La Rue (1958) suggests that they are climatic in origin. In New Guinea the lowland savannahs are considered to be possibly natural in origin but greatly extended in area by human influences (Lane-Poole 1925, Heyligers 1965) while other types of grassland are variously considered anthropogenic in origin or natural (Taylor 1964a, 1964b, Heyligers 1965, Ro[illegible]s 1960, 1963, Haantjens et al 1965).

It appears to be fairly widely accepted that, even if not originated by man's action, at least many of the tropical grasslands have been extended by his influence, especially by his methods of shifting cultivation, his use of fire and grazing of domestic animals (Spencer 1966, Bartlett 1956). However, once again controversy reigns as to the effect of each of these factors. Some authors (De La Rue 1958, Robbins 1963) consider that shifting cultivation alone can be responsible for the degradation of forests to grassland but as Conklin (1959) points out for the Phillippines 'the simple equation of grassland climax with shifting cultivation is inadequate.' Other factors such as population density and distribution, climate, topography, vegetation and soils, use of fire and grazing and hunting practices are extremely important and must be taken into consideration. Conroy (1963) discussing New Guinea and Barrau (1959) Melanesia express similar views. The shifting cultivator, more often than not, recognizes the value of his natural resources and is conscious of conservation (Conklin 1957, Pelzer 1958).

Fire is perhaps the most important single factor in the development of grasslands, whether natural fires caused by lightning, volcanism or other means (Komarek 1964, Daubenmire 1968), or fires started purposefully or accidentally by man (Stewart, 1956). Fires appear to do little damage in undisturbed tropical forests as they take place under exceptional weather conditions and are usually local (Richards, 1952). Conklin points out also that 'where climatic and terrain conditions are ideal for swidden agriculture, a single firing of cut jungle does not - by itself - start a succession to grassland.' However, repeated burning of the same site over a period of time may well do so and many examples have been cited of the combined effects of cutting and repeated burning (Budowski 1956, Pelzer 1945). In New Guinea it is widely held that a combination of these practices has led to the development of large areas of grassland, especially in the highlands and that fire is the factor maintaining them (Keleny, 1963).

Once established it is generally agreed that savannah and grasslands are maintained predominantly by fire, which if often used for hunting purposes, in warfare, for track clearing and for 'improving' grass for grazing. Various authors consider fire is used carelessly by the shifting cultivator but others disagree (see discussion 1963 UNESCO Symposium by Robbins, McIntosh, Keleny, Meggitt and Geddes). Browzing and grazing are also held responsible for the maintenance and extension of tropical grasslands (Bartlett 1956, Bryan 1963) but according to Conklin (1959) it may also aid in secondary regeneration, in that cattle keep the grass low and scatter undigested seeds of pioneer trees. In New Guinea the pig is the only grazing animal of any importance. It has been present in the country for at least 5000 years (Bulmer, 1966) and was most likely introduced by man as a semi-domestic or domestic animal, later becoming in part feral. The pig is omnivorous and when feral a forest dweller, tending to forage in undergrowth, uprooting seedlings and young growth (Aitchison, 1963). Both domestic and feral pigs cause damage to native gardens and fallow lands and when present in large numbers, as in parts of the highlands, they may well play a part in the maintenance of certain grasslands (Walker, 1966a).

If the pressures maintaining artificial grassland or savannah are removed then secondary succession to scrub and forest finally will take place and examples of this are readily available (Holmes 1952, Clayton 1958). However, the ease with which this secondary succession can take place and the time required for it to do so depends on many factors such as the extent of the cleared land, the duration of the interference by man and the clearance methods used. Soil, topography and climate affect the sequence. The floristic composition of the nearest forest, availability of the seed dispersal agents, the characteristics of the plants available to invade, their ability to compete and to withstand further destructive agents are important also (Kostermans, 1963).

The general degradation of soil structure, loss of organic matter, of soil moisture and of nutrients and the increase in erosion which has been stated generally to occur after shifting cultivation, burning and grazing (Pelzer 1958, Budowski 1956) has been questioned to some extent by more recent workers (Popenoe 1959, Watters 1960, Daubenmire 1968). Once again many factors are involved and few if any generalizations can be made. In New Guinea some highland soils are considered to be naturally infertile (Haantjens et al 1967, Rutherford & Perry 1965). While subsistence agriculture practices are considered generally to degrade the soil few studies appear to have been carried out to test this (Clarke & Street, 1967). It seems likely that in some highland areas, at least, soil fertility is maintained or even initially increased by the relatively elaborate methods of garden preparation used, by crop rotation and planted tree fallows. Certainly the Chimbu (Brookfield & Brown, 1963), the Enga (Waddell, 1968) and the Medlpa people classify soil types and are aware of their differing potential in crop production and the need for conservation measures.

It can perhaps be concluded from the above discussion that under favourable climatic, topographic and edaphic conditions, shifting cultivation practised by relatively low populations, employing long fallow periods and restricted use of fire, while altering the status of the forest is unlikely to result in the production of grasslands. However, given less favourable environmental conditions, and or greater land pressure, with populations employing shorter fallow periods and more frequent use of fire, then degradation to grassland is likely to occur. Once established it is relatively easily maintained by fire, especially if rainfall is seasonal, and regeneration will be a slow process, if possible at all. However, it must also be concluded that while a number of the studies cited above are based on critical observations and quantitative data, many are not and it seems obvious that until much more work is done on individual situations taking into account all the factors involved, few valid generalizations can be advanced.

One approach which perhaps can provide a more objective statement on the problem of the origin and development of grasslands in any particular area is the historical one, provided by pollen analysis. In Europe human influences on vegetation were recognized in pollen diagrams by Iversen (1949), Godwin (1944, 1956) and Troels-Smith (1960). They considered that from the time of neolithic man large areas of forest were modified and cleared for use in grazing and cultivation. These differing influences could be distinguished in pollen diagrams as temporary fluctuations in certain tree pollen frequencies and by the intermittent appearance or increase of herbaceous species, in particular ruderal and crop pollen. The main problem to be resolved was the distinction between climate, natural autogenic successions and human influences, and while controversy still prevails over individual cases, it is now widely accepted that these influences can be distinguished in most diagrams. Recent studies over many parts of the British Isles have shown in detail differing patterns of forest modification, clearance and land-use and combined with radiocarbon dating these have enabled widespread comparisons to be made. Thus the selective use of certain tree species (e.g. leaves and shoots of elm as fodder) considered by Troels-Smith (1960) to be reflected in the pollen diagram by changes in composition and frequency of tree pollen is observed also by Pennington (1964, 1965), Walker (1966b) and Dewar & Godwin (1963). Similarly, the occurrence of small, temporary clearances, comparable to the <u>landnam</u> of Iversen (1949) is indicated in many British diagrams and has been studied particularly by Turner (1965), Oldfield (1963) and Morrison (1959) among others. Widespread clearance or disforestation, followed by little forest regeneration or replacement by herbaceous communities has been observed in diagrams from later periods (Walker 1966b, Pennington 1965) as have changes in land-use such as from grazing to cultivation (Godwin 1967). Turner (1970) reviews much of the data on post-neolithic clearances and suggests sophisticated lines of study to resolve further the problems of identification and characterisation of clearance phases.

While it has been generally accepted that neolithic and later man has caused disturbances to natural vegetation, palaeolithic and mesolithic man on the other hand have been considered to do little damage, living within the forest and being dominated by it (Godwin 1956, Iversen 1949). Recently, Smith (1970) has questioned this view. He considers that mesolithic man, especially if using fire, could have caused considerable damage to forests, and he brings forward evidence from pollen analytical studies in Britain and other European countries to support his contentions. Once again, changes in pollen frequencies usually accepted as due to climatic influences are being considered as at least partially induced by human activities. Obviously further work is required before conclusions can be drawn.

The importance of climatic changes in the Quaternary period and the possible world-wide correlation of these, put forward by von Post (1946) has been upheld recently by Frenzel (1966) considering European and North American data but many workers would consider that for Europe anyway, 'much of the record is now explained in terms of prehistoric agriculture, soil retrogression and natural autogenic porcesses' (Morrison 1966) and while much of the North American work is acceptable as it stands (McAndrews 1966, Nichols 1967, Livingstone 1968), Davis (1965) states that man's influence on the vegetation there has not been considered adequately.

This certainly appears to be true for most of the tropical and subtropical studies now becoming available. Thus van Zinderen Bakker (1962a, 1962b, 1963, 1966) and Coetzee (1964, 1967) consider that all vegetation changes shown in their diagrams from East and South Africa (five in all) are climatic and they correlate them in detail with European changes. Both Livingstone (1967) and Morrison (1966, 1968) criticise their interpretations and consider that their detailed correlations with Europe are premature given the present inadequate state of knowledge of climate, vegetation tolerances and autecology and pollen rain for the African area today. Livingstone (1967) working in the Ruwenzori Mountains at slightly higher altitudes to Bakker and Coetzee (2960m, 3920m,3990m cf. 2400m, 2900m, 3140m) states that while some of the vegetation changes shown may be climatically determined, others must be considered in terms of indigenous land-use practices. Morrison (1966, 1968) also has difficulty in interpreting a Uganda site diagram (alt. 2256m) in terms of climatic change only. He points out the variation in altitudinal ranges of certain vegetation 'zones' on different mountains in Africa and questions the status of some of the 'climax' vegetation types, especially the Hagenia-forest. He considers that both volcanic activity and human influences may have affected the vegetation history of the site and hence it cannot be related in its entirety to climatic changes.

Archaeological studies in Africa suggest that early homonids were present there more than 1,000,000 years ago and that a widespread Early Stone Age culture was replaced about 50,000 years ago by more distinctive regional cultures (Cole, 1963). These included the Fauresmith culture, common in South Africa, the highlands of Kenya and Ethiopia and the Early Sangoan culture described from the Congo, Angola, Uganda and West Kenya. The latter is dated by Davies (1967) to approximately between 42,500-36,700 years B.P. and he considers that by this time the use of fire must have been well established throughout the continent. Later cultures also are described and dated radiometrically by Cole (1963) and Davies (1967); they include, among others, the Stillbay (38,000-10,000 B.P.) the Mangosian (10,000-7,000 B.P.) and the Wilton cultures (7,000 B.P.-) widespread over eastern and southern Africa, together with the Early Lupembar (30,000 years B.P.), the Late Lupembar and Tsilotian cultures (15,800-9,555 B.P.) recorded from Angola, Congo, Rhodesia, Zambia and western Kenya and many neolithic sites (dated from 7,000-4,300 B.P.) from N. Africa, Egypt and the Sudan. Davies suggests also that the Sangoan pick is adapted for digging and that the beginnings of tuber agriculture, in particular of African yams, may date back to Sangoan or Lupembar times. Grain agriculture probably developed later (millet and rice) and 'the knowledge of true agriculture and domestic animals must have reached Africa via Egypt ..... not much earlier than 4,000 B.C.' (Davies, 1967). Clark (1962, 1967) on the other hand, considers for sub-saharan Africa that intensified collecting dates from about 9,000 B.C. and incipient cultivation and 'vegeculture' from about 5,000 B.C. He suggests that the development of agriculture in the western and central forested regions only took place after the introduction of American and Asian food plants.

Van der Hammen and Gonzalez (1960a, 1960b) have studied a number of sites in Colombia, South America and they too have considered almost all vegetation changes shown in their diagrams to be climatically induced and comparable to various European changes. Human influences, shown by an increase in Poaceae and Plantago pollen have been dated from charcoal at 70cm depth to 1650 A.D. (1960a). It is interesting to note, however, that charcoal was used for radiocarbon dating as far down as 265cm - the date being 7010 (± 400) B.C. Was this charcoal formed in natural fires within Myrica-dominated vegetation or does it indicate human intervention? Certainly the date given is not unreasonable for man's presence in South America given other C14 dates such as 11,000 B.P. for the Palaeo-Indian stage in Brazil and Patagonia and 8,000 years B.P. for food-grinding implements in Argentina (Proto-Archaic Stage). Other, largely undated, archaeological sites attributable to these stages have been studied in Peru, Bolivia, Ecuador, Chile and Venezuela, while Pre-projectile stage sites older than 11,000 years (undated as yet) occur in Uruguay and Colombia as well (Kreiger 1964). In North America these stages date:

pre-projectile 38,000 years -
paleo-indian (13,000) - 11,000-9,000 years B.P.
proto-archaic 9,000 years B.P.

An agricultural site is recorded from Tehuacan, Mexico (MacNeish 1964a, 1964b, Mangelsdorf et al 1964) with plant collecting dated to ca 7200 B.C., gardening of wild and domesticated plants (corn, chili, avacardos, gourds, amaranth, tepary beans, squash) to ca 5200 B.C.

and large areas or ridged field systems recorded from lowlands South America and the Andean highlands are undated as yet but certainly agricultural (Denevan 1966, Parsons and Denevan 1967).

Recent palynological studies (Tsukada in Cowgill et al 1966, Tsukada and Deevey 1967) of sites in both lowland and highland areas of Guatemala and El Salvador provide evidence of human disturbance from ca 1000 years B.C. which is associated with southern Mayan cultures.

The results of a study of vegetation history of 2 lake sites in Western Iran, a region believed important as a locus for animal and plant domestication are given by van Zeist & Wright (1963) and van Zeist (1967). In both papers the authors consider vegetation changes predominantly in terms of climatic change. Van Zeist (1967) does discuss possible human influences in the upper part of his Lake Mirabad diagram, from 5500 B.P. onwards, but appears to consider climatic influences more important. Two levels, poor in pollen, rich in carbonised fragments he seems to imply have resulted from natural burning. He considers that no recent changes have occurred in the Lake Zeribar diagram, although in the earlier paper he and Wright (1963) suggested that a sharp minimum of oak at a depth of 5m (age between 0-546 B.P. at 10m) along with a peak in Plantago and grasses may point to temporarily more intensive human activity in the area. An earlier increase in Plantago and Cerealia-type grasses (at about 13,000 years B.P. extrapolated date) they suggest records climatic change rather than interference by prehistoric man. Again archaeological evidence points to the presence of man in the area more than 40,000 years ago, with cultivation possibly developing ca 11,000 years ago and domestication of grains ca 9000 years ago (Braidwood & Howe 1960, Helbaek 1959, Hole et al 1965).

Finally recent Japanese work must be considered. Tsukada (1966a) discusses late pleistocene vegetation and climate in Taiwan. He distinguishes four pollen zones, all of which show climatic changes (which can be correlated with Europe and America) and the uppermost also anthropogenic changes. He considers destruction of forests in the area took place 11,000 years ago, 'probably caused by early human activities', at the same time as a rise in subtropical and warm-temperate species is shown. 'Intensified agricultural activities' date from 4200 ± 60 B.P. and are indicated by 'a steep increase in grass pollen together with Liquidambar and Chenopodiaceae'. While the evidence for the more recent human impact is readily acceptable, it is difficult to see the evidence for the earlier disturbance, unless the so-called subtropical and warm-temperate elements are also indicators of secondary regrowth. The increase of pine, on the other hand, may indicate secondary forests (Tsukada, 1966b) although he considers here that it is due to long distance transport. Archaeological work in the same area provides a C14 date for pottery of the order of 19,670 ± 450 B.P., although some doubt exists in regard to this date (Chang & Stuiver, 1966). However, in Japan, Oba & Chard (1963) have pottery dated to some 10,000 years ago.

Cereal pollen occurs as early as 4500 B.P. in another diagram of Tsukada (1966b), from Lake Nojiri in central Japan and here widespread clearance of forests is indicated at some short time before 1530 ± 160 B.P.; subsequent to this, intensive cultivation of cereals and buckwheat (Fagopyrum) was carried on and a secondary forest of Pinus densiflora, Cryptomeria and Salix developed. These effects are well illustrated in the pollen diagram.

It can be concluded, then, that while a few authors consider and look for evidence of human impact on vegetation in tropical and subtropical areas, most have imputed climatic causes to vegetation changes. While this must frequently be true, that it is probably often an oversimplification is prompted by the widespread agreement that modern man has a much greater effect on vegetation than any other natural agent and by the long history of agricultural man now attested by archaeological materials radiometrically dated. Although many of the sites studied are at relatively high altitudes and often situated above or within 'undisturbed' forest, most have disturbed vegetation somewhere in the vicinity and it seems highly unlikely that human influences are not present in the pollen diagrams.

NEW GUINEA

The island of New Guinea, approximately 2,415km (1,500 miles) long and up to 805km (500 miles) wide, lies wholly within the tropical zone between the equator and latitude 11°S and extends from near 130°E to 151°E longitude. It is bounded to the north by the Pacific Ocean, by the Indian Ocean to the west, with nearest neighbours Indonesia and Australia. Politically the island is divided into three parts, the western half, West Irian, being administered by Indonesia, while the eastern half, the United Nations Trust Territory of New Guinea and the Territory of Papua, is administered by Australia.

New Guinea is an island of great variety and contrast in physiography, climate, vegetation and ethnography. Geologically it is relatively young (Thompson, 1967) and in many areas tectonic and volcanic activity are obvious and continuing. High parallel mountain ranges with peaks rising to 5040m (16,531 ft, Carstensz Pk.) in the west and to 4500 m (14,760 ft, Mt Wilhelm) in the east, and intermontane valleys with floors at 1520 to 2128 (5,000 to 7,000 ft) form a WNW-ESE backbone over much of the island. These are flanked by areas of lower relief, by low mountains and strongly dissected foothills and by broad plains to the north and south. A few large rivers drain the whole area. In Western New Guinea the Mamberamo Rv. drains to the north, the Eilanden and Digoel Rivers among others to the south; in eastern New Guinea the Sepik, Ramu and Markham drain to the north coast, the Fly, Kikori and Purari to the south.

Although New Guinea lies wholly within the 'humid tropics' its climate is far from uniform. Annual rainfall ranges between 2500mm (98 ins) and 3750m (146 ins) in most parts of the island, but may be as great as 6000mm (234 ins), as in the Finisterre Ranges and as low as 1000mm (39 ins), as in Port Moresby. In many areas seasonality is apparent. In the lowlands temperature and humidity are uniformly high throughout the year and diurnal variation is often greater than seasonal. With increased elevation temperatures become lower and humidity decreases slightly, while seasonal variations become more marked (Brookfield 1966, Brookfield & Hart 1966, Haantjens et al 1967).

Vegetation types are also extremely diverse, their distribution being related closely to climate, altitude, drainage conditions and the activities of man. Large areas are covered with dense tropical rain forest (about 80 per cent of eastern New Guinea according to Lea & Irwin, 1967) of extremely variable nature, while others are covered with swamp grasslands, swamp forests, savannah, subalpine and alpine communities, grasslands, secondary forests, native gardens and associated plantings. Many species are represented and the area generally is one of great taxonomic, ecological and phytogeographical interest. Various authors (Lane-Poole 1925, Brass 1941, 1964, Robbins 1960, Womersley & McAdam 1957) have classified the vegetation on the basis of a number of criteria, including climatic, edaphic, biotic, floristic and physiognomic.

In general, the rain forest, of widespread occurrence, changes physiognomically and floristically as altitude increases from a tall dense lowland tropical type through a variety of intermediates to a low, open, highland subalpine type. Various formations, associations, and communities are distinguished and described by Lane-Poole (1925), Womersley & McAdam (1957), Brass (1941, 1956, 1959), Robbins (1958) and Robbins and Pullen (1965) among others. Other forest types such as mangrove (*Rhizophora* spp.), lowland swamp (including *Nipa*, *Metroxylon*, *Pandanus*, *Campnospermum*), highland swamp (*Pandanus*, Myrtaceae and Podocarpaceae), monsoon and savannah are of more limited distribution and possibly are more readily distinguished. They have been described in general terms by Lane-Poole (1925) and Womersley & McAdam (1957), while more detailed accounts are given by Taylor (1964a, 1964b), Heyligers (1965), Robbins and Pullen (1965) and Robbins (1968).

Non-forest vegetation types in both the lowland and highland areas of New Guinea have been described and classified broadly into grassland, swamp and bog communities by most of the authors cited above. In the lowlands swamp communities are developed over large areas fringing the coast, on river banks and river floodplains. Various herbaceous communities are described by Heyligers (1965) and Robbins (1968). In the highlands valleys *Phragmites* and *Leersia* swamps are well developed locally and a number of mixed Poaceae-Cyperaceae bogs have been described for both these areas and higher altitudes (Robbins 1958, Robbins and Pullen 1965). Recently, Wade (1968) has studied the subalpine and alpine vegetation of Mt Wilhelm in detail; he describes and classifies a number of bog and fen communities. Extensive grasslands are found in the Waria, Markham, Ramu and Sepik valleys (McAdam, 1951), as well as dispersed throughout the intermontane valleys of the highlands and on the high mountains (Hoogland 1958, Robbins and Pullen 1965, Wade 1968). Native gardens, fallow lands and regrowth scrub and forests are an integral part of the landscape and have been considered in most of the studies cited previously. The natural landscape has been changed considerably, especially in the highlands, where large populations living between 1220 and 2440m (4000-8000 ft) altitude practise subsistence agriculture. Garden types and associated plantings are described and classified by Robbins (1958), Robbins & Pullen (1965) and detailed descriptions are given for restricted areas by Brookfield & Brown (1963), Bowers (1965), Walker (1966), Waddell (1968) among others.

Within this extremely varied country a population of over three million indigenous peoples live, about two million in eastern New Guinea, about one million in the west, unevenly distributed. About 40 per cent of people inhabit the central highlands area, between about 1220m and 2440m (4000-8000 ft) altitude, although other smaller areas of equally dense population are found along parts of the north and south coasts. Over the rest of the country densities are very low, large areas being virtually uninhabited. The New Guineans belong to the Melanesian race but show extremely varied physical characteristics and marked diversity within and between populations. Their present diversity is explained in terms of hybridization between Australoid and Mongoloid-Australoid groups by Coon (1966) and others (Howells 1943, Birdsell 1949) but on the basis of genetic heterogeneity arising from a number of sources, including random genetic drift operating on small isolated breeding populations, the occurrence and spread of new mutants, the mixing of gene pools from different groups and selection by environmental factors by Kirk (1966, 1968). He and others (Cavalli-Sforza & Edwards 1964, 1967) consider that Melanesians are more closely related to

Australian Aborigines than to any other populations, and that both these groups shared a common ancestry with Africans, possibly 100,000 years ago (Kirk, 1968).

Great cultural and linguistic diversity is apparent in New Guinea peoples also. There are about 700 different languages spoken in the island as a whole, about 500 in eastern New Guinea. In the lowland regions many, more or less unrelated languages are used, which are restricted to relatively small regions and spoken by a few hundred people only. In the highlands, on the other hand, about 50 languages are considered interrelated (the East New Guinea Highland Stock) and are spoken by many thousands of people (Wurm 1964, 1966). Cultural diversity is shown in almost all spheres of life: in social organization, in dress and ornamentation, settlement patterns and house styles, material culture, art, music and religion as well as in details of subsistence gardening.

Subsistence gardening is the occupation of most New Guinea people, supplemented by gathering, fishing, hunting and trading. A method of shifting agriculture is found throughout the area but this varies from the relatively rapidly shifting 'slash and burn' cultivation found extensively in the lowlands (Barrau, 1958) to a more or less permanent, rotating field system in parts of the highlands. Crops grown include sweet potato (*Ipomoea batatas*) taro (*Colocasia esculenta*), yams (*Dioscorea* spp.), sugar cane (*Saccharum officinarum*), bananas (*Musa* spp.), *Setaria palmifolia*, *Saccharum edule*, *Rungia klossii*, *Oenanthe javanica*, *Amaranthus* spp., *Psophocarpus tetragonolobus*, *Lagenaria siceraria*, among others.

The New Guinea highlands appeared in many ways to provide an ideal situation to study the historical influences of man on the vegetation and to test the pollen analytical method further in distinguishing climatic, anthropogenic and natural successional influences.

Evidence of previous climatic change comes from glacial land-forms (Reiner 1960, Bik 1967) and from a recent vegetation history study (Flenley, 1967). Glacial land-forms are described from Mt Wilhelm by Reiner (1960) and he considers they indicate a former lowering of the snowline there by about 1050-1200m (3400 to 4000 ft). He cites similar evidence from Dozy (1937) for the Carstensz Mts, suggesting a former lowering of the snowline by 950m.

Evidence of glaciation down to 3000m a.s.l. on Mt Giluwe and to 3350m on Mt Hagen is cited by Bik (1967). Flenley (1967). studying vegetation history at 2 sites in the Western Highlands found evidence for the occurrence of alpine grassland at one of them (Lake Inim, 2550m alt.) between about 8500 years B.P. and 12000 B.P. (the base of his deposit). Considering the present altitudinal range of alpine vegetation, he states that a change in altitudinal factors affecting vegetation equivalent to at least 500m of altitudinal shift is implied by the evidence.

Flenley gives evidence also for reduction in forest, probably due to human influences, having started from about 2000 B.P. at Lake Birip (1900m alt) or 1600 B.P. (inferred age) at Lake Inim. An acceleration of forest decline in both sites, accompanied by a rise in regrowth elements, dates from 100-300 B.P. at Lake Birip and ca 260 B.P. (inferred age) at Lake Inim.

At the same time ecological studies suggest widespread human influence on vegetation in the highlands (Robbins 1958, 1963a, 1963b) and subsistence agriculture is practised there today (Brookfield, 1962). Observations on natural successional patterns after volcanism (Taylor, 1957) are available, as well as outlines of successional trends after gardening, firing and pig grazing (Walker, 1966a).

Archaeological studies indicate that man has been in the New Guinea highlands for at least 11,000 years (S. & R. Bulmer 1964, S. Bulmer 1964, P. White 1967) and possibly longer. An older date is available now for a fringe area of the highlands at Kosipe - ca 25000 years B.P. (P. White, pers. comm.) and the early Australian dates of ca 22,000 years B.P. (C. White, 1967) are also relevant here, as the route into Australia at this time may well have been via New Guinea and the Torres Strait.

On the basis of their archaeological data S. & R. Bulmer (1964) postulate at least 3 phases of highlands prehistory. The first, (Phase I) dated from ca 8400 B.C. to 4000 B.C. is characterised by pebble and flake tools. The people are considered to be pre-neolithic hunters and gatherers, unlikely to have cleared forest to any extent. Phase II, dating from 4000 B.C. to at least 3000 B.C. saw the introduction of lenticular-sectioned axe-adzes and waisted flaked blades and it is suggested that people at this time cleared forest extensively and practised agriculture. Phase III, occupying the time range after 3000 B.C. to ca 1930 A.D. is marked by the presence of planilateral-sectioned axe-adzes, of pottery in the eastern highlands and by more specialized agricultural practises, including the cultivation of sweet potato.

The dating of pig-bone from the Kiowa site to 3000 to 4000 B.C. (Bulmer, 1966) may give some support to the suggestion of crop cultivation in the highlands at this time but is dependent on the future determination of whether the pigs represented were domesticated or feral.

More recent work (P. White, 1967) supplements the earlier study and provides points of conflict as well as agreement.

Other workers also suggest changing patterns of history for the highlands. Thus Robbins (1963a, 1963b) considers that the distribution of successional phases of grassland ('tall' grassland being younger than 'short' grassland etc.) is intimately bound up with age of settlement and he explains an observed east to west gradient in distribution of short grasses, weeds and introduced lowland species in terms of initial entry of man from the east with subsequent migration westwards. The actual age of the grasslands cannot be determined; he states, however, that 'the time taken for development of some of the larger grasslands must be measured in hundreds of years'. (Robbins, 1963a). Linguistic studies by Wurm (1964, 1966), blood group studies and physical anthropological studies by a number of workers (Macintosh et al 1958, McLennan et al 1959, Macintosh 1959) and cultural studies (Read, 1954) all suggest relatively long periods of occupation of the highland areas involving differentiation and development under partially isolated conditions. These studies, together with those of archaeology, suggest also that while the eastern and western highlands have had somewhat different histories, the western highlands has not necessarily been populated from an eastern centre.

The density and distribution of population also is considered to have shifted during highlands prehistory. S. & R. Bulmer (1964) suggest that before the introduction of sweet potato, populations lived mainly at lower altitudes, depending on such crops as taro, bananas, sugar cane, Pueraria and yams. With the introduction of intensive sweet potato cultivation (post 15th century A.D.) major redistributions of population, especially in the western highlands may have taken place. A similar viewpoint is expressed by Brookfield (1964). Watson (1965a, 1965b) takes up this theme and postulates that following the introduction of sweet potato there were widespread changes in agricultural practices, an increase in domesticated pig populations (if already present), rapid population growth and redistribution of populations especially to higher altitudes and profound social changes, including the development of permanent settlements and more stable social structure systems. All these changes are considered to have taken place within the last 300 years; previous to this the highlands were occupied by purely hunters and gatherers or at most by small groups practising 'intermittent or supplementary' cultivation, with few if any pigs, relying mainly on hunting and foraging within the forest environment.

All these studies provide interesting background and suggest that there is a wide spectrum of human activity present in the New Guinea highlands which can be analysed historically as well as at the present time. Since all these studies, with the exception of the archaeological and single vegetation history project, are synchronic in approach they cannot date accurately any of the hypothesized developments. Accordingly, pollen analytical sites were sought in the highlands which might provide more critical evidence and dates for vegetation changes and suggest answers to at least some of the following questions:

Has there been any climatic change in this tropical region during Pleistocene and post-Pleistocene times?

What has been man's influence on the vegetation and when did it occur/begin?

Can vegetation changes due to man's influence be distinguished from those induced by climate or geomorphic factors?

When did the sweet potato arrive in the highlands and what were the pre-sweet potato crops?

Are changes in the intensity of human influence apparent?

If so, could these be related to post-sweet potato entry times?

Is a time-scale available for the domestication of crops such as Pandanus, bananas, sugar cane, Rungia?

Under what ecological conditions were the prehistoric people living?

What is the present status of the vegetation of the area?

Have the eastern and western highlands had different vegetation histories and if so are these related to climatic, biotic or successional factors?

Has the eastern highlands been occupied for longer?

The present study was initially conceived as a comparison of vegetation history of the eastern and western highlands involving pollen analysis of selected sites together with studies of stratigraphy, extant vegetation and modern pollen rain. Small lakes or swamps suitable for pollen analysis were sought in areas of concentrated land-use, with forested land not too far distant and road access if possible. After an initial survey of the air photographic mosaics and available literature, five possible sites were chosen for field reconnaissance. Field work was started in February, 1966 but due to adverse weather and road conditions the initial field reconnaissance had to be abandoned and the two sites most readily accessible were chosen for study. These were Noreikora Swamp, about 10 miles SE (by road) of Kainantu in the eastern highlands, and Draepi, a small pond and adjoining swamp situated about 15 miles NNW of Mt Hagen township in the western highlands district.

Studies of present day vegetation and site stratigraphy were carried out in both areas during two field trips over a total period of sixteen months. During the first field period a recently discovered archaeological site, about 10 miles E of Mt Hagen township was investigated also, in conjunction with A.N.U. archaeologists. Towards the end of the second field stay further archaeological deposits were found near Draepi and it was decided to include these in the study. The extension of field work in the Mt Hagen region resulted in a greater amount of material than could be handled in the remaining time available for the study. In view of the richness of archaeological material, the proximity of two sites and the time periods indicated by initial radiocarbon dates, all subsequent work was concentrated in the Mt Hagen area.

Altogether six pollen diagrams have been prepared. The vegetation changes shown in these diagrams are discussed in relation to the various factors involved and conclusions drawn where possible considering both the pollen and other lines of evidence available for the Mt Hagen region.

CHAPTER 2

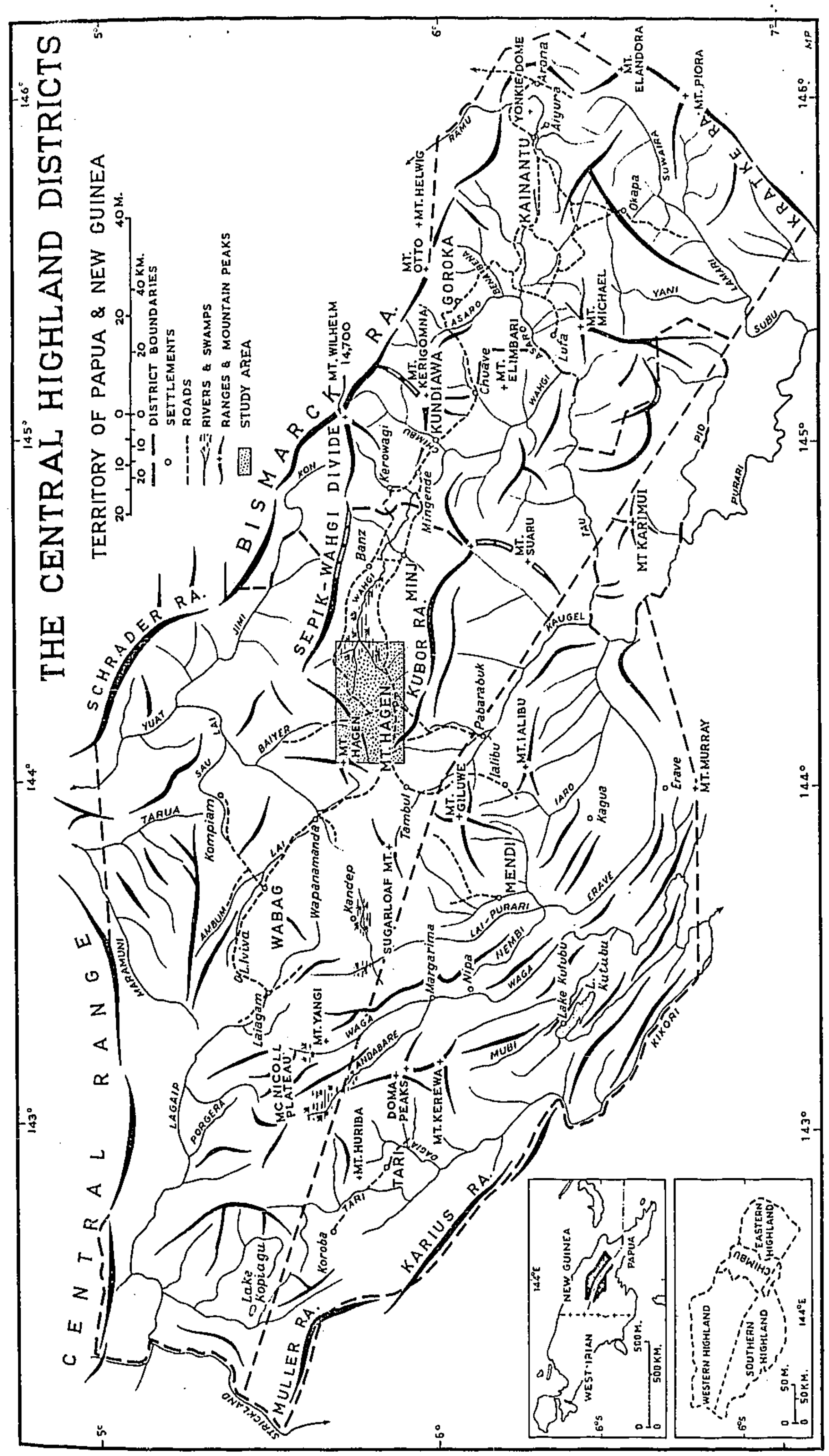
THE MT HAGEN REGION

The Wahgi Valley, the largest intermontane valley of the central highlands of eastern New Guinea (at 5°45'-5°50'S and 144°05'-145°00' E.) is bounded to the south by the Kubor Ranges, to the north by the Sepik-Wahgi Divide, a western flank of the Bismarck Ranges. Blocking the western end of the valley is Mt Hagen, a broad range rising to an altitude of 3650m (11,972 ft), (Figure 2.1). Mount Hagen township, situated at 1730m (5670 ft) at the base of Mt Hagen is the Australian Administration Centre for five subdistricts which together form the Western Highlands District. The Mt Hagen Region, defined specifically for the purposes of this study, lies within the Mt Hagen Subdistrict. It includes portions of the summit and eastern slopes of Mt Hagen, the northern slopes at the western end of the Kubor Range, the Baiyer River 'divide' area and the Upper Wahgi Valley (Figure 2.2). While discussion of results will be restricted to this closely specified region, background information taken from secondary sources where relevant will range over a greater area.

THE VEGETATION HISTORY SITES

The two vegetation history sites lie 19 km (12 miles) apart. One of them, Draepi, (Plate 1A) lies about 13 km (8 miles) NNW of Mount Hagen township on the Baiyer River Divide; an area of rolling hilly country of volcanic ash and lahar deposits which separates the Baiyer River valley from that of the Wahgi. This site was seen by Walker during field work in the New Guinea Highlands in 1965 and was suggested to the author as a possible site for pollen analysis. Swampy depressions, often with small ponds, are common throughout the area and a number of these were visited before the final decision to study Draepi was made. Draepi fulfilled a number of the requirements for a vegetation history study of the type envisaged. It comprised a small pond ca 90m long by 50m wide, together with about 0.8 km (½mile) of narrow swamp. The pond drains by seepage only, except in times of continuous heavy rainfall, to the SE into Ogulg Ck. The

Figure 2.1 The Central Highlands of New Guinea and the Wahgi Valley.



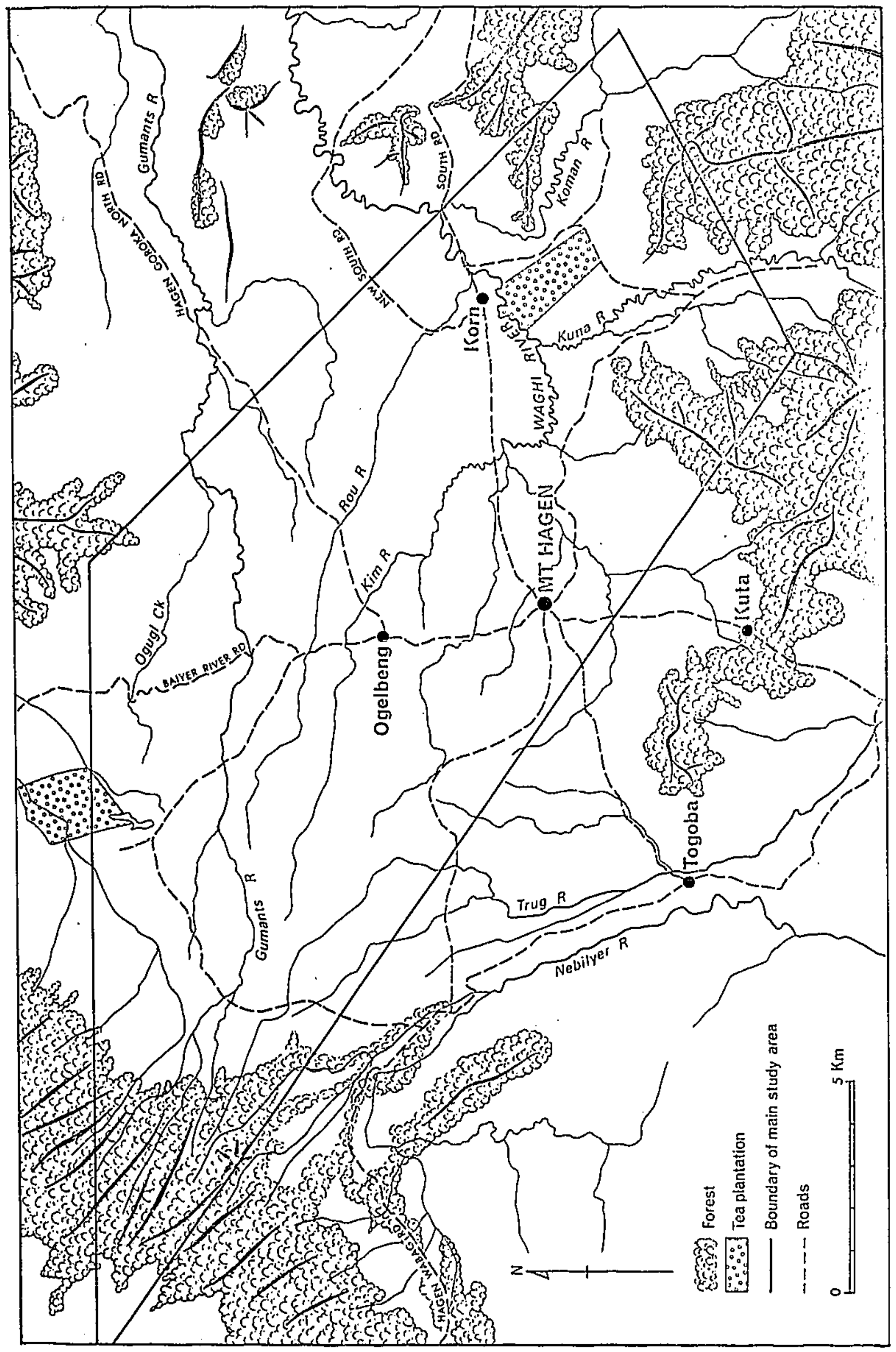


Figure 2.2 The Mt Hagen Study Region.

northern end of the swamp is drained by the Monga Ck and an eastern extremity by another branch of the Ogulg Ck. Water movement appears slight at all times and sediment mixing and redeposition seem unlikely at least under present conditions. Water depth in the pond was about 3m. Test bores from near the lake edge and swamp margin indicated a sediment depth of between 5 and 7 metres, resting on solid, unweathered volcanic ash. The presence of a broad clay band mixed with organic material between two zones of organic sediments suggested possible problems of erosion and redeposition but as a similar sequence had been found in other sites investigated in the preliminary survey of the area it had to be accepted.

The site is at 1890m (6200 ft) and surrounded by gently sloping hills, the highest point being at 2075m (6800 ft). It is accessible by road and not too far distant from both native gardens and forested areas. The former lay about 1.6 km (1 mile) to the east, reached in 20-30 mins walking time and about 2.5 km (1½ miles) to the west, accessible by road; the forests lay further to the west and south west but again could be reached by road. The land surrounding the site was devoid of trees; it had been gardened formerly according to local information. In the near past it had been a no-man's-land and fighting ground for the two tribes living nearby, the Nenka of Bukapena settlement and the Minimbe of Weylk settlement. Present vegetation on the hills surrounding the swamp consists of grassland dominated by Themeda australis, Arundinella setosa and Capillipedium parviflorum on the dry slopes and by Ischaemum barbatum, Dimeria dipteros and Sacciolepis indica together with tree ferns on the lower, wetter slopes. Ischaemum barbatum dominates the northern part of the swamp, while Leersia hexandra and the cyperaceous species Machaerina rubiginosa, Juncus cf. prismatocarpus and Cyperus globosus are found on the southern, very wet margins of the pond.

During the period of field work part of this site and the area adjoining it were developed as a tea plantation. This involved drainage of the northern part of the swamp and led to the discovery of archaeological materials there. Samples were collected for pollen and macrofossil analysis from an area which appeared to have

PLATE 1A

The Draepi vegetation history site is shown in the centre of the photograph, situated on the volcanic plain at the base of Mt Hagen. Weylk settlement area is in the foreground, the Minjigina tea plantation land on the right.

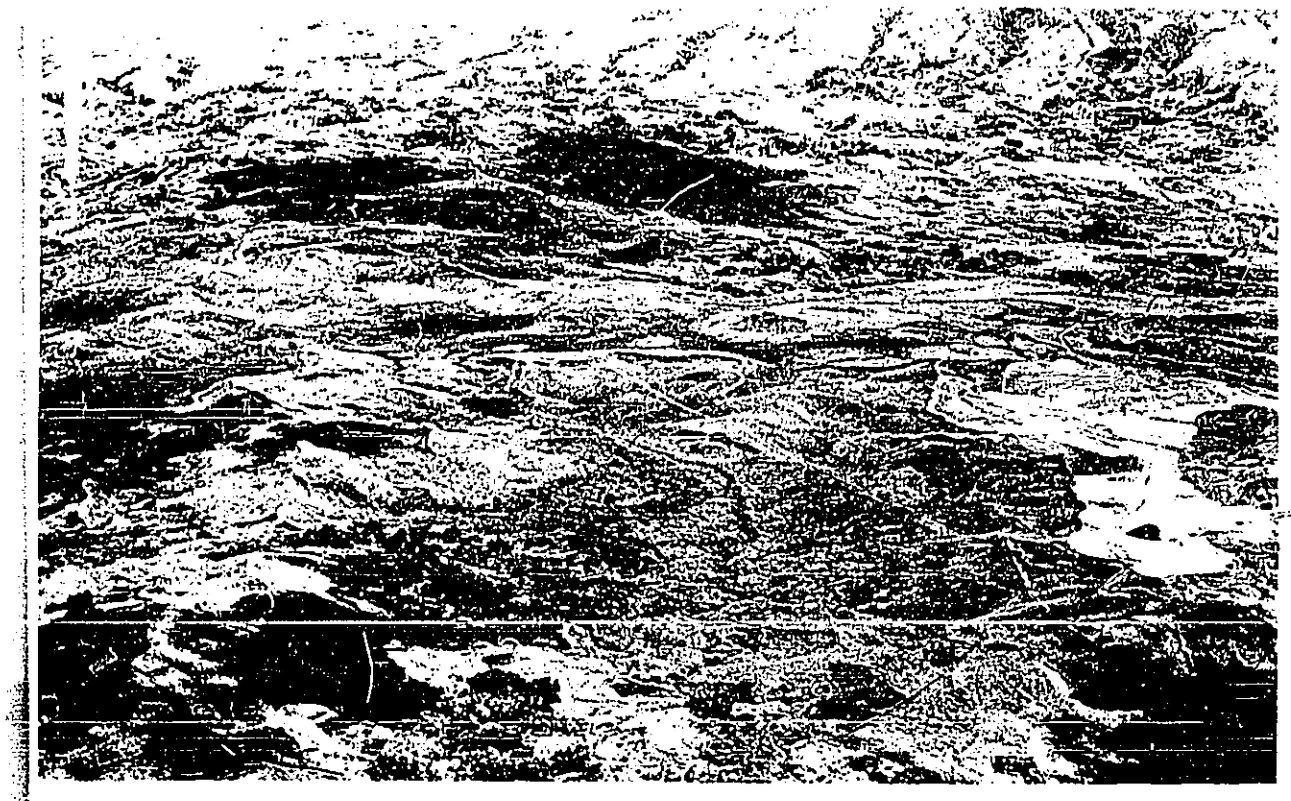
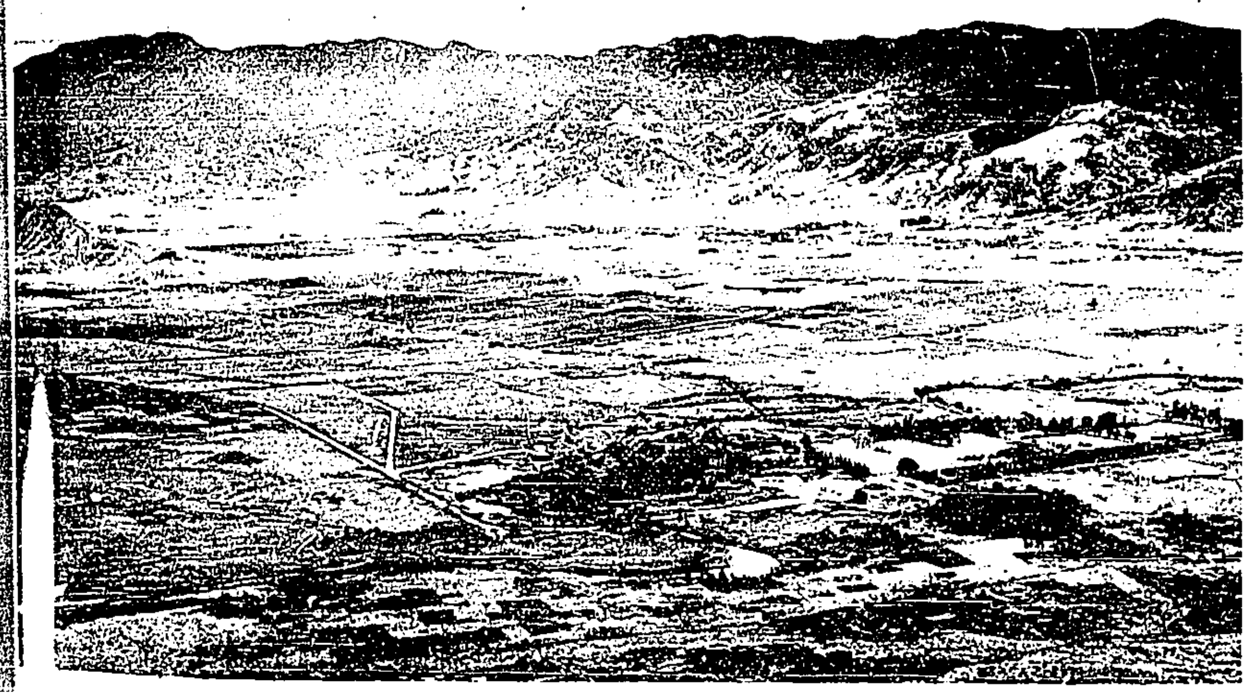


PLATE 1B

The Manton vegetation history site is shown in the centre of the photograph within the tea plantation land. The Kubor ranges form the background, Korn Farm agricultural station is in the foreground.



a cooking pit adjacent to a former ditch and subsequently this small site was excavated by Lampert (A.N.U. Prehistory).

The Manton site, (Plate 1B) an open archaeological site was discovered in 1966 when an area of swampland, leased to I.V. Manton, was being drained for development as a tea plantation. The plantation property, of 858 acres lies 10 km (6 miles) east of Mount Hagen township, 3 km (2 miles) north of the foothills of the Kubor Ranges, at an altitude of 1590m (5200 ft). Before drainage it was covered predominantly with 2-3m high Phragmites karka, with the water table up to 50 cm above ground level. In some parts gravel ridges provided drier areas which were covered with Leersia hexandra, Isachne globosus, Ischaemum barbatum among other grasses and shrubs such as Glochidion sp. and Melastoma? affine. During drainage of the apparently undisturbed swampland, wooden and stone artefacts were found lying within and below the swamp peat. The artefacts were distributed fairly widely along the 70 miles of modern drainage ditches and included polished stone axe blades, pointed wooden digging sticks and paddle-shaped wooden spades. Subsequently an area was selected for excavation by A.N.U. archaeologists on the basis of artefact concentration in nearby channels. An area of 300 square yards was excavated over a period of four weeks.

The site did not appear ideal for palynological work as it was an extensive swamp with underlying alluvial deposits. Stratigraphy was complex and natural mixing of sediments could be expected; as well, organic deposits were shallow, rarely exceeding 2m in depth. These disadvantages were overruled, however, by the archaeological possibilities of the site, which could be tied in directly with pollen analytical work. Also, the other requirements were fulfilled, as native gardens bordered the swamp and forests were present on the upper slopes of the surrounding hills. All were accessible by road.

GEOLOGY

The Wahgi Valley, about 60 miles long and up to 20 miles wide, is a Rift Valley lying between the Kubor Anticline and the Bismarck Fault Zone. The Wahgi River rises in the Mt Hagen Range, flows east to join with the Chimbu River and finally with the Purari River which drains south into the Gulf of Papua. Preliminary studies of the geology of the western highlands appear in Spinks (1936) and Noakes (1939), while Rickwood (1955) gives a more detailed account. His account remains the most comprehensive for the Hagen area although more recently Thompson & Fisher (1965), Dow & Dekker (1964) and Dekker & Faulks (1964) have expanded it for other parts of the western highlands (Figure 2.3).

The oldest rocks in the area are the pre-Permian granodiorities and the unfossiliferous grey and green pyritic shales exposed in the core of the Kubor Anticline. These are overlain unconformably by an incomplete succession of marine sediments ranging from Permian to Miocene in age and reflect periods of emergence, erosion and deposition in shallow and deeper waters. At the western end of the Kubor Range, near Mt Hagen and in the Sepik-Wahgi Divide, limestones of Permian age, shales and limestones of Upper Jurassic age, Cretaceous andesitic tuffs, shales, greywackes and Eocene limestones can be found exposed (Rickwood, 1955). A period of rapid uplift in Middle Miocene times ended marine sedimentation and with subsequent folding and faulting during this and the Pliocene, many of the features seen today were formed. The orogenic activity was followed by vigorous erosion with alluvium being deposited in the rift valley bottoms. In the western region, near Mt Hagen, the process of alluviation was complicated by Pleistocene volcanics. Volcanic rocks which cover most of the folded marine sediments can be found here and include coarse agglomerates, tuffs, vesicular and porphyritic basalts and andesites. The greatest thicknesses of the rocks occur at the old foci of eruption, Mt Hagen, Mt Giluwe and Mt Ialibu. Volcanic activity of Mt Hagen and Mt Giluwe appears to have ceased at least towards the end of the Pleistocene, as both these mountains carry fossil glacial land forms

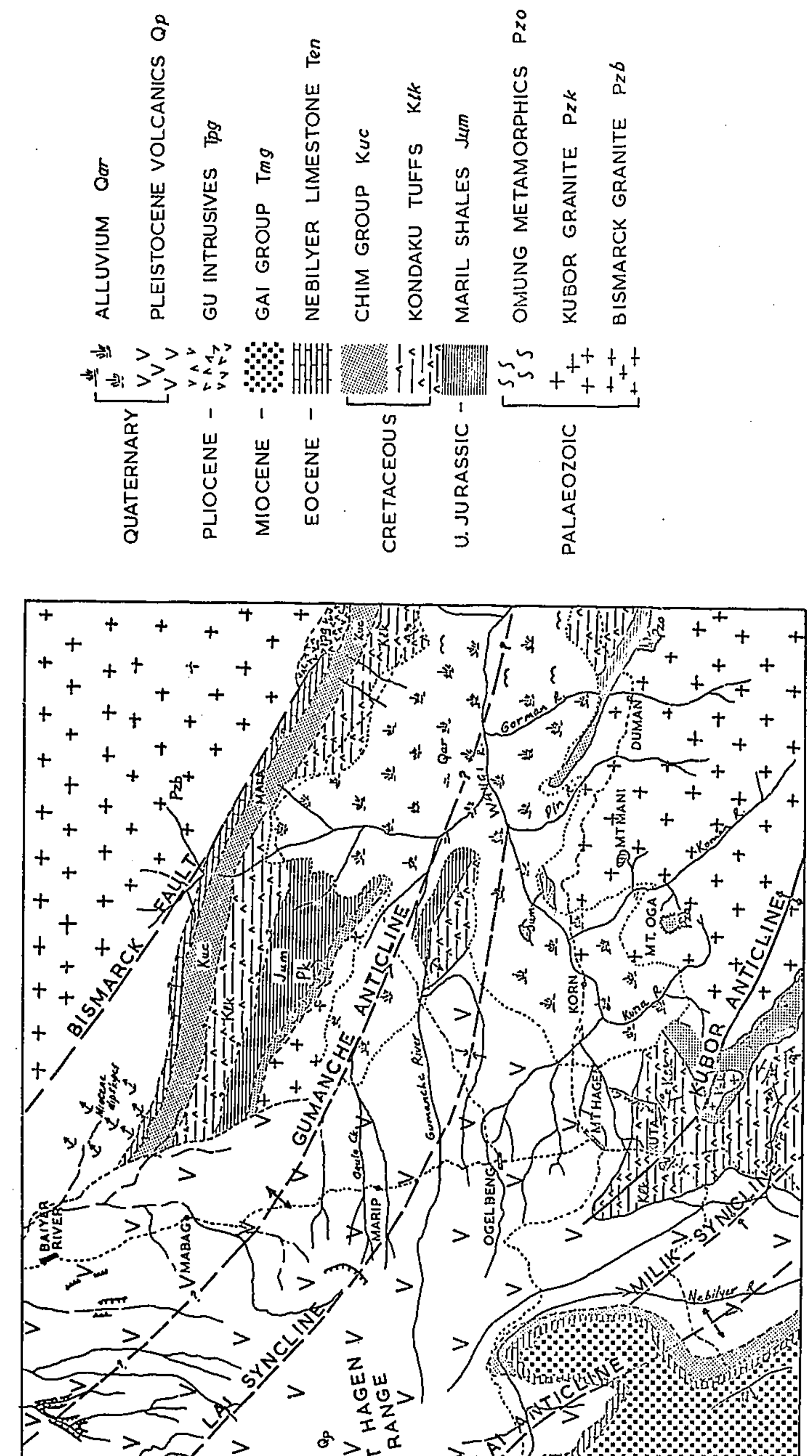


Figure 2.3 Geological map of the Mt Hagen region.

which have been neither damaged by volcanic activity nor covered by volcanic deposits. Minor centres of eruption were active until a later date, however, and ash deposits recur into the Recent period (Bik, 1967). Mt Wilhelm to the east was glaciated also during Pleistocene times.

PHYSIOGRAPHY

Much of the topography seen today in the Mt Hagen region relates closely to underlying structure. For general descriptive purposes it is convenient to divide the study region into a number of areas, as shown in Figure 2.4.

A. The Kubor Range area: (Plate 2) This area comprises the Bismarck, Ambun, and Omahaiga land systems of Haantjens et al (in press). In the Kubor Range the relict granodiorite areas form broad, rounded hills, while prominent hogbacks are present where the main divide is in Permian arkose and limestone, for example at the head of the Kuna and Koman valleys. All the highest peaks are Permian residuals and extremely rugged in form. Ridges are steep and narrow, streams deeply incised and landslide scars are prominent on the long, steep (45-60°) slopes. Rolling country is present at the western end of the Kubor Range where calcareous shale-breccia prevail; here ridge crests are broader and less steeply sloping (15-25°). The drainage pattern is predominantly dendritic, the whole area being well drained, some parts excessively. Colluvial soils and humic brown clay soils are most common, with humic brown and red latosols developed locally.

B. Mt Hagen summit and slopes: (Plate 3) Land systems Giluwe, Ialibu, and Nemarep are included in this area (Haantjens et al, in press). The summit area of Mt Hagen is rugged with sharply crested ridges and steep-sided valleys. These have well drained or excessively drained shallow sandy colluvial soils, with much rock outcrop. Small areas of flat or gently sloping ground have poorly drained peat soils. Steep, strongly dissected slopes with more or less parallel ridges are characteristic below the summit area. Ridge crests are narrow, sloping 20-35°, separated from one another by V-shaped valleys with side slopes of 40-60°. Towards the base of the

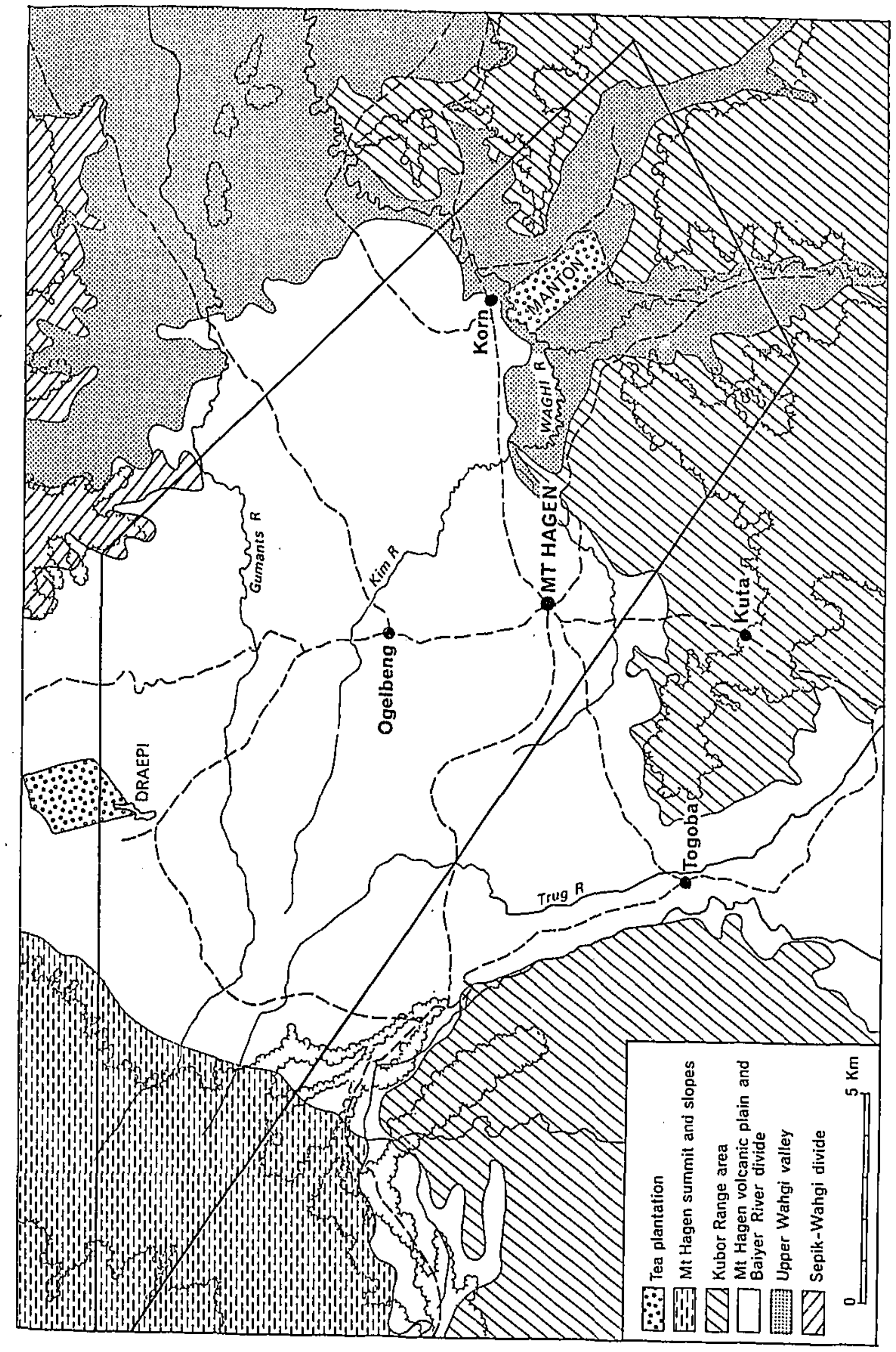


Figure 2.4 Physiographic areas.

PLATE 2A

The Wurup ridge at the western end of the Kubor range. The vegetation is degraded and partly cleared oak forest together with native subsistence gardens.

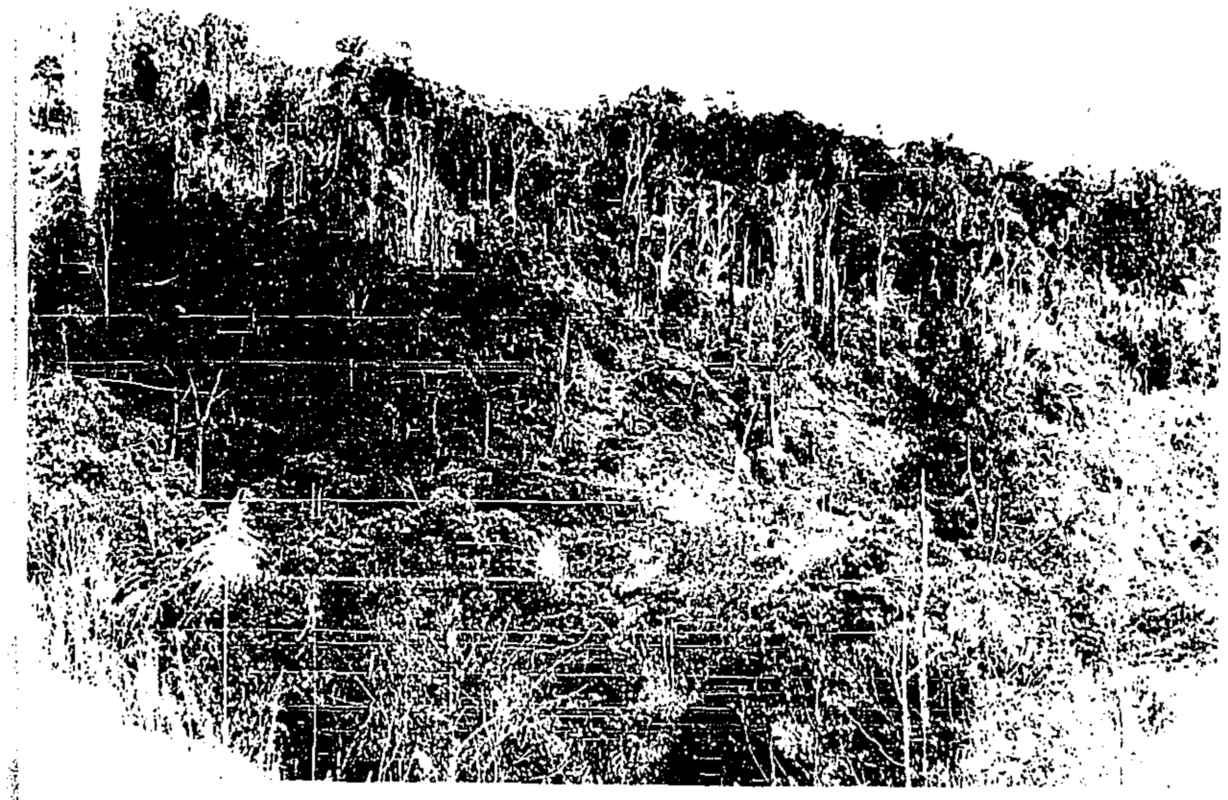


PLATE 2B

Mt Oga in the Kubor ranges. The slopes are covered with oak forest and mixed oak-beech forest above 2130 m. Grassland, regrowth shrubs and native gardens occupy the lower slopes. Phragmites cane-grass borders the Kuna river, shown in the foreground.

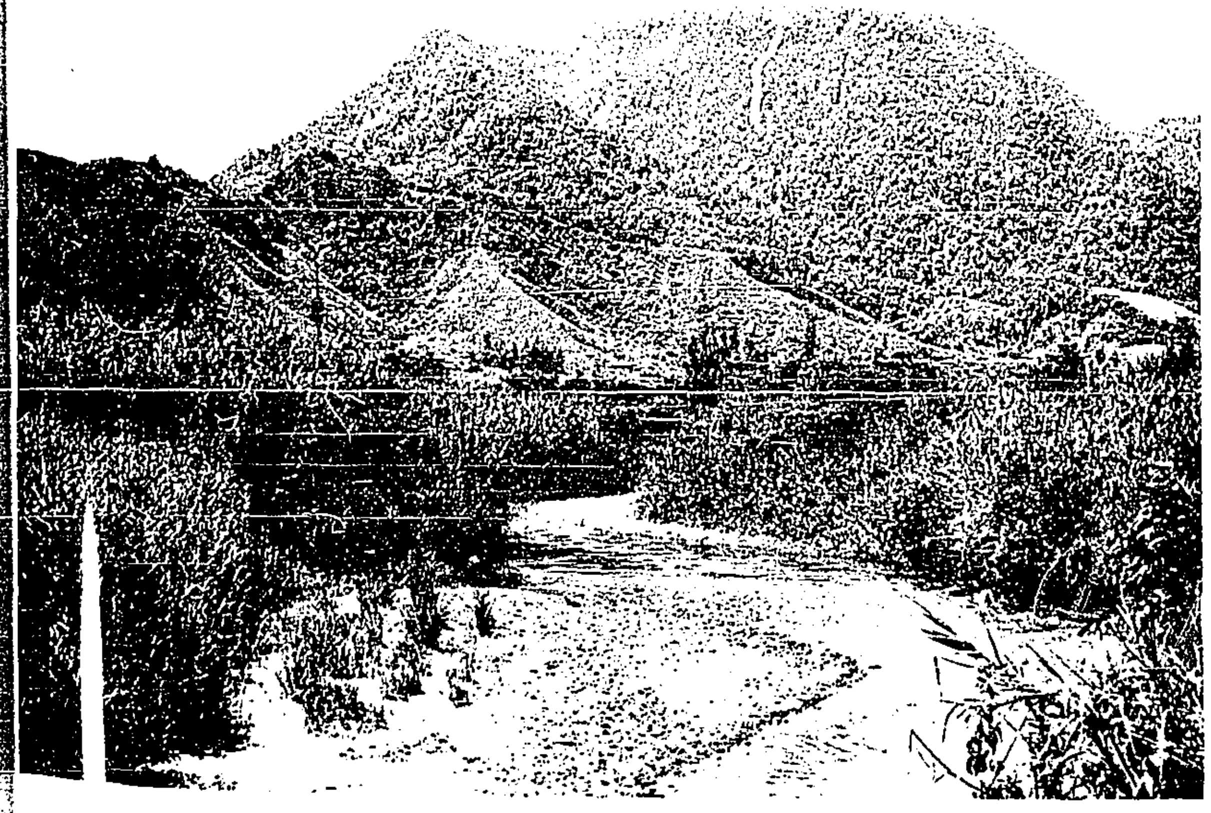
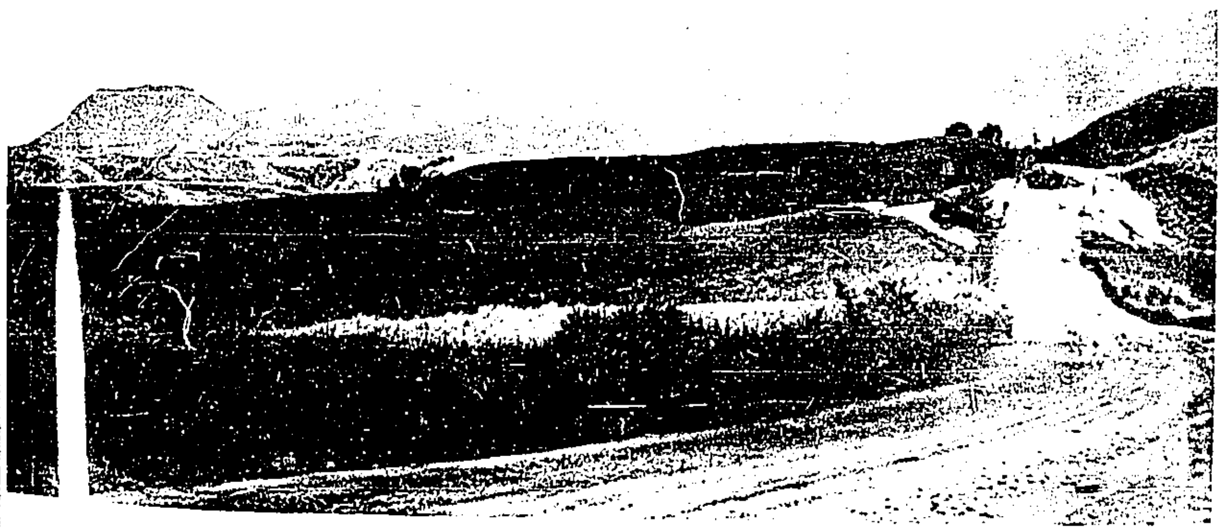


PLATE 3A

Looking towards Mt Hagen (on the left), the Baiyer River divide area (centre background) and the Sepik-Wahgi divide (on the right). The Upper Wahgi valley area is shown in the foreground.

PLATE 3B

Looking towards Mt Hagen summit and slopes from the Baiyer River divide area. The summit is grass-covered, the higher slopes forested (mixed forest and beech forest) while the lower slopes and the volcanic plain are covered with a mosaic of short grassland, native gardens and regrowth vegetation.



mountain the ridges broaden, with undulating surfaces and slopes of 8-20°. The alpine humus soils and humic brown clay soils present here are well drained.

C. Mt Hagen volcanic plain and the Baiyer River divide area: (Plate 3) Volcanic ash, agglomerate and lava deposits form an undulating plain at the base of Mt Hagen on the eastern side and to the northwest form a low divide between the Wahgi and Baiyer river valleys. Here the country is rolling to low hilly (relief up to 120m), with rounded ridges, irregular slumped and benched slopes (10-30°), colluvial fans (up to 5° slope) and local depressions. The drainage pattern is coarse, with the large streams deeply incised. Well drained humic brown clay soils predominate but locally dark colluvial soils, red and brown latosols, gleyed humic brown clay soils, gleyed and lateritic latosols are present. The depressions are imperfectly to poorly drained and swampy, with meadow podzolic and organic soils developed. The area is described in more detail in Haantjens et al (in press) under land systems Teiga, Nunga, Ogu and Tari. The vegetation history site, Draepi, is stituated within land system Ogu, described more fully in Chapter 9.

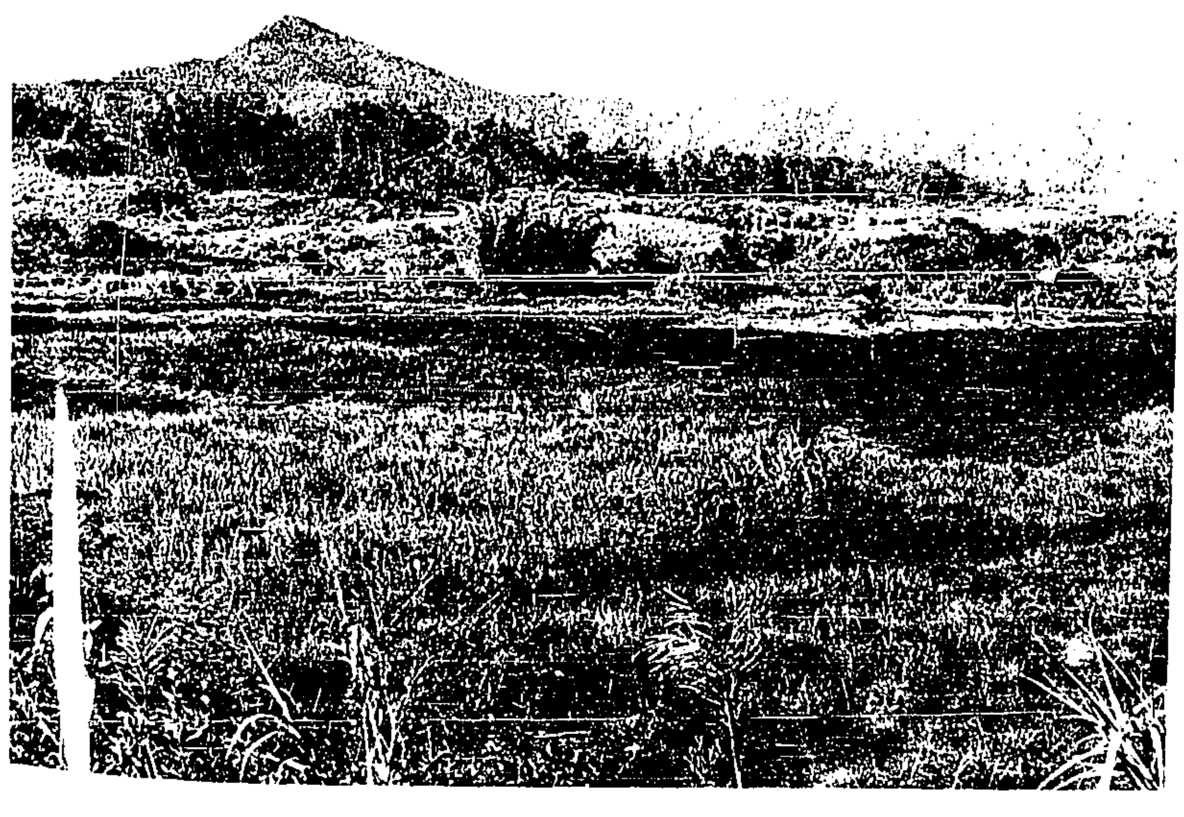
D. The Upper Wahgi Valley area: (Plate 3A, 4A) The Pleistocene volcanism upset the earlier drainage pattern dictated by the Kubor and Bismarck fold-axes and it seems likely that the eastern drainage of the Gai River and some of the Nebilyer River drainage was captured by the Wahgi. The extended catchment of the Wahgi with no increase in the fall of the stream in its middle reaches led to the deposition in the region of Korn and northwards of thick alluvium derived from the Mt Hagen Range (Rickwood, 1955). The stable and partly aggrading alluvial plains, flood plains and back-plain swamps of this area are described as land systems Ko and Wahgi by Haantjens et al (in press). The plains are flat or gently undulating and usually very poorly drained, although locally developed gravel rises may be well drained. Tributary drainage courses are ill-defined while major streams are entrenched up to 6m (20 ft). Medium to fine textured alluvial soils and gleyed humic brown clay soils are present on the higher levées, meadow soils and organic soils on the lower swampy areas. The Manton vegetation history site is situated in this area.

PLATE 4A

Alluvial flats of the Upper Wahgi Valley. The Kuna river (centre) is bordered by mixed Phragmites - shrub vegetation (Ficus spp., Saurauia spp.). Miscanthus floridulus and short grasses form the grassland in the foreground.

PLATE 4B

Looking towards the forest-covered upper slopes of the Sepik-Wahgi divide from the Baiyer river road. The stand of Casuarina marks a settlement area, with mixed gardens, bamboo and grassland nearby. Sweet potato gardens and fallow grassland are shown in the foreground.



E. The Sepik-Wahgi divide area: (Plate 4B) The rugged foothills of the Sepik-Wahgi Divide join the Mt Hagen volcanic plain to the NNE of the study region. Developed on greywacke and shale, the area is characterised by irregular, branching ridges and V-shaped valleys. Ridge crests are narrow, gully slopes 15-40°. The brown colluvial soils, humic brown clay soils, lateritic and gleyed latosols present are well to excessively drained. This area belongs to the Koge land system of Haantjens et al (in press).

CLIMATE

Factors affecting the climate of New Guinea in general are the island's position just south of the equator, the large expanses of ocean surrounding it, and the alternation of northerly monsoon winds and south-easterly trade winds through the year. Strong orographic effects are also shown (Haantjens et al, 1967). The highlands climate is considered to be largely independent of the general lowland circulation. Thus Brookfield & Hart (1966) state 'The climate of the enclosed valleys of New Guinea is undoubtedly affected by local circulations which operate independently of all but the most dominant of general conditions.' Also, due to the great complexity of terrain, climates vary over relatively short distances even within the highlands. Brookfield (1961, 1962, 1964) has considered the highlands climate in some detail in relation to settlement and agricultural patterns, while rainfall regimes have been subjected to detailed study by Fitzpatrick et al (1966) and Brookfield & Hart (1966). Results of short term studies for restricted areas are given by Walker (1966a), Fitzpatrick (1965), McVean (1968) and Wade (1968).

Table 2.1 gives the main data available on climate for the Mt Hagen region.

Rainfall: Rainfall records are available from Mount Hagen township, from Togoba and Kuta. The location of these stations is shown in Figure 2.2, their mean monthly rainfall distribution in Figure 2.5.

Fitzpatrick et al (1966) using harmonic analysis of mean monthly rainfall and mean weekly values have analysed available rainfall data fully. In the general

Table 2.1 Climatic data for the Mt Hagen region.

	Mean Monthly Rainfall Data mm			Monthly Temperature Records - °C					Relative Humidity		Evap.* (mm)	Cloudiness Scale 0 - 8			
												Total amount		Low amount	
	Kuta	Hagen	Togoba	Mean Max.	Mean	Mean Min.	Highest Max.	Lowest Min.	0900	1500		0900	1500	0900	1500
Jan	318	267	297	24.2	18.8	13.4	27.3	10.6	87	67	99	7	7	5	5
Feb	322	274	302	24.2	18.8	13.3	26.3	10.6	87	67	89	7	7	5	5
Mar	352	287	317	23.8	18.6	13.5	26.0	10.9	88	71	89	7	7	5	5
Apr	360	269	305	23.9	18.8	13.7	26.1	11.3	89	69	86	7	7	5	5
May	239	178	170	24.4	18.8	13.4	26.6	10.1	89	66	89	7	7	5	5
Jun	135	127	127	23.2	17.8	12.4	25.6	8.3	91	69	79	7	6	6	5
Jul	192	133	147	22.4	17.4	12.5	24.9	8.9	92	68	79	7	6	6	5
Aug	264	178	171	22.7	17.7	12.7	25.6	9.4	91	70	81	7	6	6	5
Sept	257	237	228	23.3	17.9	12.6	25.7	8.8	87	67	86	6	6	5	5
Oct	199	206	208	23.9	18.2	12.5	26.5	7.9	83	64	102	6	7	4	4
Nov	246	215	197	24.3	18.5	12.7	26.6	9.1	82	63	102	6	7	4	5
Dec	300	229	274	24.0	18.6	13.3	26.1	10.9	85	67	99	6	7	4	5
Mean Annual	3184	2599	2743	23.7	18.3	13.0	27.3	7.9	88	67	1080	7	7	5	5
Highest Annual	3800	3336	3093												
Lowest Annual	2697	2133	2226												
Altitude (m)	3036	1672	1652												
Length of record (years)	7	15	11												

*Evaporation - Fitzpatrick's method (1963)

Figure 2.5 Mean monthly rainfall distribution at three stations in the Mt Hagen region.

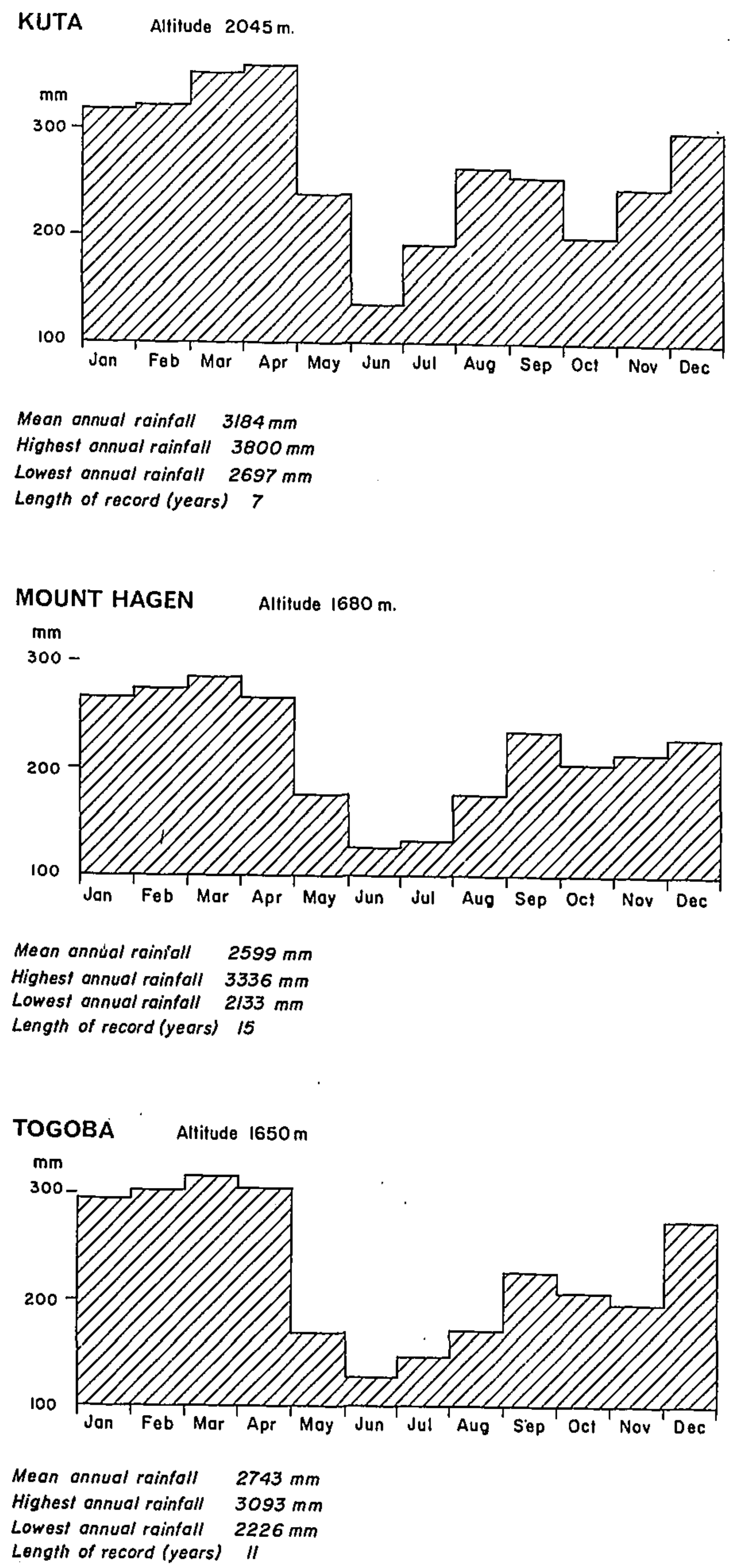
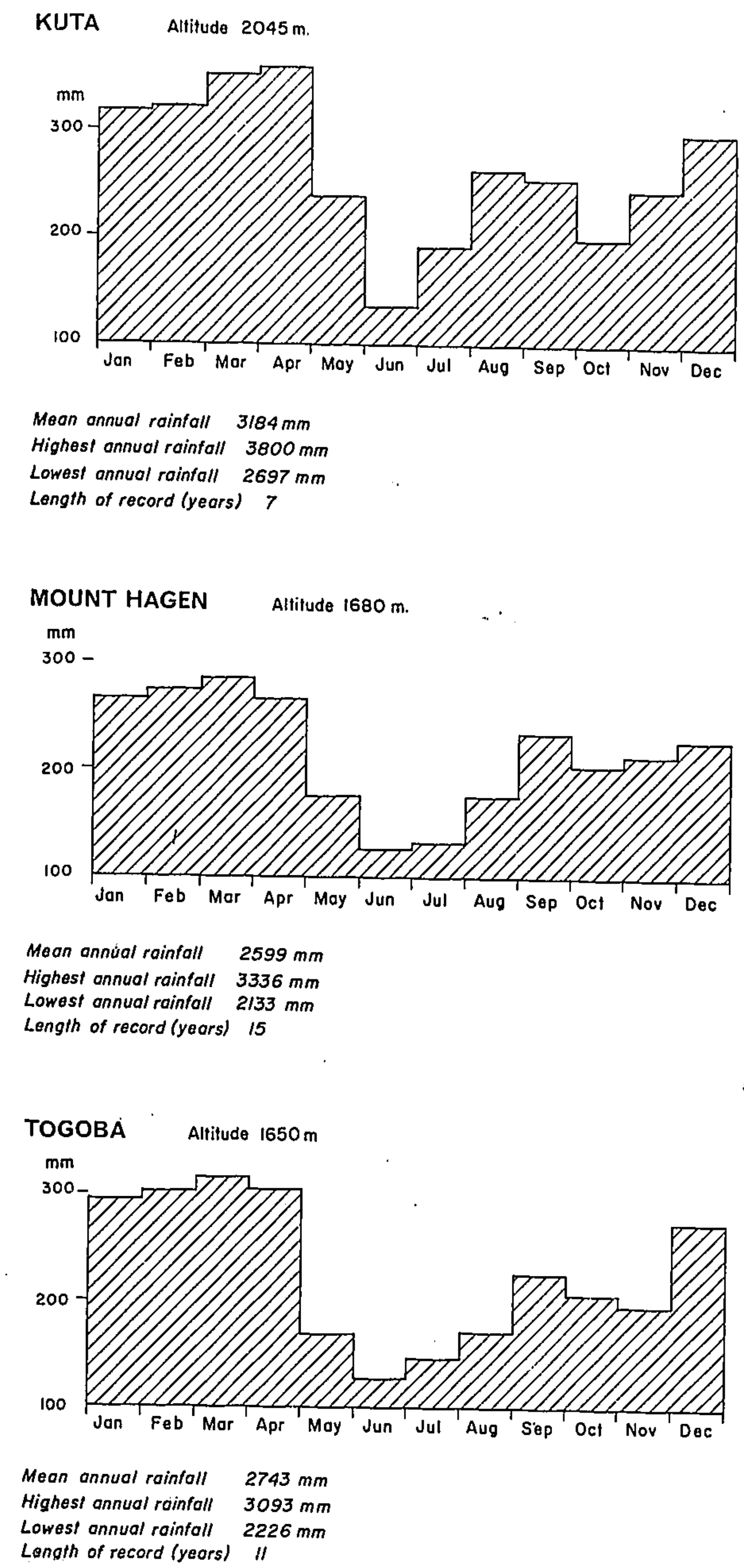


Figure 2.5 Mean monthly rainfall distribution at three stations in the Mt Hagen region.



classification of rainfall regimes the Wahgi Valley falls into type S3, characterized by 'moderate range - heavy to intermediate' falls. The mean annual rainfall for Mount Hagen and the upper Wahgi Valley is ca 2600mm (102 ins) and for the marginal Kubor ranges somewhat higher: between 3175 and 3810mm (125-150 ins). The early year is wet, with a rainfall crest the second week in February; the mean rainfall for this week is 65mm (2.5 ins). The mid year is dry with the rainfall trough falling in the last week of June; the mean rainfall for this week is 25mm (1 in).

Table 2.2 gives data on rainfall intensity and Table 2.3 on length of rainy and rainless periods throughout the year for Mount Hagen township (McAlpine, in press). Rainfall intensities are similar throughout the year; heavy rainfall, over 100mm (4 ins) per day is unrecorded at Mount Hagen and daily falls of over 50mm (2 ins) are rare. The distribution of rainy and rainless periods also does not vary greatly from one part of the year to another, the first two quarters providing the extremes of wet and dry weather respectively.

Table 2.2 Mount Hagen : Rainfall distribution and intensity

Intensity	Number of rain days per quarter			
Daily Rainfall (mm)	J F M 90 days	A M J 91 days	J A S 92 days	O N D 92 days
0.2 - 6.0	31	27	36	27
6.5 - 25.0	29	23	22	25
25.5 - 50.0	9	7	4	7
50.5 - 100.0	1	1	1	1
> 100.5	0	0	0	0

Temperature: Figure 2.6 illustrates mean monthly temperature data for Mount Hagen. Temperature variations are slight throughout the year, with diurnal variations exceeding seasonal. Monthly mean temperatures vary between $17.4^{\circ}C$ ($63.4^{\circ}F$) and $18.8^{\circ}C$ ($65.8^{\circ}F$) in July and January respectively, while the lowest minimum record is $7.9^{\circ}C$ ($46.2^{\circ}F$) for October, the highest maximum $27.3^{\circ}C$ ($81.1^{\circ}F$) for January. Ground forests occur infrequently at 1830m (6,000 ft) altitude, commonly at 2600m (8,500 ft).

Table 2.3 Mount Hagen : Distribution of rainy and rainless periods

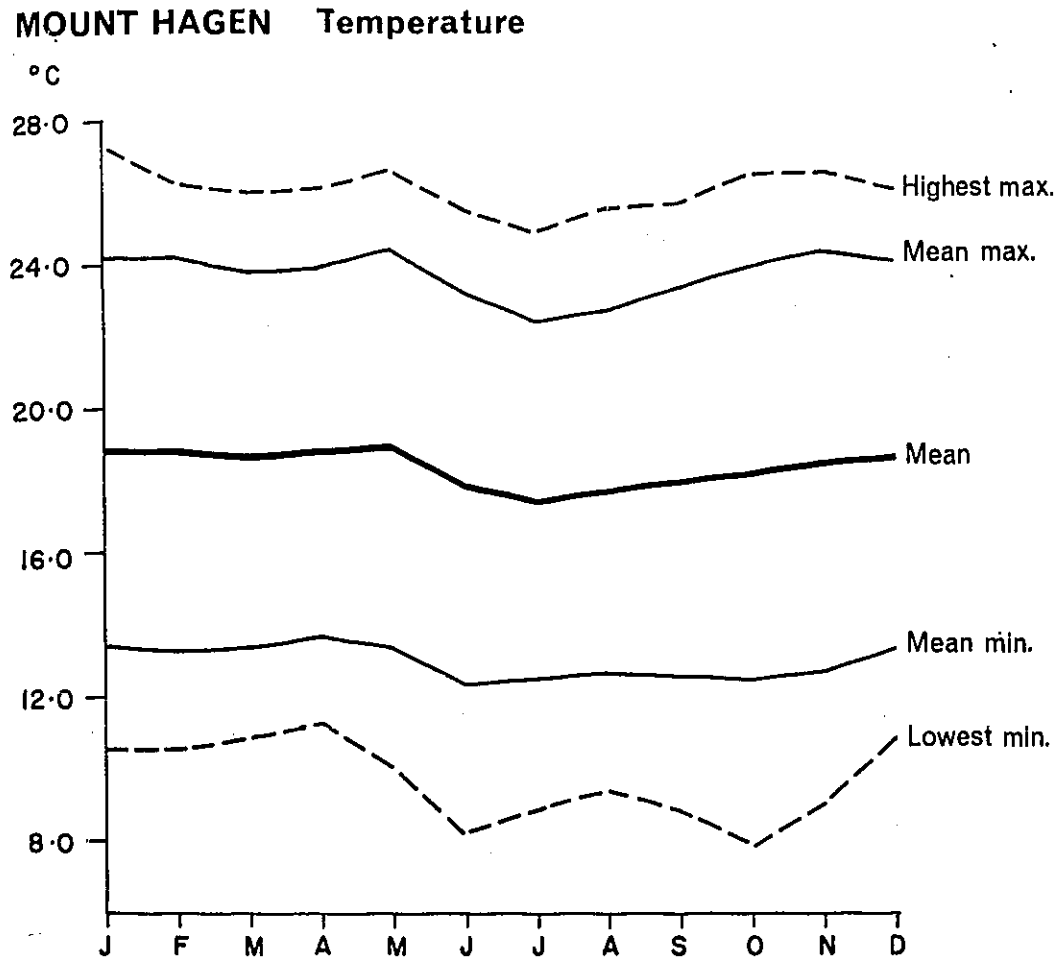
	Number of days per quarter			
	J F M	A M J	J A S	O N D
Rainy period				
Average length	5.5	3.8	4.3	3.9
Greatest length	44	34	28	20
Average no. rainy days	71	57	63	59
Rainless period				
Average length	1.6	2.3	2.0	2.1
Greatest length	7	22	7	18
Average no. rainless days	20	34	29	32

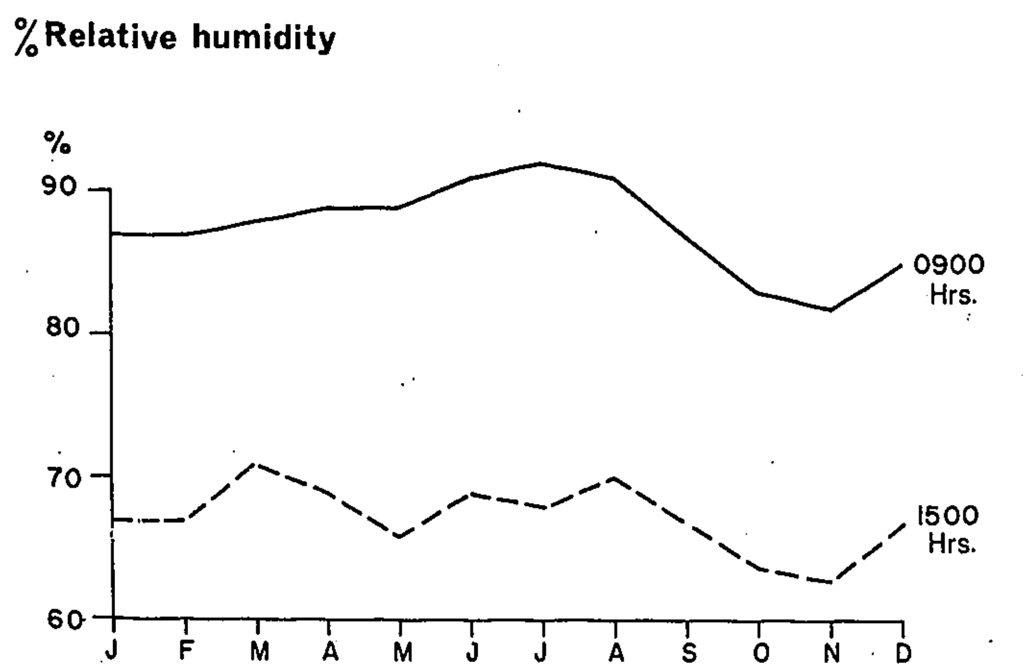
Relative Humidity: Mean monthly values for relative humidity are illustrated in Figure 2.7. Humidity is high throughout the year and shows little seasonal variation. Early morning atmospheric conditions are nearly always saturated, resulting in heavy fog in valley basins. By 0900 hours this is reduced slightly, a range of 82 to 92% being recorded (annual mean 88%) for monthly means, and by 1500 hours it has decreased by another 20%, a range of 63 to 71% being recorded with an annual mean of 67%.

Evaporation: No direct measurements of evaporation are available but estimates derived from mean monthly maximum and minimum temperature, vapour pressure and day length data are given in McAlpine (in press). The estimated mean average total evaporation for Mount Hagen is 1080mm (42.5 ins) suggesting that a water deficit is unlikely. On a monthly basis, also, evaporation does not appear to exceed rainfall and data on soil moisture content indicate that soil moisture

Figure 2.6 Mean monthly temperature data at Mount Hagen.

Figure 2.7 Relative humidity at Mount Hagen.





is never depleted by more than 50% in the Mount Hagen area.

Winds, cloud and daily weather: The Wahgi valley, enclosed by high mountains and with locally high hills breaking up the valley bottom terrain, is subjected to variable wind conditions throughout the year. Winds are seldom strong although they may be during the 'dry' season (May to September) especially in the upper Wahgi valley, when south easterlies tend to dominate. Local daily winds and cloud patterns described for the highlands generally by Brookfield and Hart (1966) are typical for the Mt Hagen region, at least during the 'dry' season. They state: (p.11);

> 'Because of the greater radiation exchange at higher altitudes, upslope winds set in early in the day, yielding a local situation in each basin in which rising air on the valley sides is compensated first by descending air in the centre of the basin, and later in the day also by up-valley winds from lower altitudes. Toward evening and at night the flow is reversed, so that air sinks on the valley sides, at first rises in the centre, and later the whole flow becomes down-valley. We thus find temperature inversions with inversion fog in the early morning, giving place to rapid formation of cumulus on the surrounding mountains while the valley centre remains clear. Toward evening cloud forms over the valley centre, appearing to spread from the sides, and the mountain tops tend to clear. Late in the night the whole sky clears as air descends at all altitudes.'

At other times during this season clear, fine days may prevail for as long as a week. Cloud, if forming at all does so in the late afternoon. The nights are clear and cold with frosts occuring occasionally at the higher altitudes.

Toward the beginning of the wet season (November to March) storms build up in the early afternoon and rain falls during most of the night. On other occasions morning fog will develop into light rain, or after a few hours of cloudy weather rain falls most of the afternoon and throughout the night.

VEGETATION

General descriptions of plant communities in the central highlands are given by Brass (1941, 1956, 1964), Robbins (1958), Robbins and Pullen (1965), while more detailed ecological studies are reported for restricted areas by Walker (1966a), Flenley (1967) and Wade (1968). Forest trees studied in the present work lie between 1980m (6,500 ft) and 3355 (11,000 ft) altitude and may be compared in general with forests described as lower montane oak, beech and mixed forests by Robbins and Pullen (1965) and the midmountain, beech and mossy forests of Brass (1941, 1956, 1964). Other notes on the Mt Hagen forests are given in Hitchcock (1964) and in unpublished forestry reports by Cavanaugh (1959) and Jenkin & Lowien (1963).

Forests were formerly much more widespread in the highlands according to Brass (1941), McAdam (1951) and Robbins (1958, 1963a). Today the lower altitude oak forest is almost non-existent, while the higher altitude beech and mixed forests have been greatly disturbed (Brass 1941, Saunders 1965, Walker 1966a, Flenley 1967). The timber line on many of the mountains has been depressed as well through burning (Lane-Poole 1925, Brass 1941, Womersley & McAdam 1957). Evidence for disturbance of forests in the Mt Hagen region is available everywhere, from the cutting of trees and gathering of plant products within the high altitude forests to the large scale clearance of secondary growth for gardening purposes.

Various seral stages of forest regrowth after gardening, burning and other biotic activities are described for highland areas by Robbins (1958) and Robbins and Pullen (1965). They occur widely in the study region and will be considered further in Chapters 4 & 5.

The widespread grasslands of the central highlands have already been mentioned. Several types of grassland are present in the study area, including the swamp grasslands dominated by <u>Phragmites</u> and <u>Leersia hexandra</u>, and the 'anthropogenic' grasslands dominated by 'tall' grasses such as <u>Miscanthus floridulus</u> or by 'short' grasses such as <u>Themeda australis</u>, <u>Arundinella setosa</u> and <u>Capillipedium parviflorum</u>, between 1525m (5,000 ft) and 2440 (8,000 ft) altitude. At higher altitudes other 'natural' grasslands are found. Robbins and Pullen (1965) described a 'lower montane grassland' from the western highlands, occupying valleys at 2440-2745m (8,000-9,000 ft); they are considered to be the result of frost-pocket conditions. This type of grassland is not present within the study region. Alpine grassland has been described by a number of workers (Hoogland 1958, Brass 1941, Robbins and Pullen 1965) from altitudes above 2745m (9,000 ft). Wade (1968) questions the validity of the term 'alpine' for most of these grasslands, himself restricting it to grasslands above 4090m (13,400 ft). He describes and classifies a number of subalpine and alpine grasslands from Mt Wilhelm and considers that, while the alpine grasslands are probably natural in origin, the subalpine grasslands are mainly anthropogenic. The grasslands found from ca 3345m (11,000 ft) to the summit on Mt Hagen have not been studied in detail. However, forest outliers are present in sheltered areas almost to the summit and the grasslands must be considered subalpine and are probably partly anthropogenic in origin.

Within the altitudinal range 1525m (5,000 ft) to 2440m (8,000 ft) native subsistence gardens and associated plantings of Bambusa and Casuarina are present. They have been described and classified by Robbins (1958) and will be considered further below.

Figure 2.2 shows the areal distribution of forest and non-forest vegetation in the study region; further description is given in Chapters 3, 4 and 5.

THE PEOPLE

The Wahgi Valley was probably first sighted by Europeans in February, 1933, from 2290m (7,500 ft) in the Iliwochi Hills south of Daulo (Leahy, 1936), although Vicedom and Tischner (1943-48) state that Behrmann observed the Hagen-Wahgi area from a peak in the Schrader Ranges some 20 years earlier. Contact was made with the large populations inhabiting the valley in 1933 when the Leahy brothers and Taylor travelled from Bena Bena to set up a camp and patrol post at Mt Hagen and in 1934 when from there they explored country to the north, south and west. The Roman Catholic and Lutheran Missions entered the area in 1934 and the Administration set up a permanent patrol post in 1938.

The people inhabiting the whole of the Wahgi Valley show overall similarities in social organisation, settlement patterns and agricultural practices. Early descriptions of them appear in Chinnery (1934a, 1934b), Leahy (1936), Ross (1936), Williams (1937) and Gitlow (1947), while a more comprehensive account is given by Vicedom and Tischner (1943-48) for the upper Wahgi Valley tribes, and by Reay (1959) for the Middle Wahgi tribes. The latter can be distinguished in linguistic and cultural details from those further west and will not be considered further.

According to recent figures about 113,353 people live in the Mt Hagen administrative subdistrict, which includes the Kaugel, Nebilyer, Baiyer and Jimmi River valleys as well as the upper Wahgi valley. Population densities have been estimated as medium, in excess of 60 persons per square mile (Brookfield, 1961), but as distribution is very uneven, with some area virtually unoccupied, others probably carry up to twice this number per square mile. The Medlpa language, spoken by perhaps 60,000 people in the Mt Hagen, Baiyer River and Jimmi River areas, belongs to the Hagen Subfamily of the East New Guinea Highlands Stock (Wurm, 1964). A number of different dialects are present but have not been studied as far as known.

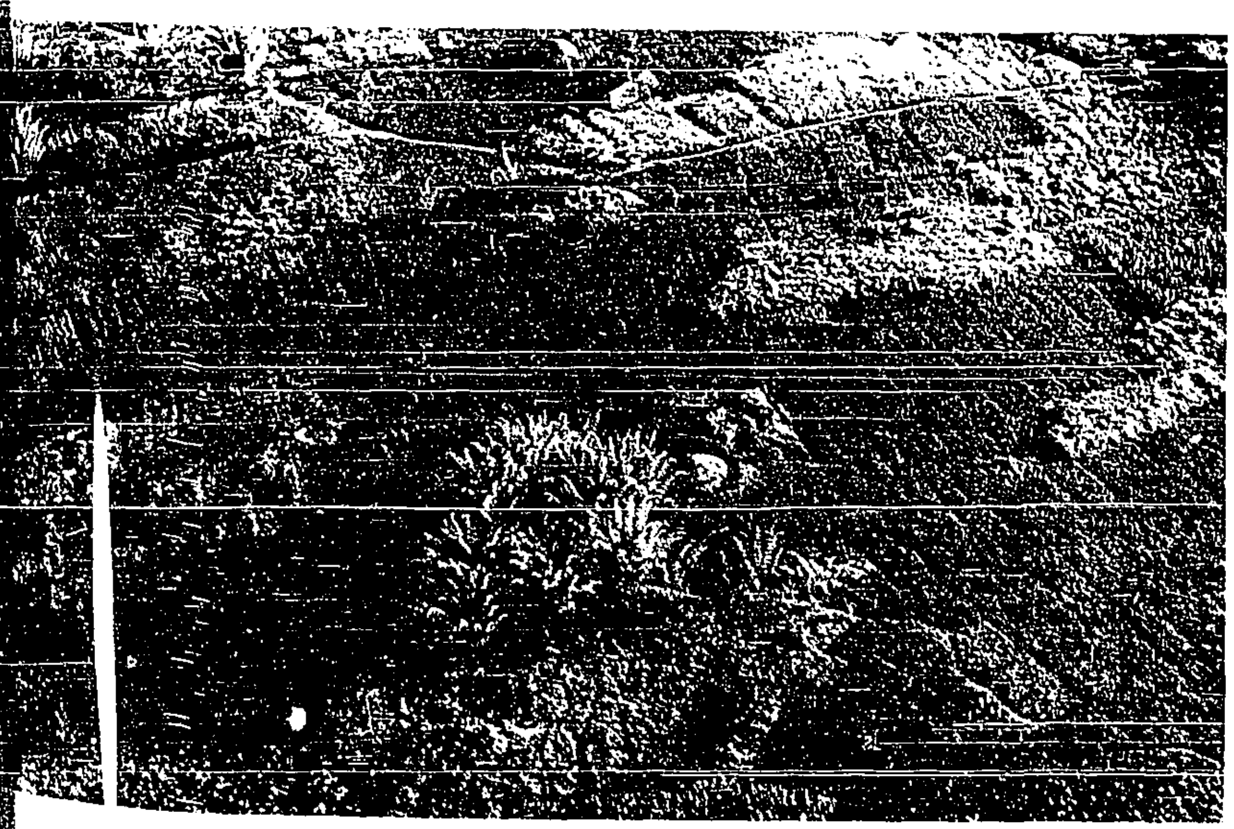
The average Mt Hagen man is tall and strongly built with brown skin and dark brown or black woolly hair. The women are shorter in stature and smaller generally in build (Plate 5A). Little is known of their origins and relations. Blood group studies (Dunn et al 1956, Macintosh et al 1958, Champness et al 1959, MacLennan et al 1959) are largely inconclusive with regard to the relationship of the New Guinea highlanders to other New Guinea populations. The highlanders generally have a lower frequency of M and a higher frequency of S genes than the coastal areas. Macintosh suggests that they reflect hybridization between an earlier widespread population and a later immigrant one and preliminary studies on skin colour may support this also (Macintosh

PLATE 5A

A pig exchange ceremony at Kelua settlement area.

PLATE 5B

A typical settlement area in the Upper Wahgi Valley. Note the patches of Bamboo near men's (round) and women's and pig' (oblong) houses, the chequer-board pattern of sweet potato gardens and patches of mixed grass fallow.



et al 1958, Macintosh 1959). In S gene frequencies there is a gradient from high in the Wabag area to low in the Goroka area and Walsh (in Macintosh et al, 1958) considers this may indicate 'infiltration of a group of people either from the west or from the east along the highland ridge, into an earlier population.' The group patterns for the Mt Hagen area natives is similar to that in other parts of the highlands and no definite relations with groups outside the highlands could be formulated (MacLennan et al, 1959). Many of the people of this region consider their original homes were in the south and southwest (Vicedom & Tischner, 1943-48) but MacLennan found that, while some similarity between the Mt Hagen, Mendi and Gulf regions was shown in gene frequencies, no definite gradients were present.

Social organisation, material culture and economy: In the Mt Hagen area the people are grouped into a number of tribes, each of which has well defined land boundaries. Details of habit and custom differ between tribes and different dialects of Medlpa may be spoken. Intertribal warfare was common, although trading and marriage also took place at this level of social organisation. Within each tribe there are a number of more or less exclusive patrilineages and each of these, depending on the size of families, has one or more settlement areas or kona (Plate 5B). These are made up of a number of houses, dispersed within garden areas, or built near a common ceremonial ground (Plate 6B). Each kona has its headman, usually the richest and most powerful person of the lineage. Trading between different kona occurs and ceremonial exchanges and intermarriage are important features of this social level.

Detailed descriptions of material goods and culture are given by Ross (1936) and by Vicedom and Tischner (1943-48) and they will be considered here only in relation to plant products utilized. Secondary sources have been supplemented by the author's own observations.

Dress and personal ornamentation: A broad bark belt (*Prunus* spp.) upto 20cm wide, often carved or bound with split cane thongs (*Saccharum* sp.) is worn by the men. From this they hang a fine netted apron or bilum woven from *Pipturus* and other Urticaceae fibre, which reaches

PLATE 6A

A man's house at Weylk. Bananas are planted at the side and *Cordyline* trees mark the boundary of an adjacent mixed garden. The shrub is *Ficus adenosperma*.

PLATE 6B

Ceremonial ground at Weylk. The central tree is *Araucaria Cunninghamii*. *Casuarina* spp. are the main trees bordering the ground and *Cordyline* sp. form a lower fenceline on the left hand side.

to below the knees in the front. Behind, cut tanket leaves (<u>Cordyline terminalis</u>) are hung over the belt, petiole upwards. Stems and leaves of variegated <u>Croton</u> sp. may be used in the same way. Their hair is often enclosed in bark cloth (<u>Pipturus</u> sp.) and covered by a finely woven net. Various Lauraceae leaves (including <u>Cinnamomum</u> sp., <u>Endiandra</u> sp., <u>Cryptocarya</u> sp.) may be used as ornamentation on the headdress, also cuscus fur or a band of bark cloth sewn with white cowrie shells. The whole is often crowned with cassowary plumes. Neck and chest ornaments include pig tusks, teeth, bailer and gold lip pearl shell and often a set of parallel bamboo rods. The women wear skirts consisting of knotted strings dyed black or purple. They are made from various fibres, including <u>Broussonetia papyifera</u>, <u>Trema amboinensis</u>, <u>Ficus</u> sp., <u>Acalypha</u> sp., and <u>Debregeasia</u> sp. Lengths of bright red or blue trade cloth are wrapped around the body and a large woven bilum hangs from their head. Ornaments are brightly coloured, multistranded trade beads, strips of marsupial fur, and pearl shells. Formerly strings of <u>Coix lacryma-jobi</u> seeds were worn. For ceremonial occasions dress and ornamentation are more elaborate; these have been described by Strathern (in press). Protection against rain is afforded by a sewn mat made from <u>Pandanus</u> sp. leaves.

<u>Houses</u>: Depending on whether a man has one or more wives, so he builds a large family house, or a men's house and a series of women's houses (Plate 6A). The pigs sleep within the women's house. Guest houses and ceremonial houses are built also. These are all described in detail by Vicedom and Tischner (1943-48). While the structural style varies between rectangular and round, the method of building and the materials used are the same in all cases. After the site has been chosen and levelled or even excavated to a depth of 30cm, the centre post of <u>Castanopsis</u> sp. is raised. Then planks are cut of dried <u>Castanopsis</u> and <u>Casuarina</u> and driven into the ground in pairs along the house walls. The space between the two walls is filled with horizontally packed grass, usually <u>Imperata cylindrica</u> and <u>Ischaemum polystachyum</u>. Linings of <u>Casuarina</u> bark and dried <u>Pandanus</u> leaves are added. The tops of the inner and outer planks are then bound together with lianes

(Monimiacea, Rosaceae, Vitaceae) and further bundles of grass added. The scaffolding of the roof consists usually of closely placed bamboo (Bambusa sp.) rafters, although saplings of Dodonaea viscosa and some Urticaceae may be used also. Purlins of Miscanthus and Phragmites are bound in where necessary. The roof structure is covered with intersheathing bundles of Imperata cylindrica which are not tied down. About 15 cm away from the house a 20 cm deep ditch is dug and the excavated soil is thrown on the wall and trampled down.

Weapons, household goods and tools: Many of the weapons and tools used formerly have disappeared today or are produced in rougher form for sale to tourists as curios. Vicedom and Tischner (1943-48) describe a number of these material goods, and wooden artefacts, recovered from archaeological sites in the area provide further information. Casuarina and Bamboo are the two plants most widely used. Thus 3 types of spears, bows, axe handles and gardening implements are made from Casuarina; bows, bowstrings, arrow shafts, arrow heads, sleeping platforms, plaited mats, water tubes and knives from bamboo. Forest hardwoods are used in the ceremonial spear and shields are made from oak species (Castanopsis and Lithocarpus). Plaited mats are also made from split Miscanthus and Phragmites cane and Pandanus leaf mats are common. Gourds (Lagenaria siceraria) are used as water bottles, as lime and fat containers. Fibre is obtained from a number of plants including Trema amboinensis, Pipturus sp., Debregeasia sp., Ficus sp., Acalypha sp. and Broussonetia papyifera. Trema is most frequently used for general purpose tying and binding. Vines from the forest provide stronger ropes, for example, Rubus sp., Piper sp., Palmeria sp., Tetrastigma sp., Cayratia sp., and various Ericaceae. Resin is collected from Araucaria and Evodiella trees.

Table 2.4 lists some of the wooden artefacts excavated and collected from archaeological sites in the upper Wahgi valley. The wooden gardening implements are of interest as most have been replaced by European spades and hoes; only the small diameter pointed digging stick, used by the women, is widespread today. Table 2.5 lists and describes features of the gardening implements and selected forms are illustrated in Figures 2.8 and 2.9.

At least 5 types of gardening implement can be distinguished, namely the large spatulate spade (with blade tapering to handle, or angled to it), the smaller paddle-shaped spade, the short-handled hastate spade, the large and the smaller diameter pointed digging sticks. Many of these were in use at the time of European contact; the large spatulate spade is mentioned by Williams (1937) and Ross (1936) and this, together with the large and small diameter pointed digging sticks are described and illustrated by Vicedom and Tischner (1943-48). Nilles (1942) mentions similar types for the Kuman people of the Bismarck Ranges.

Table 2.4 Botanical identification of artefacts from archaeological sites in the upper Wahgi valley

Type of artefact	No. of specimens	Botanical Identification	
Large-bladed spade	11	Casuarinaceae	Casuarina ?oligodon
" " "	1	Rubiaceae	Neonauclea sp.
" " "	1	Flacourtiaceae	Hydrocarpus sp.
Small-bladed spade	2	Casuarinaceae	Casuarina ?oligodon
Small hastate spade	2	Fagaceae	Nothofagus sp.
Pointed digging stick	5	Casuarinaceae	Casuarina ?oligodon
" " "	2	Euphorbiaceae	?Phyllanthus sp.
" " "	1	Rutaceae	
Axe haft	1	Euphorbiaceae	Glochidion sp.
Club	1	Moraceae	Ficus sp.
Fence posts	7	Casuarinaceae	Casuarina sp.

An informant at Kelua village, Ogelbeng, who had used similar implements formerly, explained and demonstrated the use of the different types. The large spade was used by the men for cutting and lifting out material from the ditches, the smaller hastate spade for marking out plot lines, for cutting the surface turf and for shaping and lifting material out of small holes. The large diameter pointed digging stick was used for clearing ground, for uprooting tough grass rhizomes and for planting, and the small diameter pointed digging stick was and is used by the women for breaking up the soil and for general weeding, planting and harvesting purposes.

Table 2.5 Description of wooden gardening implements

No.	Type	Blade-Handle Characteristics	Handle	Section	*Full Length	Blade Length	Blade Width Max.	Midpt Thick. Range	Edge Thick. Range
Tibi 3	Large spatulate spade	Blade tapering to handle evenly	Long, rounded at end	Oval	204	98	14.5	2.2-3.7	1.4-3.1
Tibi 4	" "	" "	Long, pointed at end	Roughly square	210	100	10.7	2.5-3.2	1.4-2.8
Tibi 13	" "	" "	Long, pointed at end	Circular to oval	168	70	9.5	2.5-3.3	1.4-2.7
Tibi 5	" "	" "	Broken	Oval	127+	116	14.0	3.0-3.5	1.2-3.0
Tibi 12	" "	" "	Short	Oval	153	110	12.0	3.0-4.0	1.9-3.0
Tibi 2	" "	Slight angling of blade away from handle	Broken	Oval	136+	96	12.0	3.6-4.0	1.7-2.5
Tibi 17	" "	" "	Broken	Oval	123+	98	12.0	2.9-3.5	2.0
Tibi 1	" "	Sharply angled blade	Broken	Oval to square	244+	120	16.5	3.3-4.7	1.8-3.3
Tibi 8	Rough out of spatulate spade	Tapering to handle	Unfinished	Roughly circular	226	88	11.0	4.5-6.3	2.2-3.2
Tibi 9	Small paddle-shaped spade	Black angled at 45° to handle	Long, narrow, round at end	Flattened oval	157	37	9.0	1.2-2.6	1.1-1.7
Tibi 10	" "	" "	Broken	Semicircular	122	c.43	9.8	2.2-3.3	1.0-2.1
Tibi 11	Short hastate spade	Blade shoulder at 90° to handle	Short, narrow, rounded	Narrow oval	93	57	12.0	1.4-1.9	0.6-1.0
MIJ 1	" "	" "	Short, broken	Oval	69	39	11.7	1.3-2.4	1.0-1.1
							Diameter range		
Tibi 16	Pointed digging stick	Sharpened on one side only to point	Undifferentiated	Roughly circular	102	14	2.9-3.1		
Tibi 14	" "	" "	"	" ", broken	67	19	2.4		
Tibi 6	" "	" "	"	" ", broken	90	18	2.6-3.4		
Tibi 7	" "	" "	"	" ", broken	81	30	4.4-5.2		

* All measurements given are in cm.

Figure 2.8 Gardening implements recovered from archaeological sites in the Upper Wahgi Valley.

A1. Large paddle-shaped spade, blade tapering to handle.

A2. Large paddle-shaped spade, blade angled to handle.

B. Small-bladed spade.

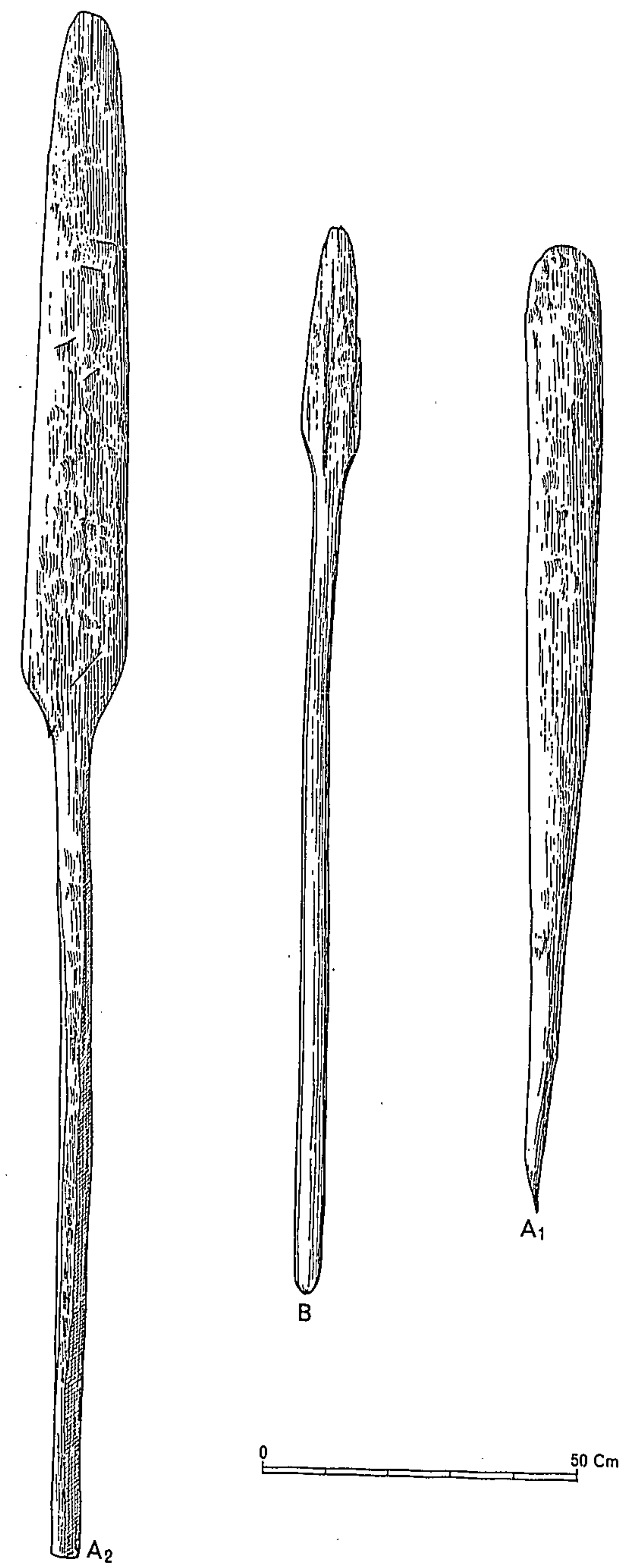


Figure 2.9 Gardening implements recovered from archaeological sites in the Upper Wahgi Valley.

C1, C2. Short-handled, hastate spades.

D1, D2. Large-diameter, pointed digging sticks.

E. Small-diameter, pointed digging stick.

Land use: Despite a relatively large population in the Mt Hagen region, pressure on land is not apparent. Flying over the upper Wahgi valley the impression is gained of large areas of unused grassland and swampland with dispersed, comparatively small cultivated areas, marked by precisely arranged gardens, clumps of bamboo and Casuarina and neat houses surrounded by bananas and ornamental shrubs. The kona is the main unit of land use; it has its own boundaries, streams and woods. Throughout the area there is a mosaic of cultivated and fallow lands, of land occupied by houses, ceremonial grounds, forest remnants and 'waste' ground used for pig grazing. Land is owned individually by the male members of the family and is inherited patrilinearly. Land use is not rigidly controlled, however, and land may be loaned for cultivation or grazing purposes to a friend or member of another lineage or tribe who is currently residing in the area. Subsistence agriculture is the main pursuit of the Mt Hagen inhabitants with animal husbandry also important and hunting and gathering playing a subsidiary role, at least at certain times of the year. Sweet potato forms the staple crop, while bananas, sugar cane, taro, yams, winged beans, edible pitpit and a variety of small herbaceous species are planted also. Corn, cucumbers, peas and beans, tomatoes, onions and cabbages, among others have been introduced by Europeans. These, together with coffee, peanuts, passionfruit and more recently tea, are grown mainly for commercial purposes. A number of garden types can be distinguished on the basis of crops grown, techniques of gardening employed, type of land used and fallow period, among other features. These will be considered in detail in Chapter 5.

The ceremonial or singsing grounds form the centre of communal life at all levels of social organization. They vary in size from 50-150m long by 20-30m wide (Plate 6B). There is usually one per kona but there may be more depending on the size of the settlement area and the number of influential men living there. The main area of levelled ground is grass covered, carefully planted and regularly cut. Specimen trees such as Araucaria cunninghamii, Papuacedrus papuanus, Ficus sterrocarpa, Podocarpus sp. and Casuarina sp. are planted within wooden boxed mounds along the centre, while both sides have hedges of Cordyline, Casuarina and bamboo. Colourful shrubs such as Croton sp. and the purple-flowered Graptophyllum pictum are planted, together with numerous variegated herbs such as Coleus sp., Plectranthus sp., Elatostema sp. and members of the family Araceae. Self-sewn woody species are maintained also and the following have been observed lining both sides of the ground: Maesa sp., Elaeocarpus spp., Ilex sp., Saurauia sp., Glochidion sp., Trema sp., Pipturus sp., Schefflera sp., Macaranga sp., Castanopsis acuminatissima, Ficus sp., Dodonaea viscosa, Gardenia sp., Acalypha sp., Alphitonia sp., Wendlandia sp., and Omalanthus sp. A ceremonial men's house is built within a recessed area at the head of the ground and is surrounded by ornamental shrubs, trees and high bamboo. Here Eurya meizophylla, Claoxylon sp., Ficus dammaropsis have been observed as well as the usual Araceae, Cordyline and Casuarina.

Animal husbandry: Domesticated and semi-domesticated animals of the Mt Hagen people include pigs, dogs, cassowaries, marsupials, chickens, cockatoos and sporadically birds of prey. The pig is the most important domestic animal from economic, social and religious points of view (Plate 5A). They are used as a medium of exchange and figure in economic payments such as payments to workers who have helped prepare a garden, to native doctors and priests, as part of a bride price. Pigs are a major item of wealth; the possession of many pigs contributes much to the power and prestige of a man in the community. There appears to be no social or ceremonial occasion at which pigs are not slaughtered and eaten. Ross (1936) states that they are killed when a man or women dies, at annual singsings, at marriage feasts, before a large hunting party leaves, as a thank offering to spirits after a good harvest, when building a new house and for naming a newborn child. The pig figures prominently in the rectification of wrongs and in local politics, for 'fines' may be paid in pigs and one tribe or kona will often tender pigs as a peace offering to another (Gitlow, 1947).

The pig is well treated at all times and is always raised in the settlement. Piglets are carried in the women's net bags, food is often pre-chewed for them and they may be suckled. When older they may be either tethered to poles in the garden near to where the woman is working, or taken to otherwise unused ground to root in the scrub for insects, grubs, fern roots and other foods. At night they are called back, fed and tied up in separate compartments in the back of the women's house. Food is prepared for them every day and includes sweet potato tubers and vines, young bamboo sprouts, Setaria palmifolia and other small greens and ferns. It is eaten raw or cooked. In the Mt Hagen area there is a pig cycle which involves exchange and killing of pigs over a period of about five years. More and more pigs are raised and maintained over this period and studies have suggested that often over 80% of the sweet potato crop is fed to the pigs for some time before the final round of ceremonies. In some cases towards the end of the cycle when there are a great number of pigs to be kept, a special pig grazing area is established in uninhabited grassland. The pigs are housed and fed here and tended by a number of the men and women from the settlement. Food may be taken to the area each day by the women, or if some distance from the settlement, sweet potato gardens may be prepared nearby to supply their needs.

Dogs are common and used especially for hunting purposes. The cassowary is kept as a captive wild bird, mainly for its feathers. Chickens are also kept mainly for their feathers according to Vicedom and Tischner, although they are quite frequently eaten. They are not plentiful. Cockatoos and marsupials may be kept as pets, also more rarely the eagle. Dogs, cassowaries and marsupials may be killed as sacrifices and their meat eaten but this occurs infrequently (Vicedom and Tischner, 1943-48).

Hunting and gathering: Ross (1936) states that a variety of marsupials and birds are quite plentiful in the forested areas and these are hunted by the people living on the forest edge. Dogs are used widely, bows and arrows, traps and nets also. The people inhabiting the grassland areas only occasionally form forest hunting parties. Instead they catch the rats and mice and small birds living in the grassland, using sticks and arrows as weapons, or by setting traps. Group hunting on a large scale may consist in firing a large stretch of kunai and watching along the borders. Fish are not plentiful; eels, catfish and other small fish are available and are generally caught in traps, net bags, or by hand. Vegetable poisons may also be used in still water (Vicedom and Tischner, 1943-48). Frogs, small insects and grubs provide further variety to the diet.

Generally speaking a particular lineage of tribe will have hunting and gathering rights over certain areas of forest and within this, plant products are gathered and forest animals hunted. Many of the utilised plant products mentioned in previous sections are gathered from the forest areas. As well, certain tree species such as Pandanus spp. belong to individuals; they are tended within the forests, the fruit being harvested when ripe.

CHAPTER 3

THE PRESENT VEGETATION

The hypothesis that the extensive grasslands found in both lowland and highland areas of New Guinea are the result of human influences on the vegetation there, together with archaeological evidence of long human occupation of the island, provide premises for the present study. The ecological work on which the 'anthropogenic grasslands' hypothesis was based, however, was of a general, extensive nature and the hypothesis remained to be tested in a well-defined context such as the Mt Hagen region offered.

Moreover, interpretation of the vegetation history of the region would be extremely difficult, if not impossible, without a knowledge of extant vegetation types and for a more controlled interpretation of fossil pollen assemblages knowledge of the relations of the present day vegetation to the modern pollen rain is desirable.

The aims of the ecological study, therefore, were:

(1) to describe the vegetation types present in the Mt Hagen region and to note the areal extent and distribution of each type,

(2) to hypothesize on the environmental relations and successional status of each type, and

(3) to identify indicator taxa for the various vegetation types which might be useful in interpreting pollen diagrams.

VEGETATION TYPES

Vegetation types within the Mt Hagen region are, for the most part, clearly delimited on aerial photographs. They are classified by inspection of these and by initial traverses on the ground into the following categories:

1. Forest Vegetation

1.1 Oak forest

1.2 Beech forest

1.3 Mixed forest

1.4 Subalpine forest

2 Non-forest Vegetation

A. Woody vegetation

2.1 Patches of trees and shrubs associated with settlement areas

- 2.1.1 Oak patches
- 2.1.2 Mixed garden regrowth
- 2.1.3 Other settlement area vegetation

2.2 Patches of forest and scrub within grassland

- 2.2.1 Forest patches on steep slopes
- 2.2.2 Stream bank vegetation
- 2.2.3 Regrowth scrub in grassland

B. Herbaceous vegetation

2.3 Grassland

- 2.3.1 Short grassland
- 2.3.2 Tall grassland
- 2.3.3 Mixed grassland
- 2.3.4 Subalpine grassland and mires

2.4 Gardens

- 2.4.1 Sweet potato gardens
- 2.4.2 Mixed crop gardens
- 2.4.3 House gardens
- 2.4.4 Commercial gardens and plantations

2.5 Swampland

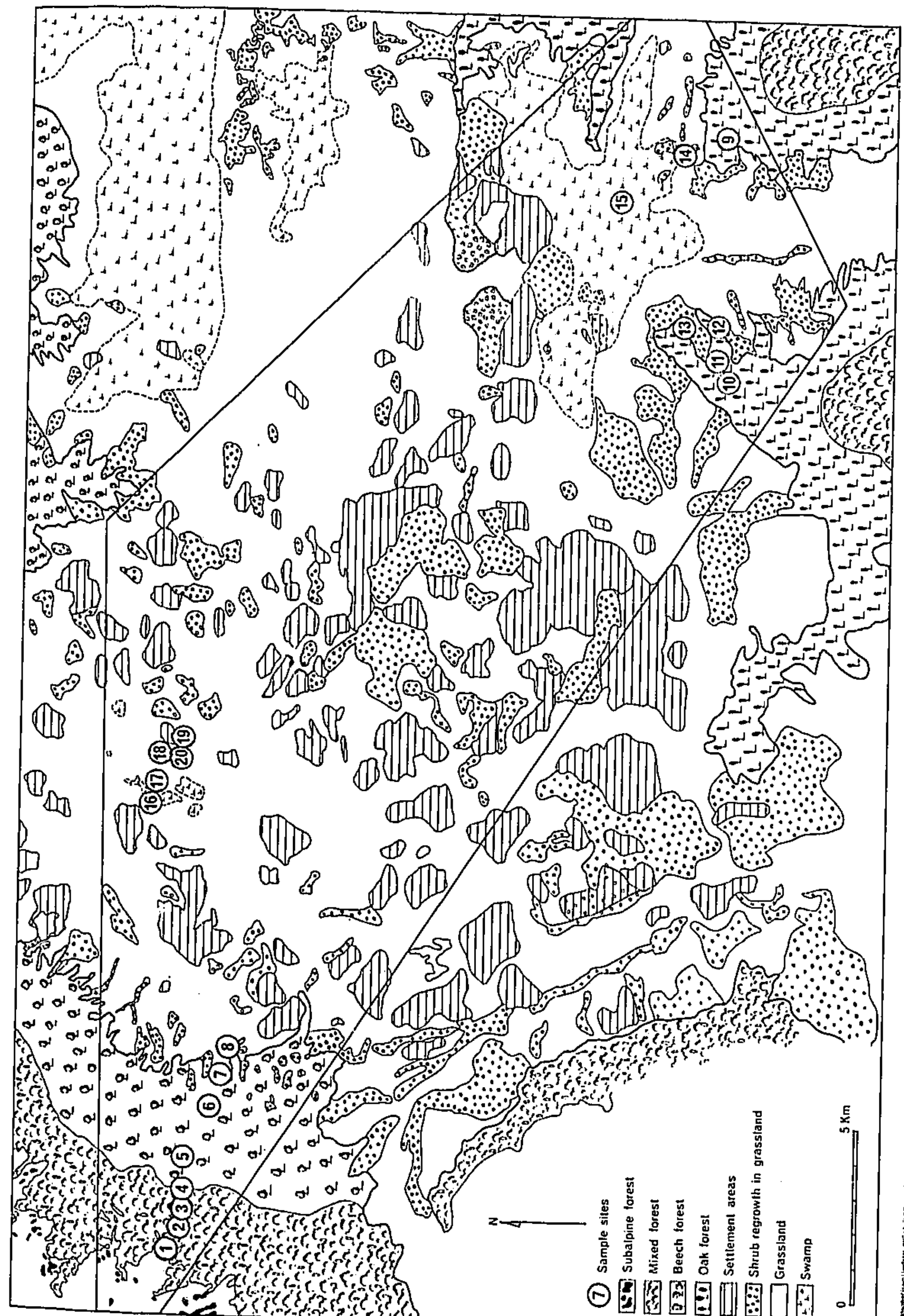
- 2.5.1 Cane grass swamp
- 2.5.2 Short grass swamp
- 2.5.3 Sedge swamp

Within the study region as a whole, forest covers 35 sq. km (13.6 sq.mi.), ca 10 per cent of the total area, non-forest woody vegetation 55 sq. km (21.3 sq.mi.), ca 17 per cent of the total area and herbaceous vegetation an estimated 272 sq. km (105.1 sq.mi.), ca 73 per cent of the total area. Figure 3.1 shows the distribution and areal extent of the main vegetation types listed. Due to mapping difficulties patches of trees and shrubs associated with settlement areas are mapped as a single unit with gardens and mixed grassland.

CHOICE OF FIELD SAMPLING METHODS.

Many authors emphasise that basically the sampling methods chosen in any vegetation study must depend upon its aims (Fosberg, 1958); often they also depend upon the author's concept of vegetation. Detailed discussion

Figure 3.1 Vegetation of the Mt Hagen region.



of the different ecological concepts, of the relative merits of the community type and continuum approaches, is outside the scope of the present study; a number of recent reviews is available (Whittaker 1962, 1967, McIntosh 1967, Cantlon, Egler and others 1968). It appears that controversy between the two main schools of thought has lessened recently and acceptance of both continuity and discontinuity in vegetation is widespread among ecologists at the present time. Thus McIntosh (1967) states that proponents of the continuum hypothesis do not deny discontinuity in vegetation, especially at the physiognomically recognized formation level, while proponents of the community type concede individual variation and continuity of the flora but maintain that vegetation is largely discontinuous (Daubenmire, 1966). McIntosh refers to many recent workers who have subjectively recognized continuity in vegetation without applying specific methods to demonstrate it and to others, such as Hanson (1958), Coupland (1961), McVean & Radcliffe (1962) and Poore (1962, 1964), who 'consider that vegetation constitutes a continuum but find it more useful to classify it' (McIntosh 1967, p.141).

Certainly most authors studying tropical vegetation have accepted continuity there, although they may have described subjectively chosen vegetation units for convenience (Hewetson 1955, van Steenis 1958, Schulz 1960, Richards 1963, Ashton 1964, Walker 1966a). Van Steenis (1958) questioned the application of methods and concepts developed for temperate vegetation types to those of tropical regions. He stressed the problems of a 1 - 2 hectare 'minimal area' sample in the tropics, the lack of uniformity in edaphic factors, the complexity of the vegetation and the difficulty of defining composition in terms of 'dominant' or 'tracer' species concluding that the sampling methods of the Zurich - Montpellier and Scandinavian schools were of no value in mixed tropical forest. Many authors appear to agree with him (De Rosayro 1958, Richards 1958, Fosberg 1958, Schulz 1960, Ashton 1964 among others). Greig-Smith (1965) considers that sample areas of up to 10 hectares are required for even a low precision of measurement and Poore (1968) found that a plot size of 2 hectares was inadequate for enumeration of canopy species.

Ashton (1964, 1965) found that a plot size of 0.4 hectare was the largest practicable on relatively homogeneous physiography, although a sample size of 2 hectares was ideally necessary for adequate description of the forest.

Schulz (1960) stressed further problems in applying the Zurich-Montpellier techniques to mixed rain forest, considering the enormous floristic diversity of the forests, the practical impossibility of making estimates of cover of tree species and the difficulties inherent in determining fidelity under such conditions. Richards (1958) stated also that the system placed too much emphasis on floristics and on species of high fidelity, usually rare species of little ecological importance.

On the other hand, Bharucha (1958) cited the studies of Mangenot (1950a, b) as examples of the success of the Zurich-Montpellier approach in the Belgian Congo and West Africa. Schulz (1960) suggests that these studies and others (Emberger 1950, Heim 1950, Germain et al 1956) owe their success to the special nature of the vegetation there, 'although their conclusions have been bitterly contested (e.g. Chevalier (1953), Aubreville (1950-51).' (Schulz 1960, p.213).

Poore (1955, 1956, 1962) modified the Zurich-Montpellier methods, overcoming the problems of fidelity by the use of constancy as the basic criterion for separation of vegetation units. He accepted also that vegetational variation is largely continuous but considered it convenient for descriptive and classificatory purposes to establish 'noda' or points of reference. These are arbitrary groups of taxa in some cases but in others they have absolute validity as communities identifiable in the field. Recently, Wade (1968) has applied Poore's methods to the high altitude vegetation of Mt Wilhelm, New Guinea, describing and classifying a number of forest and non-forest vegetation types with some degree of success.

In the present study the methods of the Zurich-Montpellier school and those of Poore were not used, mainly because characterization of the vegetation rather than classification were the aims of the study and absolute measures of density and structure were required.

Also, since the vegetation was unfamiliar to the author, it was doubtful that the limited time available for the study would allow collection of the large number of releves necessary to describe and separate 'noda' from the wide range of vegetation present. Accordingly, methods involving collection of numerical data were sought for sampling the vegetation. Various types of sampling procedure were considered.

Plotless sampling. A number of methods have been developed utilizing distance measures to determine relative density, dominance and basal area in forest vegetation. They include point to plant measures such as the closest individual method (Cottam, Curtis & Hale, 1953) and the point-centred quarter method (Curtis, 1950), and plant to plant measures such as the nearest neighbour method (Cottam, Curtis & Hale 1953, Clarke & Evans 1954, 1955) and the random pairs method (Cottam & Curtis, 1949). The relative value of these methods compared to that of plot (quadrat) sampling is considered by Cottam and Curtis (1956); they conclude that the point-centred quarter method is the most reliable and relatively less time consuming than plot sampling. However, since the methods assume random dispersion of individuals within the population none of the distance measures will give accurate density figures if clumping of these occurs. In fact, the closest individual method has been used by Pielou (1959, 1960) to detect non-randomness of pattern in vegetation.

In the context of the present study such methods have the following special limitations:

(1) they are applicable only to forest trees,

(2) the number of sampling points required to give an adequate sample in complex vegetation would be large and since these must be randomly spaced logistic problems would arise due to the size of the study region,

(3) the methods are inaccurate if individual taxa within the population are not randomly dispersed; this appears unlikely in New Guinea considering the comments of van Steenis (1958) on tropical vegetation in general.

A number of workers have used the point-centred quarter method systematically, collecting data for various plant categories at fixed intervals along set traverse lines (Baylis & Mark 1963, Mark et al 1964, Kowal 1966); in this way logistic problems and the restrictions on the type of data collected may be overcome but resultant densities appear low when compared with correlated quadrat data (Mark,1963). Ashton (1965) considers that the low density of even the most abundant species in the Brunei forests would make the use of these methods impracticable.

Other plotless methods used by Atkinson (1962) and Boaler (1966) involve enumeration of a larger botanical sample at set points along predetermined lines; while they are useful survey methods, their statistical validity is open to question. Before these methods could be used with confidence in sampling tropical vegetation their accuracy must be assessed by comparison with sample plot data; this was outside the scope of the present study.

Plot Sampling

Most workers in the tropics concerned with gathering quantitative data on vegetation have used sample plots as their basic unit of study despite the problems involved and the lack of precision in the results (Greig-Smith et al, 1967). If sample plots are to be used decisions on their size, shape, number and positioning have to be made.

Random sampling, the most accurate method of studying vegetation because it allows statistical assessment of variation and error (Greig-Smith, 1964) has rarely been used in tropical vegetation and was not considered feasible in the present study. It is time-consuming, difficult to accomplish in rough terrain, such as that of the New Guinea highlands and requires a very large number of plots to sample all vegetation types adequately. Also, the use of a necessarily large plot would have transgressed environmental boundaries. Flenley (1967) attempted to use random samples in studying vegetation of the Western Highlands District of New Guinea but had to add a number of subjectively placed samples to ensure adequate sampling of all major vegetation types.

Systematic sampling, such as enumeration of belt transects arranged in an open grid pattern from initially random starting points has been used in Indonesian forestry studies but the results have not been satisfactory (van Steenis, 1958). Mixed subjective and systematic sampling procedures have been used more frequently. Thus Jones (1955) and de Rosayro (1958) set plots at intervals along predetermined lines after initial subjective selection of stands, while Ashton (1964, 1965) after dividing the whole of his study area arbitrarily into equal sized blocks positioned single plots subjectively within each block.

Single, subjectively placed plots have been used by many workers. The plots may be located to include a range of floristic, physiognomic and geographical types recognized on the basis of earlier inspection or enumeration (Greig-Smith et al 1967, Walker 1966, Schulz 1960), or within areas of known human disturbance (Ross 1954, Greig-Smith 1952, Kellman 1967).

The large size of sample area required to give adequate descriptive and numerical data in tropical forests has been considered above (van Steenis 1958, Greig-Smith 1965, Ashton 1964, 1965, Poore 1968) and further comments on the concept of 'minimal area' as applied to all types of vegetation are to be found in Hopkins (1957), Poore (1964), Goodall (1954, 1961) and Greig-Smith (1964). Kershaw (1964) stresses that each situation has to be assessed independently and that while an estimate may be obtained by plotting species-area curves or by calculating coefficients of similarity between different stand sizes (Poore, 1968) other factors such as the amount of time available and the type of vegetation being sampled usually determine the size of the sample enumerated.

In tropical forests usually a plot size smaller than that theoretically desirable must be used because of practical problems and lack of environmental uniformity over large areas. Schulz (1960) used a 10 x 10m quadrat as his basic unit in a sample area of 1 hectare, Ashton (1964, 1965) a 20 x 20m subplot within a basic sample unit of 0.4 hectare. Greig-Smith et al

(1967) a 20m square subplot within a 100 x 60m plot, Walker (1966) subplots of 10 x 5m within a sample area of 750 sq.m and Flenley (1967) subplots of 50 x 12.5m in a sample unit of 0.5 hectare.

Within secondary regrowth vegetation Ross (1954) used sample plots of 60 x 30m or 60 x 60m, Kellman (1967) subplots 5 x 5m arranged along belt transects of various lengths and Greig-Smith (1952) a 10 x 10 lattice of contiguous 1.5m square plots.

For enumeration of non-forest vegetation smaller plot sizes are employed. Richardson (1963) used 0.5 x 0.5m plots placed at 6m intervals along transects across apparently homogenous savannah vegetation in Trinidad, Flenley (1967) 4 x 4m subplots within a sample plot of 256 sq.m, Walker (1966) a 1.6m sided quadrat and Walker (1968) subplots of 1 sq.m within a 2 x 2m plot for non-arboreal vegetation types in the New Guinea highlands.

From these examples it is evident that numerous small plots have often been preferred to a single one of equivalent area. Usually this is the easiest and often the most efficient way to sample vegetation (Greig-Smith, 1964). Moreover, if the small plots are arranged in series, such as belt transects of contiguous plots, as lattices of contiguous plots or grids of belt transects, non-random dispersion patterns are readily detected (Greig-Smith 1952, 1964, Poore 1968).

Square plots are often used but Clapham (1932) and Pechance and Stewart (1940) studying herbaceous vegetation and Hasel (1938) forests, found rectangualr plots were more efficient sampling units than squares. Bormann (1953) concluded that this was true only when the long axis of the plot ran against any observed contour, soil or vegetation banding. Use of long, narrow plots involves more careful work to avoid edge effects but is often advantageous in reducing trampling within plots during enumeration. Transects of contiguous plots (belt transects) or of regularly spaced plots are useful particularly in sampling vegetation change along environmental, physical or successional gradients (Kershaw, 1964).

Many other sampling techniques have been developed to determine single attributes of vegetation such as cover by the use of of transects or point quadrats in grassland (Goodall 1952, Warren Wilson 1959, Winkworth and Goodall 1962) and basal area by the Bitterlich method (Shanks, 1954) among others. They can rarely be used to gain other information unless combined with plot techniques (McIntyre 1953, Woodin and Lindsey 1954, Lindsey et al 1958).

FIELD SAMPLING METHODS USED

In the present study the aim was to record numerical data from as many as possible of the types of vegetation classified tentatively above in the limited time available. Altogether about 5 months were spent on sampling vegetation, about 3 months on Mt Hagen and near Draepi, and 2 months in the Kubor Ranges and near the Manton site.

Collection of plant material

Since the vegetation was unfamiliar to the author considerable time was spent throughout the field work period collecting, labelling, pressing and drying plant specimens for future identification.

Native assistants readily named individual taxa and these names were used continually in recording plot data; whenever the identification was in doubt for any reason further specimens were obtained.

Sample sites

Within the continuous forest sample areas (sites) were chosen subjectively on the basis of apparent physiognomic and floristic homogeneity and relative physiographic uniformity, at altitudinal intervals of 1000-1500m. Six such sample areas were chosen on the slopes of Mt Hagen and another four on the Kubor Range. As well as these, two areas showing obvious human disturbance were selected on Mt Hagen. Within the non-forest areas choice of samples depended upon a number of criteria including known histories of disturbance, apparent gradients of environmental conditions and proximity to the vegetation history sites; eight such areas were chosen. The locations of all sites are shown in Figure 3.1.

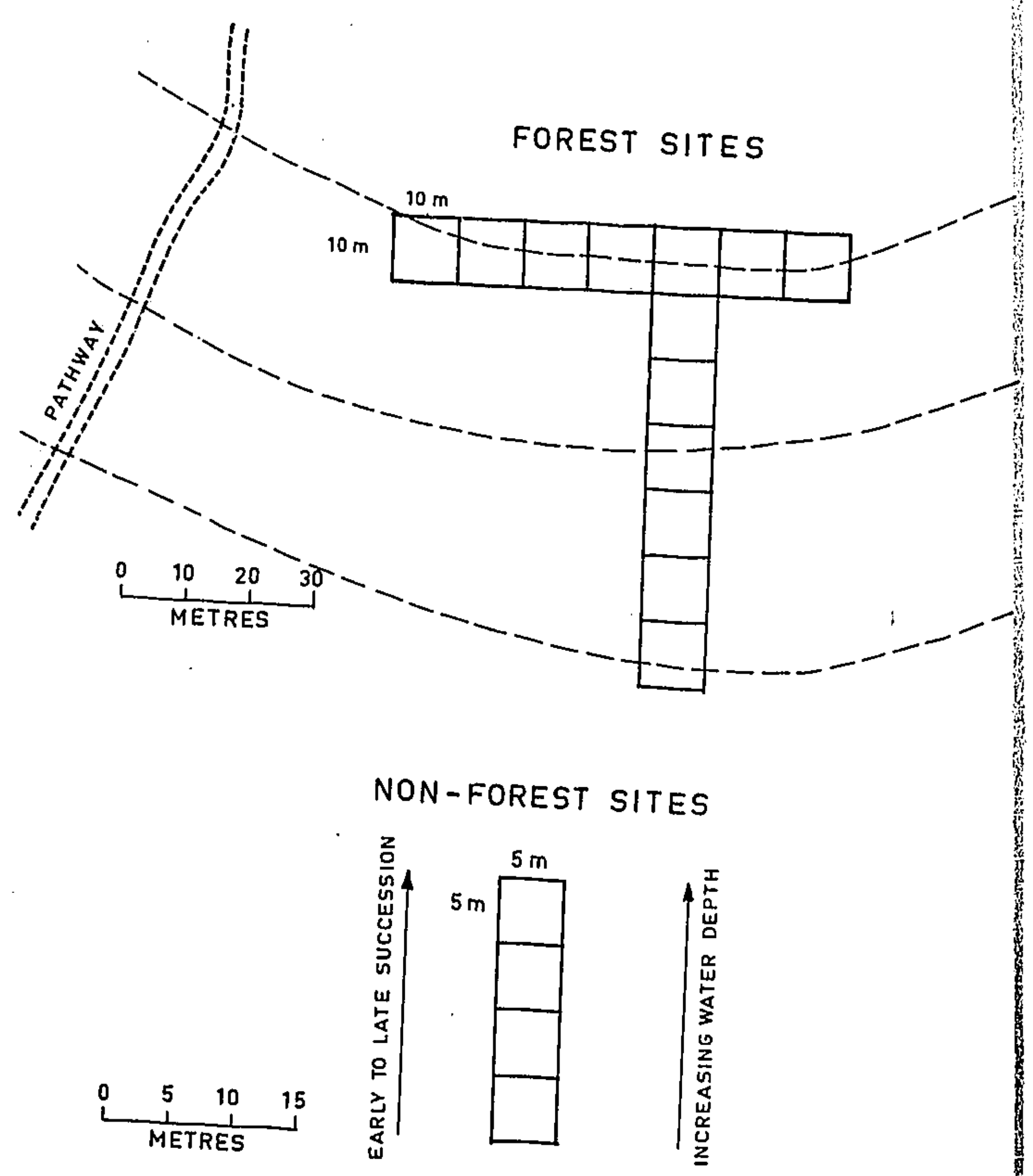
At each site the same sampling plan was followed. Within the forest a starting point was selected at least 30m away from any pathway and square plots of 10m side were laid out in contiguous series to form two lines of quadrats, the first positioned across slope, the second downslope (Figure 3.2). The number of plots enumerated at each sample site depended upon the time available. Within non-forest vegetation square plots of 5m side were arranged as belt transects, positioned across obvious vegetational changes apparently related to physical, environmental and successional gradients. The boundaries of each plot were marked with ropes and undergrowth was cleared from around the margin of the whole set of plots when necessary.

General site information

At each site the following information was recorded.

1. Location: the position of each site was indicated on aerial photographs.
2. Altitude: three aneroid pocket altimeters were used to estimate altitude, the mean value in feet being calculated at each site and converted to metres. The altimeters were checked whenever possible against a known bench mark, the Mt Hagen airstrip at 1725m (5,670 ft).
3. Site: the landform type, the site's position on the landform and degree of exposure were estimated.
4. Aspect: a small pocket compass was used to determine aspect; for ridge sites alignment of the ridge was noted also.
5. Slope: small changes in microtopography were noted subjectively and main slopes were measured at various points within the site to gain a mean slope value.
6. Soil profile: at each site a soil pit was dug to 70-100cm depth and the colour, texture, composition and depth of various horizons recorded. The pH of the uppermost soil horizon (not including leaf litter in forests) was measured in the field using the barium sulphate colorimetric method with B.D.H. soil indicator.
7. Drainage: drainage was judged on a 0-6 scale similar to that described in the U.S. Dept. Agriculture soil survey manual (U.S. Dept.Agric. 1951, Haantjens et al, in press):

Figure 3.2 Sampling plan for forest and non-forest vegetation.



(0) Swampy: water is removed from the soil so slowly that the water table remains at or above the surface permanently or for the greater part of the year. The soil is strongly gleyed throughout, commonly has prominent rusty mottled and, or poorly decomposed plant remains.
(1) Very poorly drained: water is removed so slowly that the soil remains saturated for a large part of the year. The water table is commonly at or near the surface. Distinct mottling and grey colours occur above a depth of 9 in. (23 cm).
(2) Poorly drained: water is removed from the soil slowly enough to keep it saturated for significant periods, especially in the subsoil. Distinct mottling and grey colours occur below a depth varying from 9 in. to 20 in. (23 cm to 50 cm).
(3) Imperfectly drained: water is removed from the soil rather slowly so that the soil is too wet for short but significant periods, especially in the subsoil. Distinct mottling and grey colours occur below a depth varying from 20 to 46 in. (50 to 115 cm).
(4) Well drained: water is removed from the soil readily but not rapidly. There are no indications of gleying or a water table above 46 in. (115 cm) depth.
(5) Somewhat excessively drained: water is removed from the soil rapidly.
(6) Excessively drained: water is removed from the soil very rapidly. The soil is too dry for significant periods.

Enumeration of plots

Before enumeration of plots started at each site, general features of the vegetation were noted, the native names of the main species listed and plant specimens collected when necessary. Within the forest sites notes were made on the smoothness and continuity of the canopy, the trunk and crown form of the main canopy trees and the degree of vegetation stratification and the density of the subcanopy. The presence of standing dead or dying plants, the size and abundance of stumps and logs on the forest floor and any indications of disturbance, such as browsing, trampling, cutting, bark-stripping or burning in the area were recorded.

Within each forest plot the species present were listed (bryophytes and lichens omitted) and their growth forms noted. The number of individuals or parts of individuals (such as separate stems if branching near the base) of each species were counted. Their ground coverage was estimated when individuals could not be distinguished. The height and the circumference at breast height of all shrubs and trees over 3m high were measured. The height to mid-canopy of tall trees was measured initially with a Haga tree measurer and later estimated. Circumference was measured to the nearest cm with a tape; when plants branched below breast height (ca 1m) the separate stems were measured. The abundance and distribution of epiphytes, lianes and climbers and of ferns, bryophytes and lichens were noted and the amount of bare ground estimated.

Attempts were made to determine cover in the forest plots, using the line-intercept method of Woodin and Lindsey (1954) but results were inaccurate due to the remoteness and heterogeneity of the canopy and to the density of undergrowth species.

Within non-forest sites the structure and density of the vegetation was noted and the amount of bare ground estimated. Indications of disturbance and any available information on the previous history of the site were recorded. Within each plot the species present were listed, their growth forms noted and the numbers of individuals or parts of individuals of each species counted. Percent cover of each species was estimated.

Time did not permit plot sampling of all the observed vegetation types within the study region; species lists collected when traversing some of the remaining types provide further information of some value.

CHOICE OF DATA ANALYSIS METHODS

In recent years numerical methods of vegetation analysis have been developed to aid the comprehension of large amounts of data and to provide a means of classifying vegetation and correlating it with environmental factors. They have proved useful not only by confirming and extending subjective assessments but also by providing models against which theoretical concepts and conclusions can be reconsidered and perhaps improved (Williams 1963, Gittins 1965a, Ivemey-Cook & Proctor 1966, Webb et al 1967a).

Two main approaches have been developed, namely classification and ordination. Methods of classification consider the pattern of relationship among individuals and result in a hierarchy of grouped sites (or species) which are usually ecologically meaningful. Presence-absence data are normally utilized in these methods although quantities may now be incorporated in some of them. Monothetic divisive and polythetic agglomerative methods, such as Association Analysis and Information Analysis respectively, have been developed by Williams et al (1959, 1960, 1961, 1966) and use both site ('normal' analysis) and species data ('inverse' analysis). Nodal analysis (Lambert & Williams, 1962) examines coincidences between the results of normal and inverse association analysis to give 'species - in - habitat' groupings. Similar classificatory techniques have been developed by Goodall (1953, 1954b) and Orloci (1967) among others.

Methods of ordination, on the other hand, are concerned primarily with the distribution of individuals in relation to the axes of greatest variance in the data. The resultant graphs display individual interrelations (sites or species) and suggest correlations between vegetation and environmental factors which the axes are often, although not necessarily, taken to represent. Most of these methods use quantitative data such as frequency and density but some may use presence- absence records (Gower 1966, Austin & Orloci 1966). The various methods developed include simple ordinations (Bray & Curtis 1957, Curtis 1959, Ashton 1964, Gittins 1965), position vectors technique (Orloci 1966), principal components analysis (Orloci 1966, Austin & Orloci 1966) and principal coordinates analysis (Gower 1966), among others.

There has been considerable controversy over the relative values of the two approaches and this has been confused due to classificatory techniques being associated with the community-type concept and ordination with the continuum concept (compare Greig-Smith 1964, Anderson 1965, McIntosh 1967). Both approaches have advantages and disadvantages and should be considered as complementary rather than as opposed. Advantages of classificatory techniques that have been cited include their applicability to markedly heterogeneous data, the relative simplicity and speed of computation and the practical convenience of the classification produced.

Disadvantages include their ability to misclassify, or to produce uninformative subdivisions, the uncertain and variable ecological status of the resultant groups, the lack of clear display of interrelations and the fact that the size of the sampling unit, the richness and abundance of species may affect the sensitivity of the analyses. Ordination techniques, on the other hand, are unaffected by sample unit size, they display correlations between vegetation and environment well and are generally considered to be more informative at lower levels of vegetational variation. They are uninformative, however, when applied to heterogenous data, they may exaggerate the continuum (in particular the Bray & Curtis technique- Austin & Orloci, 1966) and their graphical representation of interrelations may not be convenient for classificatory purposes (Webb et al 1967a, Greig-Smith 1964, Greig-Smith et al 1967, Lambert & Williams 1966, Orloci 1967, Ivemey-Cook & Proctor 1966, 1967, Williams & Dale 1962, Gittins 1965). A number of recent studies suggest the value of using a combination of the two approaches to investigate different levels of vegetational variation (Gittins 1965, Orloci 1967, Greig-Smith et al 1967).

Various techniques have been tested for use with tropical vegetation data (Ashton 1964, Flenley 1967, Walker 1968, Poore 1968) and combinations of both classification and ordination used by Webb et al (1967a,b) and Greig-Smith et al (1967). Webb et al, using tropical rainforest data from northern Australia, assessed the results of normal and inverse association analysis and Gower's ordination technique against environmental considerations and a subjectively developed physiognomic-structural classification. They concluded that the data should be classified first and then ordinated if classification results were insufficiently informative.

Greig-Smith et al, also used both approaches to analyse lowland rainforest data from the Solomon Islands. They suggested that after initial classification the resultant groups should be checked for misclassified stands by ordination and then reclassified into high-level vegetation types. Ordination within these types would then elucidate environmental relationships.

Both studies considered a major problem involved in analysing tropical vegetation data by numerical methods, namely the great number of species present compared with the few sites enumerated, resulting in a low overall density of entries in data-matrices. Webb et al (1967b) then investigated the use of 'subset' data which would 'serve to reproduce the pattern of the whole' and found that use of a 'large tree' grouping (269 species) was adequate and those most abundant, enough to give informative results. Austin & Greig-Smith (1968) also reduced their original data somewhat before studying further the effects of standardization of data before analysis and the value of different measures of species representation for use in both ordination and polythetic agglomerative classification. These studies extend considerably the use of numerical techniques of analysis of tropical data and suggest also that certain theoretical considerations such as the validity of stratification in tropical forests and the value of quantitative data for purposes of classification should be reviewed.

METHOD OF DATA ANALYSIS USED

In the present study limited time forced a choice between the use of numerical or subjective techniques of data analysis. Subjective analysis was chosen mainly because the diversity of the data collected, considered important in relation to the aims of the study, was not suited to computer analysis. While it is acknowledged that numerical methods would have aided enumeration of the relatively large quantity of data collected, they would also have involved a great loss of information if used alone. It is hoped that the validity of the tentative classification given above and of a number of the hypotheses erected below concerning successional status and environmental relations of the various vegetation types will be tested by computer analyses in the future.

Identification of plant specimens

Plant specimens were sorted, identified and distributed by the staff of the Herbarium Australiense (CSIRO, Division of Land Research) in Canberra. Much of the material collected was sterile and could be identified only to family or generic level. Apparent species which, for a variety of reasons, cannot certainly be identified have been given 'numbers of convenience', such as Saurauia sp.1, Saurauia sp.2; similarly, apparent genera within single families have been numbered Lauraceae gen.1, Lauraceae gen.2 and so on.

Initial treatment of plant records

When identifications of plant specimens became available the native names used in the field were compared with the botanical names. In many cases the native name correlated well with the specific level of botanical nomenclature, for example,

'kilua'	Eurya meizophylla
'kiluaglauwa'	Eurya oxysepala
'kubin'	Podocarpus imbricatus
'karbulk'	Podocarpus neriifolius
'ben'	Ficus adenosperma
'bendua'	F. endochaete
'kuneya'	F. ?novoguinensis
'kumbildim'	F. gul
'kwoting'	F. tonsa

among the trees and shrubs and

'eil'	Leersia hexandra
'pogut'	Ischaemum polystachyum
'ungimp'	Imperata cylindrica
'kukayem'	Sacciolepis indica

among the grasses.

In other cases native names corresponded to the generic level of botanical nomenclature rather than to the specific, for example, among the sedges

'drambug'	Cyperus globosus, Cyperus melanospermus
'titik'	Carex ?neurochlamys, C. ?baccans

and among the trees and shrubs

'karl'	Drimys spp.
'trogump'	Prunus costata, Prunus pullei
'wamp'	Rhododendron womersleyi, R. saxifragoides, R. macgregoriae, R. culminicolum and others
'ogutteigen'	Olearia spp.

among others. In the field specific differences were noted in these instances by qualifying terms such as large leaf, small leaf, smooth leaf, thorny stem, red-backed leaf, white-backed leaf etc., whenever present but in some cases the field record must be considered as a complex of species within the individual genus and this is indicated by the use of spp. following the generic name.

In some instances, particularly when concerned with cultivated and domesticated plants, native names distinguish subspecific and varietal levels. Thus the sweet potato, Ipomoea batatas, is known by the general name 'ogut' and varieties are named 'ogut-teiga', '-pora', '-terema', '-krate', '-baralang', '-minima', '-bombumi' etc., the taro, Colocasia esculenta, has a number of varieties, including 'gewimp', 'muglamp', 'mepim', 'meqoin', 'gitua', 'pul' among others. Varieties of banana, Musa sp., are separated also: 'dekonta', 'tugumamp', 'kumburg', 'mari' and 'ganinga' are distinguished in the Mt Hagen area. Species with both wild and domesticated forms are distinguished in the native nomenclature, for example, Setaria palmifolia and Solanum nigrum are known as 'kuga' and 'gitim' when growing in grassland, and 'mue' and 'gimbideem' respectively when cultivated. When tabulating garden and settlement vegetation cultivars based on the native names were retained.

Occasionally, among non-cultivated plants, more than one native name was recorded for a single species; for example, Cryptocarya sp.1 was known as 'mara' and 'maramoi', Syzygium sp.5 as 'kwimor' and 'kwikunt' and the species complex of Saurauia as 'trugul' and 'margeta'. The synonomous records were amalgamated during tabulation of the data. Records were amalgamated also when more than one specimen had been collected of an individual species due to identification problems in the field. A single collection number is used in the tables for convenience.

Arrangement in growth-form terms

Individual taxa were arranged firstly according to their growth-form: tall trees, small trees and shrubs, divaricating shrubs, herbs, lianes, climbers, epiphytes and pteridophytes being recognised. Within each growth form group dicotyledon families were listed in alphabetical order, followed by families of monocotyledons and ferns.

Traverse data

Traverse data collected on initial ground surveys were tabulated in presence-absence form and consideration of these, together with notes made during inspection and mapping of the available aerial photographs permitted a general description of the main vegetation types of the study region in terms of areal extent, distribution, canopy composition and dominance and aerial photographic characterisation.

Sample site data

Sample site data were tabulated from field notes.

Sample plot data

The degree to which a sample adequately represents a stand of vegetation may be judged subjectively either from the species-area curves, which record the increase in the number of species with increasing sample size (Braun-Blanquet 1951, Poore 1954), or by inspection of the fluctuations of the mean values of attributes recorded from the first 4, 8, 12, 16 ... plots (Kershaw, 1964). Figures 3.3 and 3.4 show the relevant curves for species numbers in forest and non-forest sites. Both sets of curves show that in most cases the sample enumerated in the forest and non-forest vegetation types were adequate, at least for descriptive purposes. However, the two lower altitude mixed forest-regrowth sites on Mt Hagen, the mixed garden and the regrowth shrub vegetation within grassland were inadequately sampled, due to their extreme heterogeneity.

Plot data from forest and non-forest vegetation types were treated in slightly different ways and are considered separately below.

A. Forest data

Species density: Species density, i.e. the number of individuals of a species per unit area, was included in the basic enumeration of plots in the field and is tabulated directly from field records (Appendix 1, Table 1).

Species frequency: Species plot-frequency i.e. the number of 10 x 10m quadrats in which one or more

Figure 3.3 Species-area curves for forest and non-forest vegetation sites.

Site No.:

1 Mixed forest at 3345m, Mt Hagen
2 Mixed forest at 3040m, Mt Hagen
3 Mixed forest at 2890m, Mt Hagen
5 Beech forest at 2740m, Mt Hagen
7 Degraded and regrowth beech forest, Mt Hagen
8 Regrowth beech forest at 2270m, Mt Hagen
13 Regrowth shrubs in grassland, Wurup Slopes
14 Short grassland on lower slopes of Mt Oga
15 Mixed grass swamp at Manton's
16 Short grassland on slopes above Draepi
17 Mixed sedge-grass swamp at Draepi
18 Sweet potato gardens and fallow at Weylk
20 Mixed crop gardens and fallow at Weylk.

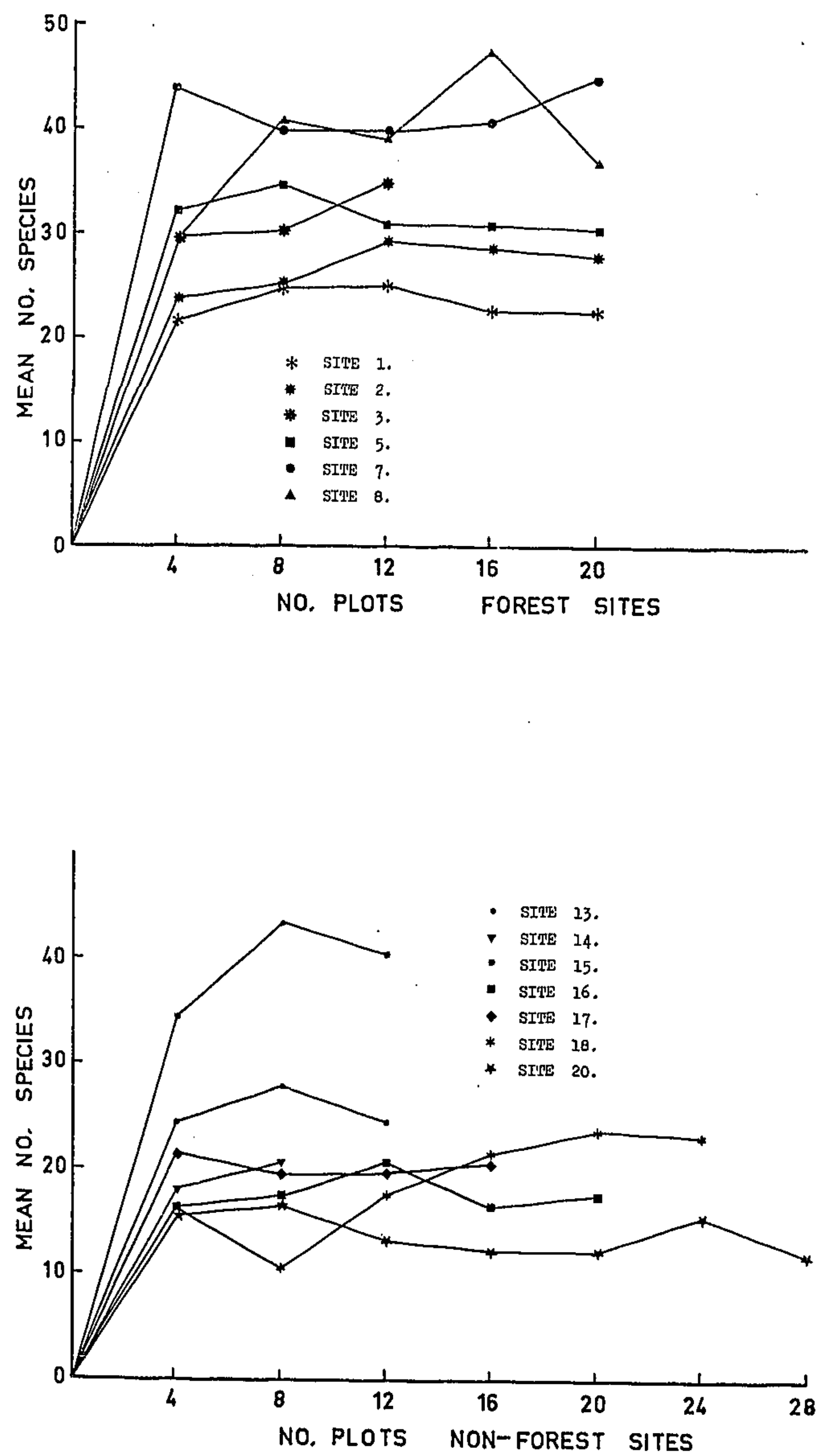
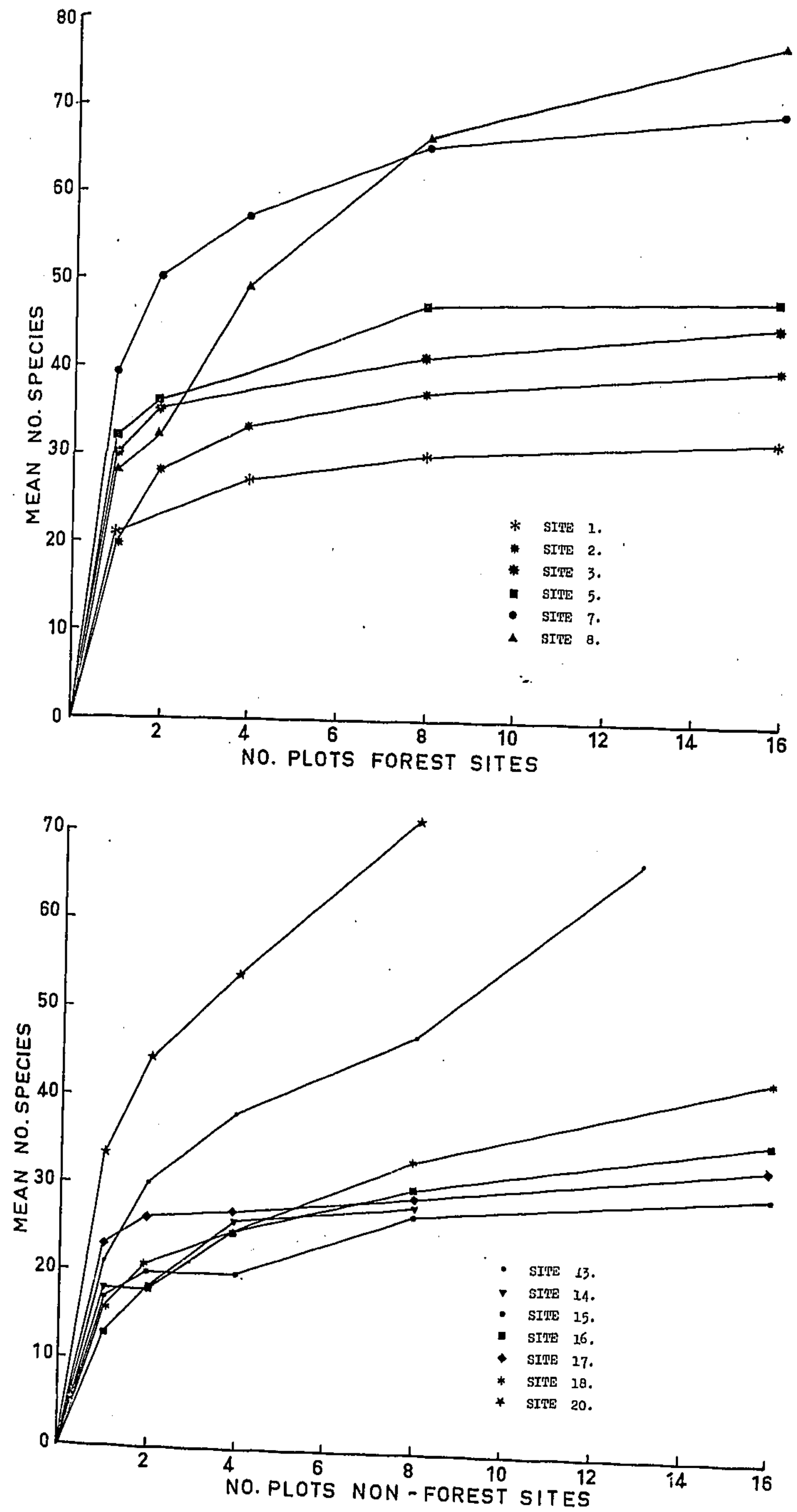


Figure 3.4 Mean number of species recorded from the first 4, 8, 12, 16... plots in forest and non-forest vegetation sites.

Site No.:

1 Mixed forest at 3345m, Mt Hagen
2 Mixed forest at 3040m, Mt Hagen
3 Mixed forest at 2890m, Mt Hagen
5 Beech forest at 2740m, Mt Hagen
7 Degraded and regrowth beech forest, Mt Hagen
8 Regrowth beech forest at 2270m, Mt Hagen
13 Regrowth shrubs in grassland, Wurup slopes
14 Short grassland on the lower slopes of Mt Oga
15 Mixed grass swamp at Manton's
16 Short grassland on slopes above Draepi
17 Mixed sedge-grass swamp at Draepi
18 Sweet potato gardens and fallow at Weylk
20 Mixed crop gardens and fallow at Weylk.



individuals of a species were noted at each sample site is expressed as a fraction of the total number of quadrats recorded at the site.

Physiognomy: Physiognomy is a complex criterion depending upon the proportions of individuals of different growth forms and their distributional patterns within the forest. The number of species in each growth form and the density of each growth form (calculated number of individuals per hectare) are tabulated for each sample site. These data, considered together with subjective assessments of abundance of epiphytes, bryophytes, prevalence of fallen logs and other general data collected at each site, aid description of the physiognomy of the forests and consideration of physiognomic changes apparently related to environmental gradients.

Height data: Height data recorded in the field for all trees and shrubs over 10 ft were converted to metric values and the number of individuals per species tabulated in 3m height-classes (Appendix 1, Table 2).

Circumference at breast height: Circumference at breast height had been measured in the field for all individuals over 3m height; diameters were calculated and the data arranged in 6 cm diameter size-classes (Appendix 1, Table 2).

Stratification of individuals: Stratification of individuals at each sample site was investigated by plotting histograms of the total number of individuals in each height class.

Canopy and understorey composition: Canopy and understorey species composition was defined initially on the basis of height data and in the absence of any clear stratification within the forests, arbitrary levels were adopted:

(a) the uppermost stratum of 'canopy and subcanopy' trees defined as those within the two uppermost height classes represented at each sample site, namely 12-18m at Site 1, 15-21m at site 2, 18-25m at sites 3 and 5 etc.; this will be referred to as the 'canopy'.

(b) the middle stratum of 'understorey trees and shrubs', defined as those higher than 3m and less than 12, 15 or 18m respectively; this will be referred to as the 'understorey'.

(c) the lowermost stratum of saplings, seedlings and other plants of less than 3m height, referred to as 'undergrowth'.

However, as height appeared to be correlated with environmental effects related to altitude, height-classes were not the most useful criterion on which to base overall comparisons of species composition and density. Height-diameter curves were constructed of the main species recorded in the Mt Hagen sites to determine whether or not the forest 'strata' could be defined in terms of diameter rather than height. Figure 3.5 gives the height-diameter curves for *Elaeocarpus crenulatus*, *Quintinia* sp. (6360) and *Schizomeria serrata* within mixed forest and for *Nothofagus* sp.2 (6294), the dominant species in the beech forest. From this it can be seen that:

(1) all the species examined show essentially similar curves from sites at altitudes up to 3040m (10,000 ft),

(2) the curves indicate a more or less direct but non-linear relationship between height and trunk diameter of large trees,

(3) tree height is depressed at 3345m (11,000 ft) relative to that at 3040m (10,000 ft) in *Quintinia* sp. (6360) and *Elaeocarpus crenulatus* but the relationship between height and trunk diameter is retained.

It is therefore valid to use trunk diameter as a transpose of tree height. From inspection of the curves relating these variables and those in Figure 3.6 (depicting the range of height and diameter measurements in tree species at various sample sites) those with trunk diameter exceeding 24 cm were allocated to the 'canopy'; this was the diameter above which most, if not all, observed canopy and subcanopy species would be included. The lower limit for the 'understorey' was set at 6 cm diameter breast height, again a somewhat arbitrary choice but one which gave results comparable to those based on height data. 'Undergrowth' was defined as plants of less than 6 cm diameter.

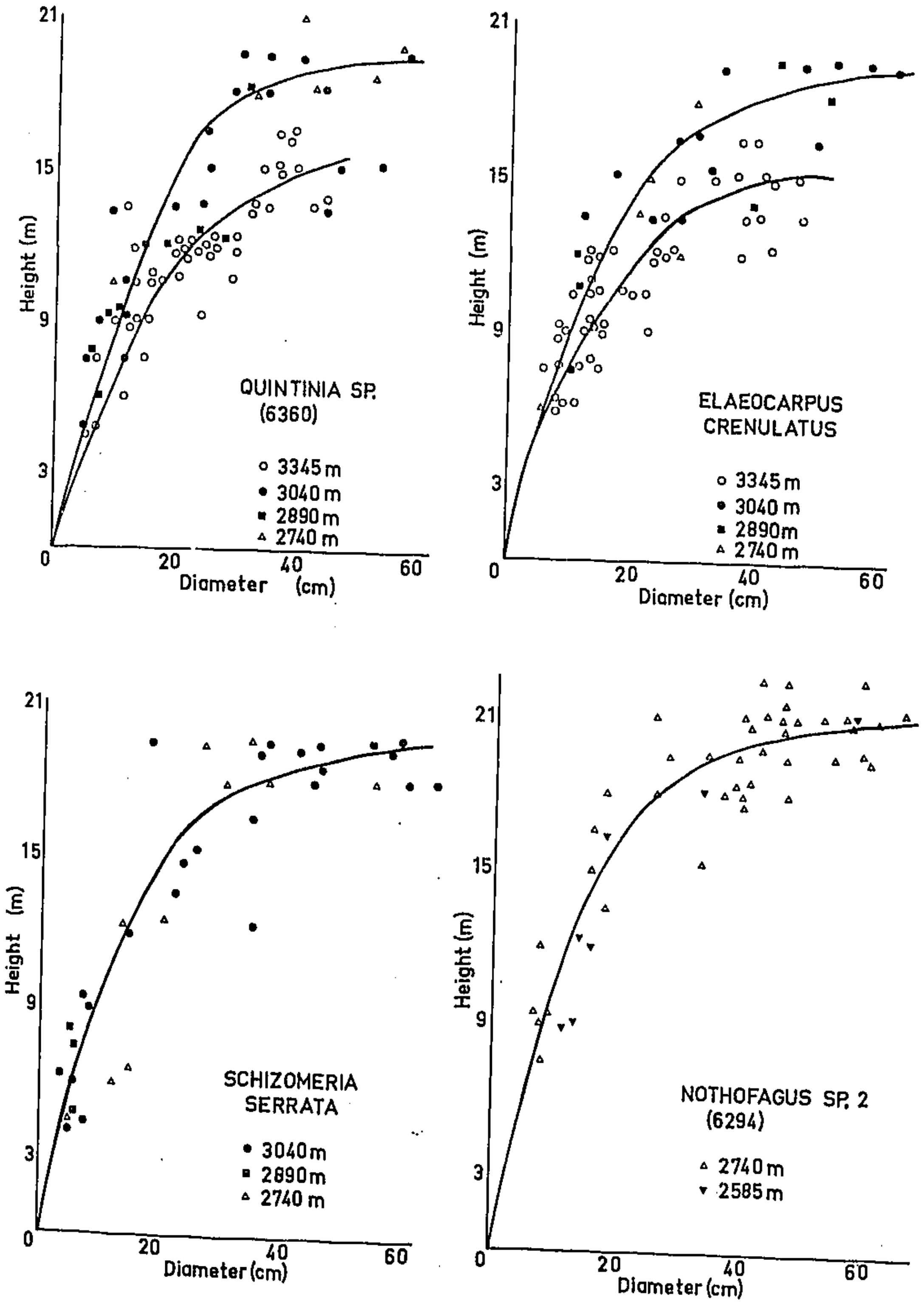
Figure 3.5 Height-diameter curves for <u>Elaeocarpus crenulatus</u>, <u>Quintinia</u> sp (6360), <u>Schizomeria serrata</u> and <u>Nothofagus</u> sp 2 (6294), at different sites on Mt Hagen.

For <u>Elaeocarpus</u>, <u>Quintinia</u> and <u>Schizomeria</u>

Site 1 = 3345m
Site 2 = 3040m
Site 3 = 2890m
Site 4 = 2740m

and for <u>Nothofagus</u> sp 2 (6294)

Site 5 = 2740m
Site 6 = 2585m.



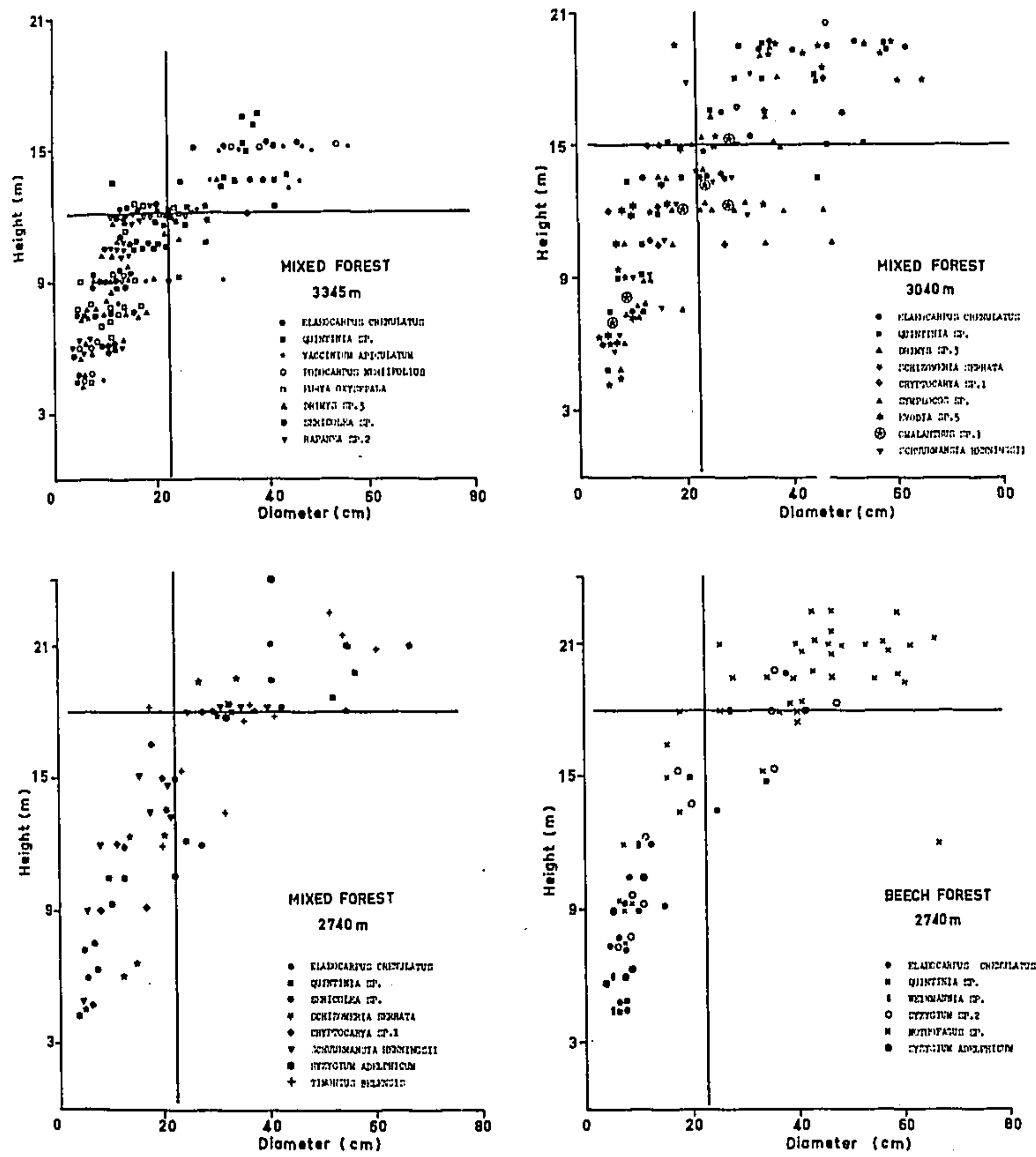


Figure 3.6 The range of height and diameter measurements in tree species at different sites on Mt Hagen.

Species dominance: Species dominance within the canopy may be judged from density data or from total basal area. An approximate basal area has been calculated for each canopy species using the midpoint of each diameter class (over 6 cm) as a standard diameter:

$$\text{Since BA (basal area)} = \pi r^2 \simeq 3r^2 = 3(\tfrac{1}{2}D)^2 = \tfrac{3}{4}D^2 \text{ where D is diameter,}$$

then

Diameter Class (cm)	Estimated basal area (sq.cm)
6 - 12	61
12 - 18	169
18 - 24	331
24 - 30	547
30 - 36	817
36 - 42	1141
42 - 48	1519
48 - (54)	1951

The estimates were checked against total basal area calculated on individual measurements for various species; results are given in Table 3.1. In most cases (71 per cent) the estimated value differs from the measured one by <20% of the latter; this is considered a satisfactory level of accuracy for present purposes.

Species regeneration: Diameter size-class distributions may give some idea of species regeneration in the forest and histograms have been prepared for the main species at the various sample sites. Once again more importance is attached to the diameter data as this is considered less likely to reflect minor environmental fluctuations than the corresponding height data.

B. Non-forest data

Non-forest vegetation types are considered in terms of physiognomy and structure, species composition, density and dominance. Individual taxa were first arranged in mixed growth form and taxonomic classes, namely, shrubs, small trees, ferns, grasses, sedges and forbs; in garden vegetation, domesticated plants are treated separately.

Table 3.1 Comparison of estimated and actual basal area of canopy species in Mt Hagen forests

Forest type		Mixed		Mixed		Mixed		Beech	
Altitude in m.		3345		3040		2740		2740	
Basal area in sq.cm		Estim.	Actual	Estim.	Actual	Estim.	Actual	Estim.	Actual
Family	Genus & Species								
Aquifoliaceae	Ilex sp. 3 (6262)	7014	7817						
Cunoniaceae	Schizomeria serrata			21916	25293	6111	6289		
Elaeocarpaceae	Elaeocarpus crenulatus	21389	19867	10034	15104**	6496	6736	2169	3245**
"	Elaeocarpus ?sayeri							6511	5291
"	Sericolea sp. (6431)	1765	1764	2519	3108**	5890	4371*		
Ericaceae	Vaccinium apiculatum	13929	15514	11316	14075				
Escalloniaceae	Quintinia sp. (6360)	21859	21348	14950	16018	9609	10342	1209	1205
Fagaceae	Nothofagus sp. 2 (6294)							60309	63713
Lauraceae	Cryptocarya sp. 1 (6426)			6665	4507**	2986	2196*		
Myrsinaceae	Rapanea sp. 2 (6265)	3115	3281						
Myrtaceae	Syzygium adelphicam	9684	8049	2937	2692	4726	5137	2026	1484*
Ochnaceae	Schuurmansia henningsii			6737	5156*	7653	5824*		
Pittosporaceae	Pittosporum pullifolium	1089	1071						
Podocarpaceae	Podocarpus neriifolius	6212	8640*						
Rubiaceae	Timonius belensis					16448	19400		
Symplocaceae	Symplocos sp. 3 (6420)			14811	15117				
Theaceae	Eurya oxysepala	7140	6872						
Winteraceae	Drimys sp. 3 (6374)	5682	5161	5214	5105				

** Error of estimate >30% of actual value.

* Error of estimate >20 <30% of actual value.

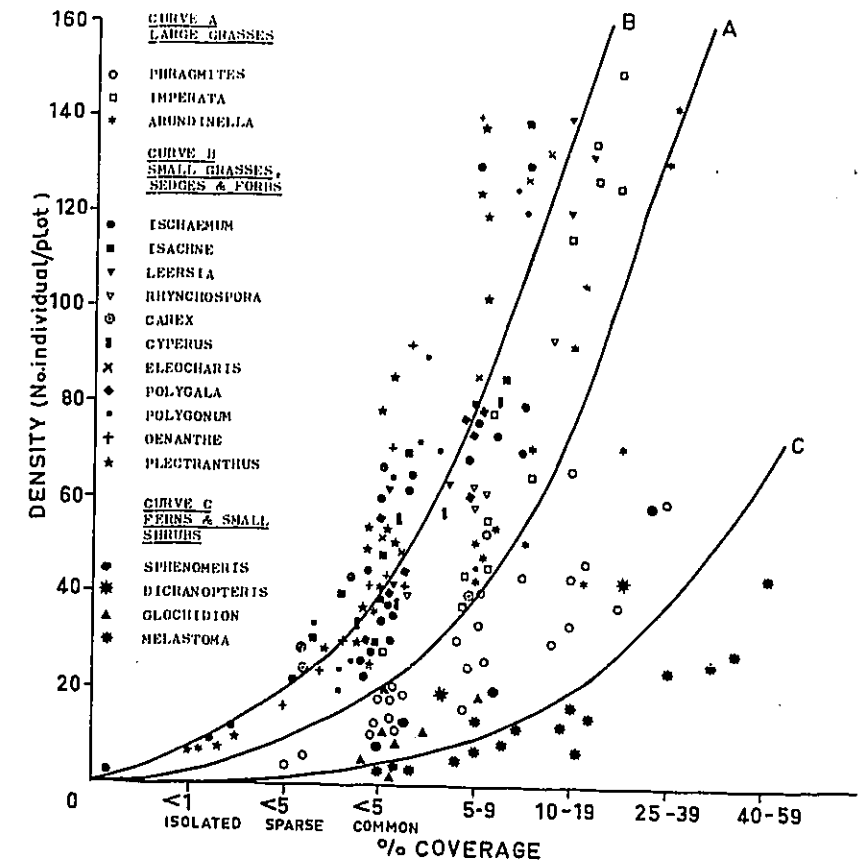
Physiognomy and structure are described subjectively on the basis of field records. Species density and estimated per cent coverage were recorded directly in the field and the data are tabulated in Appendix 1, Table 3. For comparative purposes the data were combined into a single index of cover-density similar to the cover-abundance scales of Domin and Braun-Blanquet (in Kershaw, 1964) and Connor (1964) but with more emphasis on density values. The relationship between cover and density is plotted for several taxa of different growth form in Figure 3.7 using data from the Draepi and Manton swampland-grassland transects. From this three main scales were developed for checking coverage estimates up to 39 per cent against density counts; above 39 per cent coverage, estimated figures were used directly. Table 3.2 gives the scales used for sedges and grasses (A and B), forbs (B) and ferns and small shrubs (C) and Figure 3.8 shows the relationship of density to coverage in these over the range 0 - 39 per cent coverage. The single index indicated 'dominance' in the non-forest vegetation types and allowed trends related to apparent environmental and successional gradients to be considered.

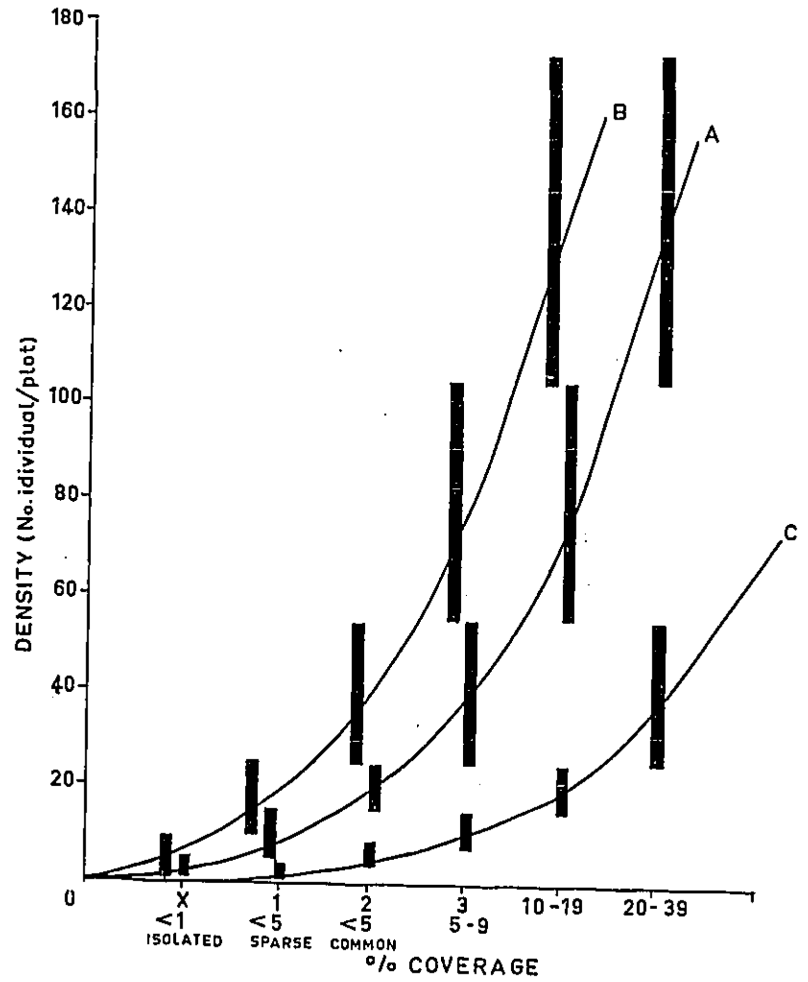
Table 3.2 Cover-density Index used in non-forest vegetation data.

Index	Coverage	Abundance	Density (A)	Density (B)	Density (C)
X	<1%	Isolated	1 - 5	1 - 10	1 - 2
1	<5%	Sparse	5 - 15	10 - 25	2 - 4
2	<5%	Common	15 - 25	25 - 55	4 - 8
3	5 - 9%	Any number	25 - 55	55 -105	8 - 15
4	10 -19%	" "	55 -105	105 -175	15 - 25
5	20 -39%	" "	105 -175	175 -265	25 - 55
6	40 -59%				
7	60 -79%				
8	>79%				

Figure 3.7 The range of cover and density measurements in non-forest taxa of different growth-forms.

Figure 3.8 The relationship of density to coverage in non-forest taxa of different growth-forms.





CHAPTER 4

THE PRESENT VEGETATION - FOREST

More or less continuous forest grows between 2440m (8000 ft) and 3345m (11,000 ft) on the northeastern and eastern slopes of Mt Hagen. Above this altitude small patches of forest occur within tussock grassland, almost to the summit at 3700m (12,200 ft). Between 2440m (8000 ft) and 2560m (8400 ft) the forests are largely degraded, due to the cutting of timber for commercial purposes, for use in native houses and fence building and for firewood; above this it appears less disturbed. The lower limit of the forest adjoins grassland, scrub regrowth and native gardens. Stands of tall forest trees mixed with lower stature regrowth shrubs are frequently found between 2440m (8000 ft) and 2135m (7000 ft). (Plates 7 and 8b).

On the north facing slopes at the western end of the Kubor Range, degraded forest occupies most of the area between 1770m (5800 ft) and the ridge tops at 2230m (7300 ft) to 2440m (8000 ft) but small patches of garden, grassland and secondary regrowth are also present. Below 1770m (5800 ft) non-forest communities predominate. On Mt Oga continuous and apparently less disturbed forest grows from 1680m (5500 ft) up to the summit at 2900m (9500 ft) and further to the east, where topography becomes rugged and steep, forest is continuous from ridge crest to valley bottom.

To the west of the Nebilyer River continuous forest grows on rugged terrain above 1830m (6000 ft) elevation and on the south and southwest slopes of the Sepik-Wahgi Divide above altitudes of 2135m (7000 ft) to 2290m (7500 ft). Here, also, the forests have been disturbed to a greater or lesser extent by the cutting of timber for various purposes and the forest, non-forest boundary is uneven.

A number of different forest types may be distinguished in the area on the basis of species composition and dominance in the canopy and amongst the emergents, where present.

PLATE 7A

Beech forest on the lower slopes of Mt Hagen. In the foreground remnant trees stand above regrowth vegetation at 2410 m altitude near Kwip.

PLATE 7B

Remnant trees of Nothofagus sp 2 (6294) at 2410 in altitude on Mt Hagen.

OAK FOREST (Plate 2)

This type of forest appears to be relatively restricted in extent at the present time but this may be due in part to the difficulty of distinguishing it in aerial photographs; crowns of the dominant tree, Castanopsis acuminatissima, are rounded and dense but appear superficially similar to those of Nothofagus species. According to both Saunders and Robbins (in press) oak forest is of small extent throughout the Goroka - Mt Hagen area as a whole and it has not been mapped as a separate unit by them. An attempt has been made to do so in the present study (Figure 3.1) but has been hampered by the scale of the aerial photographs available. An estimate of the areal extent of this forest is 7.3 sq. km. (2.8 sq.mi.), ca 2 per cent of the total study area.

Traverses of the Wurup - Mt Oga region suggest that oak forest grows mainly below 2290m (7500 ft) and while in some instances it may form pure stands, more often it is associated with Nothofagus and members of the families Cunoniaceae, Lauraceae, and Myrtaceae.

Although 19 plots were surveyed in these forests; they have been grouped for purposes of discussion into 4 sets, 1 set from the Wurup ridgetop, 2 sets from the Wurup slopes (with different known histories of disturbance) and 1 set from the slopes of Mt Oga. Table 4.1 gives habitat data and describes general features of the forest at each site, while Tables 4.2 to 4.5 give species composition, species density and species plot-frequency in the canopy, understorey and undergrowth levels for each set of plots. Basal area is included in Table 4.2 for the canopy species.*1

Site 9 : Mt Oga slopes

Physiognomically the forest appears relatively dense with evenly spaced canopy trees and abundant undergrowth.

*1 For later comparison data for the 4 sets of plots are presented within a single table for each forest 'level'. For convenience, any taxon defined as belonging to the canopy in 1 set of plots is included as a canopy species within the others. A similar practise is followed for the understorey and undergrowth taxa.

Table 4.1 Characteristics of Oak forest sites in the Wurup - Mt Oga area.

Site No.	9	10	11	12
No. plots recorded	5	5	5	4
Altitude	1975-2190 m	2130-2220 m	1885-1920 m	1970-2010 m
Landform	Ridge side	Ridge crest	Ridge side	Ridge side
Aspect	W - SW	W - SW	NE	E - NE
Slope	Steep to medium	Medium to gentle	Steep to medium	Steep
Drainage*	4	4	4	5
Soil	Dark greybrown stony loam above yellowbrown clay	Greybrown stony loam above brown clay	Yellow sandy soil over yellowbrown clay	Dark greybrown clay, stony, limestone scree
pH	6.0	6.0	5.5	6.6
Disturbance	Some local disturbance few fallen logs, no trampling obvious	Numerous fallen logs, some cut stumps; some pig rooting and trampling evident	Generally disturbed	Previously gardened strewn with logs, cut stumps; pig rooting, trampling general
Canopy & subcanopy	Continuous, relatively dense	Fairly continuous, not dense	Broken	Canopy open, subcanopy more continuous
Canopy height	18 - 21m	21 - 24m	21 - 24m	12 - 15m
Understorey	Relatively dense	Relatively dense	Relatively dense	Dense
Undergrowth	Dense	Relatively dense	Relatively dense	Sparse
Herbaceous ground cover	Almost complete	Locally disturbed	Generally disturbed	Almost entirely absent
Lianes, climbers & epiphytes	Abundant	Locally abundant	Locally common	Absent
Ferns, bryophytes	Locally abundant	Locally abundant	Locally common	Sparse

*Drainage Scale 0-6 (Chapter 3)

The canopy is largely continuous at 18-21m height and individual trees of Castanopsis acuminatissima and Nothofagus sp.1 (6485) reach 50cm and 125cm diameter respectively. Stratification of individuals within the forest is not obvious (Figure 4.1). The understorey and undergrowth levels are relatively densely stocked with saplings of canopy species and shrubs, and lianes, epiphytes and climbers are abundant. Herbaceous ground cover is more or less continuous with ferns locally abundant. Some local disturbance was noted, however, and cut stumps of Nothofagus, Castanopsis and Prunus pullei are recorded. The few fallen logs present are covered with bryophytes and epiphytic ferns.

Castanopsis acuminatissima is the dominant canopy species in these forests with an estimated density of 42 trees per 0.1 hectare and a basal area of 50144 sq.cm per 0.1 hectare. Other canopy species, present in far lower numbers include Nothofagus sp.1 (6485), Schizomeria serrata, Cryptocarya sp.4 (6459) and Prunus pullei. Among the minor species Nothofagus sp.1 (6485) shows greater basal area content than Schizomeria serrata, numerically dominant.

Regeneration of the taxa may be indicated by their diameter size-class distributions (Figure 4.1). These are even in Castanopsis acuminatissima and Schizomeria serrata implying their uninterrupted regeneration. In Nothofagus sp.1 (6485), Cryptocarya sp.4 (6459) and Prunus pullei, on the other hand, size-class distribution is very uneven; whether this is caused by natural factors affecting regeneration or is due to cutting of timber within the forests will be considered further below.

The canopy species Castanopsis acuminatissima and Schizomeria serrata numerically dominate the understorey but many other taxa are also found there. Frequently present are the canopy taxa Nothofagus sp.1 (6485) and Cryptocarya sp.4 (6459) together with Eurya meizophylla, Timonius sp. (6436) and Phyllanthus nervosus. Less densely represented are Polyscias sp. (6339), Polyosma sp. (6476), Croton sp. (6491), Glochidion sp.1 (6081), Euphorbiaceae fam.2 (6335), ?Litsea sp. (6502), ?Ardisia sp. (6441), Syzygium sp.5 (6314), Sloanea sp.2/3 (6317), Schuurmansia henningsii, Prunus costata, Podocarpus neriifolius, Acronychia sp.2 (6430) and Symplocos sp.2 (6343).

Both canopy and understorey taxa are well represented in the undergrowth, high densities of Schizomeria serrata, Cryptocarya sp.4 (6459), Polyscias sp. (6339), Glochidion sp.1 (6081), Phyllanthus nervosus, Euphorbiaceae gen.2 (6335), ?Litsea sp. (6502), Timonius sp. (6436) being recorded. Equally well represented are undergrowth taxa such as Endiandra sp.2 (6333), Evodiella sp. (6215), Kibara sp.3 (6421), Guioa sp. (6347) and Sapindaceae gen.1 (6349), all with more than 40 individuals per 0.1 hectare. Others, occurring in far lower numbers are Rhus taitensis, Sphenostemon papuanum, Cryptocarya sp.1 (6321), Gynotroches axillaris, Timonius belensis, Trema amboinensis, Alstonia sp. (6438), Macaranga ?womersleyi, Astronia sp.1 (6244), Ficus tonsa, Palmae gen.1 Finschia sp. (6289), Wendlandia sp. (6218), Evodia sp.6 (6458), Mischocarpus sp. (6331), Saurauia sp.3 (6462), Schefflera sp. (6352), Harmsiopanx sp. (6370), Evodia sp.1 (6486), Spiraeopsis brassii, Elaeocarpus poculiferus, Elaeocarpus sp.1 (6247), Cinnamomum sp.2 (6279), Streblus urophyllus, Xanthomyrtus sp. (6345), Pandanus sp.2, Evodia sp.2 (6432), Saurauia sp.11 (6467), Phaleria ?sogerensis, Drimys sp.3 (6374) and Gardenia sp. (6500).

Presence-absence data only were collected for the herbaceous taxa. Usually present were the lianes Dimorphanthera alpina, D. denticulifera, Freycinetia spp., Piper sp.1 (6408), the divaricating shrubs Amaracarpus sp.1 (6428) and A. sp.3 (6377) and members of the Zingiberaceae. The climbing bamboos, Nastus productus and Bambusa sp.('Kowa'), were also present and the tree-ferns Cyathea spp. ubiquitous.

Site 10 : The Wurup ridgetop forest

The forest on the Wurup ridgetop appears more than that on Mt Oga; canopy trees are widely spaced and the canopy is fairly continuous but not dense. The canopy is between 21-24m height and individual trees of Castanopsis acuminatissima reach 65cm diameter. A certain amount of layering of forest structure is apparent (Figure 4.1) with a relatively dense understorey at 15-16m height. Undergrowth is dense and lianes, epiphytes and climbers locally abundant. The herbaceous ground cover is disturbed in places and some pig rooting and trampling is evident. Fallen logs are common, often covered with bryophytes and ferns. These are also locally abundant on the forest floor. A few cut stumps of Castanopsis, Cryptocarya sp.1 (6321), Nothofagus sp.1 (6485) and Syzygium sp.2 (6285) are recorded.

Castanopsis acuminatissima again dominates the canopy both in density and basal area content (20 trees per 0.1 hectare, 39302 sq.cm per 0.1 hectare). Minor species occurring with it are Schizomeria serrata, the most important numerically and in basal area, and Sphenostemon papuanum, Nothofagus sp.1 (6485) Cryptocarya sp.1 (6321), Syzygium sp.2 (6285) and Timonius belensis.

Size-class distributions are more irregular in Schizomeria serrata and Castanopsis acuminatissima in these forests although most sizes are still represented; again Nothofagus sp.1 (6485) and Cryptocarya sp.1 (6321) show very irregular distributions as do Syzygium sp.2 (6285) and Timonius belensis. Sphenostemon papuanum is the only taxon to show uninterrupted regeneration.

The understorey is numerically dominated by the canopy species Castanopsis acuminatissima, Schizomeria serrata and Sphenostemon papuanum with Nothofagus sp.1 (6485) and Cryptocarya sp.1 (6321) also important. Most frequently present understorey taxa are Gynotroches axillaris and Alphitonia incana together with many recorded on Mt Oga. Others, not recorded there, include Garcinia sp.3 (6325), Macaranga ?womersleyi, Casearia sp. (6311), Endiandra sp.2 (6333), Geniostema arfakense, Astronia sp.1 (6244), Palmae gen.1, Finschia sp. (6289), Evodia sp.6 (6458), Evodiella sp. (6215), Planchonella macropoda, and Saurauia sp.3 (6462). Some of these may be light demanding taxa, indicative of the more disturbed conditions.

Undergrowth composition is similar in these forests to those on Mt Oga, with canopy and understorey seedlings and saplings dominant. Important taxa include Acronychia sp.2 (6430), Eurya meizophylla, Schefflera sp. (6352), Kibara sp.3 (6421), Sapindaceae gen.1 (6349), Eurya oxysepala, Trimenia papuana and Drimys sp.3 (6374). Others, not recorded from Mt Oga are Ilex sp.1 (6320), Galbulimima belgraveana, Macaranga ?warburgiana, Ficus gul, Discocalyx sp. (6319), Pandanus sp.1, Mackinlaya sp. (6471), Sericolea sp. (6431), Carpodetus sp. (6488), Cordyline sp., and Drimys sp.4 (6392).

Among the herbaceous taxa, Freycinetia spp., Palmeria sp.3 (6271), and Cayratia sp. (6328) are important lianes, Amaracarpus spp., Elatostema spp., and Alpinia spp. common shrubs and forbs. Taxa not recorded on Mt Oga include Dimorphanthera denticulifera, Piper sp.5 (6415), Rubus moluccanus and Tetrastigma sp. (6346) among the lianes and climbers, Cyrtandra sp.3 (6269) as a ground herb and Marattiaceae gen.1. (6086) among the ferns.

Site 11 : The Wurup slopes

Forest on the Wurup slopes has been generally disturbed by selective cutting of trees, gathering of plant products, hunting of animals and by pig rooting. At site 11 the forest is open with a broken canopy at 21-24m and low density of canopy trees. Individual trees of Castanopsis acuminatissima measure between 58-65cm diameter, however, and other canopy species such as Sloanea sp.2/3 (6317) and Syzygium sp.2 (6285) measure 49cm and 38cm diameter respectively. Understorey and undergrowth appear relatively densely stocked but no stratification is evident (Figure 4.1.). Lianes, climbers and epiphytes are locally abundant. The herbaceous ground cover is patchy but ferns and bryophytes are locally common. Cut tree trunks and limbs of Castanopsis, Nothofagus and Cryptocarya sp.4 (6459) are noted.

Castanopsis acuminatissima remains the dominant canopy species with a density of 14 trees per 0.1 hectare and basal area of 21790 sq. cm per 0.1 hectare; minor associates are Nothofagus sp.1 (6485), Cryptocarya sp.4 (6459) and Syzygium sp.2 (6285). Also present here are Sloanea sp.2/3 (6317) and Gynotroches axillaris. In terms of basal area content both Sloanea and Syzygium are more important than Nothofagus among the minor species.

Size class distributions are irregular for all canopy taxa in these plots.

Understorey composition is rather different in these forests and while some of the canopy species, such as Cryptocarya sp.4 (6459), Syzygium sp.2 (6285) and Nothofagus sp.1 (6485) may be numerically important they do not dominate the understorey level. The most important species in the understorey are Glochidion sp.1

(6081), Euphorbiaceae gen.2 (6335), Schuurmansia henningsii, Wendlandia sp. (6218), Acronychia sp.2 (6430), Ficus endochaete, Ficus gul, Evodiella sp. (6215) and Eurya meizophylla. Many others have been represented only in the undergrowth at sites 9 and 10, namely Astronia sp. (6438), Macaranga ?warburgiana, Discocalyx sp. (6319), Pandanus sp.1, Schefflera sp. (6352) and Rhus taitensis and other taxa, not recorded previously include Weinmannia sp. (6278), Omalanthus nervosus and Artocarpus vrieseanus, occurring in low numbers.

Again undergrowth composition is rather distinct with canopy and understorey species subsidiary in density to the undergrowth taxa. Most important are Acalypha sp.1 (6075) and Phyllanthus nervosus with 96 and 98 individuals per 0.1 hectare respectively; Guioa sp. (6347), Ficus tonsa and Timonius sp. (6436) are also densely represented.

Understorey taxa of nearly equal density include Glochidion sp.1 (6081), Schuurmansia henningsii, Evodiella sp. (6215). The canopy taxon Castanopsis acuminatissima shows a lower density but remains important in the undergrowth with 40 individuals per 0.1 hectare.

The herbaceous complement is much the same as previously recorded in the Mt Oga and Wurup ridge forests: Rubus moluccanus becomes important among the climbers, Dicliptera sp. (6470) among the shrubs and a number of forb taxa are recorded for the first time, namely, Desmodium repandum, Plectranthus sp.1 (6032), Poikilogyne sp. (6480) and Cypholophus sp. (6422).

Site 12 : The Wurup slopes

Some areas of forest on the Wurup slopes have been cleared previously for gardening and many others are being cleared today. Site 12 has a past history of clearance and use as a mixed garden. The forest is open, the ground strewn with logs and stumps and the surface broken in many parts by pig rooting and trampling. The canopy is open, at 12-15m height, the subcanopy more continuous. The understorey is relatively dense but undergrowth is sparse and herbaceous ground cover

Table 4.2 Species composition, species density and plot frequency in the canopy of Oak forests.

Location			Mt Oga slopes					Wurup ridgetop					Wurup slopes					Wurup slopes (regrowth)				
Site No.			9					10					11					12				
			*1 Density in			Plot*2 Freq.	Basal*3 Area	Density in			Plot Freq.	Basal Area	Density in			Plot Freq.	Basal Area	Density in			Plot Freq.	Basal Area
Canopy species			C	U's	U'g			C	U's	U'g			C	U's	U'g			C	U's	U'g		
6489	Anacardiaceae	Rhus taitensis			6	1/5								2	8	1/5	178	23	120	20	4/4	33270
6479	Aquifoliaceae	Sphenostemon papuanum			32	3/5		2	10	42	5/5	3186										
6248	Cunoniaceae	Schizomeria serrata	6	20	120	5/5	6638	8	20	42	4/5	8266			10	1/5						
6317	Elaeocarpaceae	Sloanea sp. 2/3		2		2/5	122		2	12	2/5	422	6		8	2/5	8954					
6457	Fagaceae	Castanopsis acuminat.	42	48	38	5/5	50144	20	22	80	5/5	39302	14	4	40	4/5	21790			12	1/4	
6485	Fagaceae	Nothofagus sp. 1	4	4	20	4/5	7000	2	6	70	5/5	4110	2	8	12	3/5	5230					
6321	Lauraceae	Cryptocarya sp. 1			14	4/5		2	6	70	4/5	3354		6	54	5/5	1284		5	25	4/4	480
6459	Lauraceae	Cryptocarya sp. 4	4	4	46	5/5	4698			26	3/5		2	12	32	5/5	2482		13	15	4/4	2758
6487	Moraceae	Artocarpus vriesceanus												2	2	1/5	352	3	3	23	3/4	3163
6285	Myrtaceae	Syzygium sp. 2						2	4	42	4/5	4872	4	12	20	4/5	6192			6	2/4	
6469	Myrtaceae	Syzygium sp. 3													3	1/5		3		3	1/4	1385
6434	Rhamnaceae	Alphitonia incana							6	40	4/5	1186						3			1/4	2853
6473	Rhizophoraceae	Gynotroches axillaris			18	3/5			10	52	5/5	1838	2	2	34	4/5	1454					
6344	Rosaceae	Prunus pullei	2	2	38	4/5	2670		2	52	5/5	486			8	1/5				10	1/4	
6249	Rubiaceae	Timonius belensis			10	1/5		2		8	2/5	1150										
6463	Ulmaceae	Trema ambionensis			3	1/5												3			1/4	1368

*1 Density i.e. number of individuals per 0.1 hectare in canopy (C), understorey (U's) and undergrowth (U'g)

*2 Plot frequency i.e. number of quadrats in which one or more individuals of a species were noted expressed as a fraction of the total number of quadrats observed.

*3 Basal area in sq. cm per 0.1 hectare.

Table 4.3 Species composition, species density and plot frequency in the understorey of Oak forests.

Site No.			9			10			11			12		
Location			Mt Oga slopes			Wurup ridgetop			Wurup slopes			Wurup slopes		
Understorey species			Density in U's	U'g	Plot Freq.	Density in U's	U'g	Plot Freq.	Density in U's	U'g	Plot Freq.	Density in U's	U'g	Plot Freq.
6438	Apocynaceae	Alstonia sp.		10	2/5				2	6	1/5		8	2/4
6370	Araliaceae	Harmsiopanax sp.		2	1/5							3	22	2/4
6339	"	Polyscias sp.	2	48	5/5	2	10	2/5	2	6	1/5	3		1/4
6352	"	Schefflera sp. 1		30	4/5		72	5/5	2	38	4/5		16	2/4
6325	Clusiaceae	Garcinia sp. 3				4	58	3/5						
6278	Cunoniaceae	Weinmannia							2	28	4/5		3	1/4
6476	Escalloniaceae	Polyosma sp. 1	2	36	5/5	2	8	2/5		30	4/5			
6491	Euphorbiaceae	Croton sp.	2	6	1/5									
6081	"	Glochidion sp. 1	2	66	5/5		24	2/2	6	68	5/5	8	80	4/4
5530	"	Macaranga ?warburgiana					8	1/5	2	24	4/5	3	18	1/4
6439	"	Macaranga ?womersleyi		26	2/5	2	40	4/5	2	20	2/5	3	25	3/4
6334	"	Omalanthus ?nervosus							2	10	2/5		25	2/4
6282	"	Phyllanthus nervosus	4	106	5/5	2	74	5/5		98	5/5			
6311	"	Casearia sp.				4	2	1/5						
6335	"	fam. 2	2	58	5/5	2	26	4/5	4	18	3/5			
6333	Lauraceae	Endiandra sp. 2		48	3/5	4	42	5/5		24	3/5			
6502	"	?Litsea sp.	2	60	5/5									
6482	Loganiaceae	Geniostema arfakense				2	26	3/5						
6244	Melastomataceae	Astronia sp. 1		14	1/5	2	34	2/5		4	1/5		10	1/4
6440	Moraceae	Ficus endochaete							4	6	2/5	3	30	3/4
6466	"	Ficus gul					16	2/5	4	36	4/5		85	4/4
6342	"	Ficus tonsa		34	5/5					58	5/5	5	82	4/4
6441	Myrsinaceae	?Ardisia sp.	2	22	2/5	2	16	4/5		12	2/5		30	4/4
6319	"	Discocalyx sp.					8	1/5	2	8	1/5			
6314	Myrtaceae	Syzygium sp. 5	2	14	2/5									
6380	Ochnaceae	Schuurmansia henningsii	2	20	2/5		10	1/5	10	68	5/5			
	Palmae	('Yaga') gen. 1		6	1/5	4	26	5/5		36	3/5			
	Pandanaceae	Pandanus sp. 1					18	2/5	2		1/5			
6259	Podocarp	Podocarpus neriifolius	2		1/5								5	1/4
6289	Proteaceae	Finschia sp.		2	1/5	2		1/5						
6284	Rosaceae	Prunus costata	2	42	4/5		12	1/5		30	4/5			
6436	Rubiaceae	Timonius sp. 1	4	70	5/5	4	34	3/5		40	4/5			
6218	Rubiaceae	Wendlandia sp.		4	1/5				8	32	2/5	13	60	4/4
6430	Rutaceae	Acronychia sp. 2	2	36	3/5		50	1/5	6	36	4/5			
6486	"	Evodia sp. 1		38	3/5		10	1/5		22	2/5	3	3	1/4
6458	"	Evodia sp. 6		2	1/5	2	34	4/5		12	2/5		20	2/4
6215	"	Evodiella sp.		70	5/5	2	48	4/5	4	54	5/5		25	3/4
6331	Sapindaceae	Mischocarpus sp.		4	1/5					10	2/5	8	18	2/4
6329	Sapotaceae	Planchonella macropoda				2	14	2/5						
6462	Saurauiaceae	Saurauia sp. 3		4	1/5	4	46	4/5	2		1/5			
6343	Symplocaceae	Symplocos sp. 2	2	20	3/5	2	54	5/5		16	3/5			
6298	Theaceae	Eurya meizophylla	6	20	2/5		48	4/5	4	2	1/5			

Table 4.4 Species composition, density and plot frequency in the undergrowth of Oak forests.

Site No / Location / Undergrowth species			9 Mt Oga Density U'g	9 Mt Oga Plot Freq.	10 Wurup Ridgetop Density U'g	10 Wurup Ridgetop Plot Freq.	11 Wurup Slopes Density U'g	11 Wurup Slopes Plot Freq.	12 Wurup Slopes Regrowth Density U'g	12 Wurup Slopes Regrowth Plot Freq.
6470	Acanthaceae	Dicliptera sp.						3/5		
6320	Aquifoliaceae	Ilex, sp. 1			26	2/5				
6471	Araliaceae	Mackinlaya sp.			2	1/5				
6281	Chloranthaceae	Ascarina philippinensis					8	1/5		
6417	Cunoniaceae	Spiraeopsis brassii	10	2/5	26	2/5	16	3/5	15	1/4
6348	Elaeocarpaceae	Elaeocarpus poculiferus	2	1/5			6	1/5	3	1/4
6247	"	Elaeocarpus sp. 1	6	1/5						
6431	"	Sericolea sp.			10	2/5				
6488	Escalloniaceae	Carpodetus sp.			10	2/5	38	5/5	48	4/4
6075	Euphorbiaceae	Acalypha sp. 1					96	3/5		
6337	Himantandraceae	Galbulimima belgraveana			16	3/5				
6279	Lauraceae	Cinnamomum sp. 2	26	4/5			18	2/5		
	Liliaceae	Cordyline sp.			8	1/5	12	2/5	18	2/4
6421	Monimiaceae	Kibara sp. 3	94	5/5	40	3/5	38	3/5		
5757	Moraceae	Ficus dammaropsis					4	1/5		
6427	"	Streblus urophyllus	6	1/5	22	2/5	4	1/5		
6293	Myrsinaceae	Maesa sp.					8	1/5	10	1/4
6354	"	Rapanea sp. 3					16	2/5		
6345	Myrtaceae	Xanthomyrtus sp.	28	5/5	18	4/5	2	1/5		
	Pandanaceae	Pandanus sp. 1	8	1/5	14	2/5	32	3/5		
6428	Rubiaceae	Amaracarpus sp. 1		4/5				3/5		
6477	"	Amaracarpus sp. 2				3/5				
6377	"	Amaracarpus sp. 3		3/5		1/5		1/5		3/4
6500	Rubiaceae	Gardenia sp.	4	3/5						
6432	Rutaceae	Evodia sp. 2	4	1/5			8	1/5	3	1/4
6347	Sapindaceae	Guioa sp.	42	5/5	18	3/5	56	4/5	10	1/4
6349	"	gen.1	44	5/5	60	5/5	30	3/5	18	2/4
6467	Saurauiaceae	Saurauia sp. 11	8	2/5					3	1/4
6277	Staphyleaceae	Turpinea pentandra					26	3/5		
6414	Theaceae	Eurya oxysepala			42	3/5	36	4/5	10	1/4
6481	Trimeniaceae	Trimenia papuana			50	5/5	8	1/5	8	1/4
6433	Thymeleaceae	Phaleria ?sogerensis	6	2/5						
6374	Winteraceae	Drimys sp. 3	20	3/5	92	4/5				
6392	"	Drimys sp. 4			14	2/5				

Table 4.5 Species composition and plot frequency of herbaceous taxa in Oak forests.

Site No.			9	10	11	12
Location			Mt Oga	Wurup ridgetop and slopes		
Herbaceous species			Plot Freq.	Plot Freq.	Plot Freq.	Plot Freq.
6353	Ericaceae	Dimorphanthera alpina	2/5			
6376	"	Dimorphanthera denticulifera		1/5		
6271	Monimiaceae	Palmeria sp. 3	1/5	4/5	1/5	
	Pandanaceae	Freycinetia sp.	2/5	4/5	5/5	
6202	Philesciaceae	Geitonoplesium cymosum	1/5			
6408	Piperaceae	Piper sp. 1	2/5		2/5	
6415	"	Piper sp. 5		2/5	3/5	4/4
	Poaceae	Bambusa sp.	2/5	5/5	1/5	
6261	"	Nastus productus	5/5	5/5	5/5	
5573	Rosaceae	Rubus moluccanus		2/5	4/5	1/4
6328	Vitaceae	Cayratia sp.		4/5	2/5	
6346	"	Tetrastigma sp.		1/5		
6082	Asteraceae	Blumea arnakidophora				3/4
5575	Fabaceae	Desmodium repandum			1/5	2/4
6269	Gesneriaceae	Cyrtandra sp. 3		1/5		
6032	Lamiaceae	Plectranthus sp. 1			2/5	
6480	Melastomataceae	Poikilogyne sp.			2/5	1/4
6422	Urticaceae	Cypholophus sp.			1/5	3/4
6375	"	Elatostema sp. 1	5/5	3/5	1/5	4/4
6312	"	Elatostema sp. 2		2/5	1/5	4/4
6423	"	Elatostema sp. 3	4/5	2/5	2/5	
6368	Zingiberaceae	Alpinia sp. 3	3/5	2/5		2/4
6144	"	gen. 2	2/5	2/5	2/5	2/4
6003	Cyperaceae	Carex ?beccans			4/5	3/4
6066	Poaceae	Miscanthus floridulus	1/5		1/5	1/4
6022	Cyatheaceae	Cyathea sp.	3/5	2/5	4/5	4/4
6029	Gleicheniaceae	Dicranopteris linearis	1/5		4/5	1/4
6086	Marattiaceae			1/5		
	Pteridae					2/4

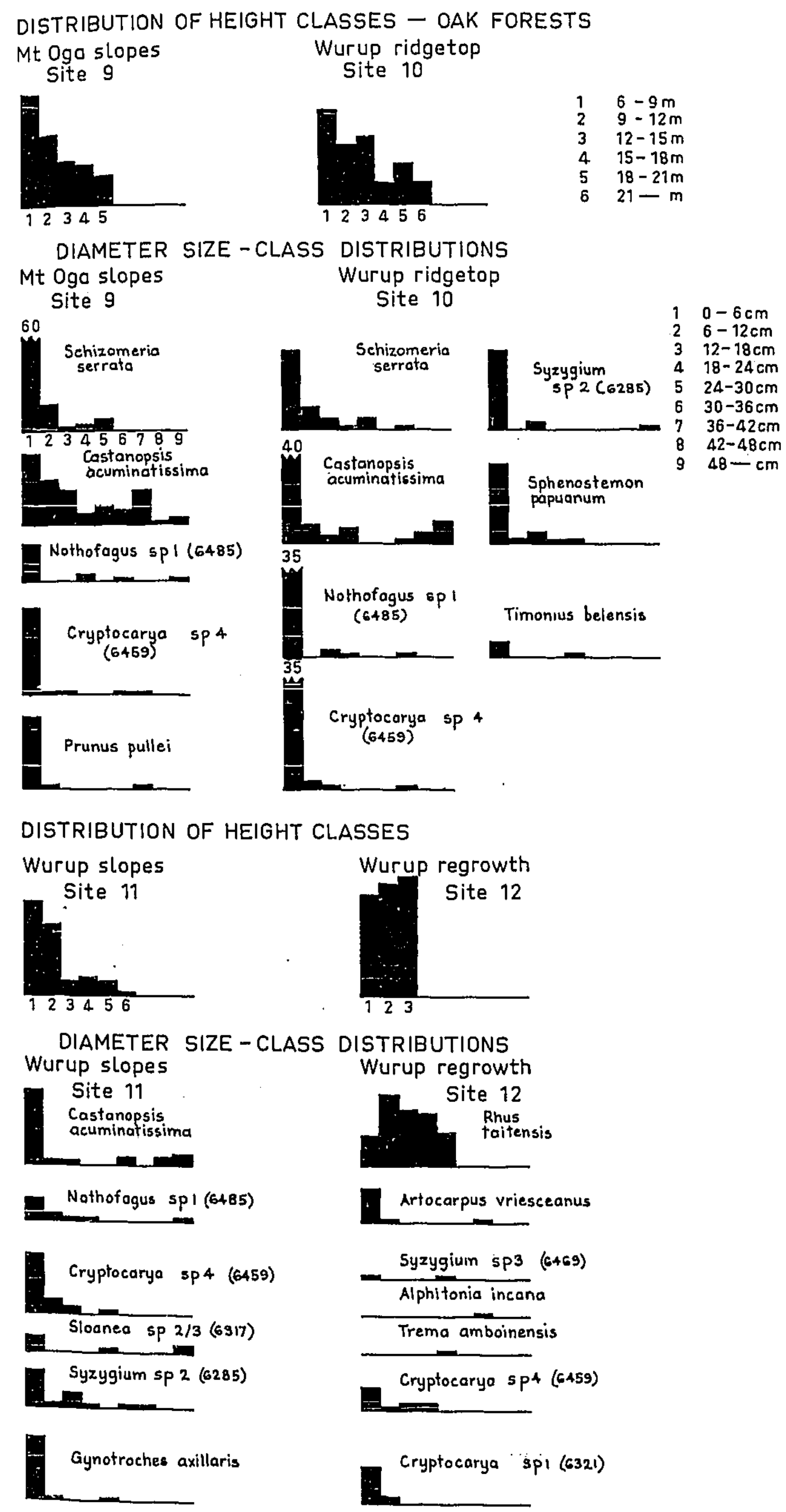


Figure 4.1 Stratification (as indicated by height-class distributions) and diameter size-class distributions of oak forest species.

almost completely absent. Lianes, climbers and epiphytes are absent, ferns and bryophytes sparse. Cut stumps and limbs of Rhus taitensis, Ficus gul, Ficus tonsa, Mischocarpus sp. (6331) and Wendlandia sp. (6218) are recorded.

Rhus taitensis dominates the canopy both in density and basal area content with an estimated 23 trees per 0.1 hectare and 33270 sq. cm basal area. Other taxa occurring with it but in lower densities include Trema amboinensis, Alphitonia incana, Syzygium sp.3 (6469) and Artocarpus vriesceanus. The canopy species recorded elsewhere in the Mt Oga-Wurup forests are absent altogether from the canopy here; some such as Cryptocarya sp.1 and Cryptocarya sp.4 (6459) are present in the understorey and others, for instance, Castanopsis acuminatissima, Prunus pullei and Syzygium sp.2 (6285) are present in the undergrowth.

Diameter size-class distribution (Figure 4.1.) is regular only in Rhus taitensis; in all other canopy species it is disrupted. Cryptocarya sp.4 (6459) shows even distribution but has not yet reached the canopy.

The understorey level is dominated by Rhus taitensis also. Other relatively important taxa include Wendlandia sp. (6218), Glochidion sp.1 (6081), Ficus tonsa, Cryptocarya sp.4 (6459) and Cryptocarya sp.1 (6321). Others, present in low number are Polyscias sp. (6339), Macaranga ?warburgiana, Macaranga ?womersleyi, Ficus endochaete, Harmsiopanax sp. (6370) and Evodia sp.1 (6486).

Understorey species such as Glochidion sp.1 (6081), Ficus gul, Ficus tonsa, Wendlandia sp. (6218) dominate the undergrowth; many others listed previously are present in low density.

Considering the herbaceous component of these forests, few lianes, climbers or small shrubs are present. Among the forbs Elatostema spp. are frequent and a number of taxa recorded at Site 11, such as Desmodium repandum, Poikilogyne sp. (6480) and Cypholophus sp. (6422) are common.

BEECH FOREST (Plate 7)

Beech forest grows on Mt Hagen between 2290m (7500 ft) and 2745m (9000 ft) and is extensive in the

Kubor Ranges and to the west of the Nebilyer River. On aerial photographs it is readily distinguished by the large star-shaped crowns of the Nothofagus trees and the coarse texture of the canopy as a whole. Nothofagus species are the sole canopy dominants on ridge crests, with individual trees reaching 25m height and 170 cm diameter at breast height, while on the steep valley sides Nothofagus shares dominance with a number of mixed forest taxa, in particular members of the Elaeocarpaceae and Myrtaceae. An estimate of the areal extent of this forest is 15.9 sq.km (6.2 sq.mi.), about 4.4 per cent of the total study area.

Plots were enumerated at 4 sites in Beech forest on the slopes of Mt Hagen. Two of these were relatively undisturbed, although within areas used for hunting and gathering, while the other two were disturbed to a lesser and greater extent. Table 4.6 gives habitat data and describes the general features of the forest at the 4 sites while Tables 4.7 to 4.10 inclusive give details of species composition, species density, basal area (where relevant) and species plot frequency for the canopy, understorey and undergrowth.

Site 5 : Beech forest at 2740m (9000 ft) on Mt Hagen

Beech forests in general appear relatively open due to the wide spacing of the dominant canopy species, Nothofagus, and its broad, spreading crown. At site 5 this characteristic physiognomy is more apparent than real, however, as canopy trees are relatively dense, understorey and undergrowth levels very dense. The canopy is more or less continuous at 21-24m height and individual trees of Nothofagus measure between 117-170 cm diameter breast height. Stratification of individuals suggests weak layering within the forest with an understorey level at 15-18m height (Figure 4.2). The undergrowth is dense and continuous with the understorey. Lianes, climbers, and epiphytes are plentiful, ferns and bryophytes abundant. There is little disturbance of the ground cover except near walking tracks and no pig rootings were noted. Fallen logs are relatively common, however, and some such as Nothofagus sp.2 (6294), Elaeocarpus ?sayeri, Syzygium sp.2 (6285), Sericolea sp. (6431), Prunus costata, Prunus pullei, Polyosma sp.1 (6424), Weinmannia sp. (6278), Streblus urophyllus and ?Ardisia sp. (6441) had been cut. A number of Nothofagus

Table 4.6 Characteristics of Beech forest sites on Mt Hagen

Site No.	5	6	7	8
No. plots recorded	20	10	20	20
Altitude	2745m	2585m	2410m	2280m
Landform	Ridge crest	Ridge side	Ridge side	Ridge crest
Aspect	E - NE	NE	E - SE	E - NE
Slope	Medium to gentle	Steep	Medium to steep	Steep
Drainage	4	4	4	4
Soil	Dark brown loam, leaf litter to 10cm brown clay at 40cm	Dark brown loam, leaf litter to 5cm, brown clayey soil, 30cm	Brown clayey soil, little leaf litter, clay at 30cm	Brown clayey loam, leaf litter 5cm, clay at 30cm
pH	5.5 - 6.0	5.5 - 6.0	6.0	6.0
Disturbance	Apparently undisturbed except for walking tracks. Some fallen logs, few cut stumps.	Locally disturbed, many fallen logs, cut stumps. Trampling obvious and pig rooting.	Previously gardened without clear felling. Many cut stumps, fallen logs. Pig rooting frequent.	Previously gardened, few logs, cut stumps. Trampling general.
Canopy & Subcanopy	Continuous, relatively dense	Discontinuous, not dense	Broken, sparse	Broken, sparse
Canopy height	21 - 24m	21 - 24m	21 - 24m	21 - 24m
Understorey	Dense	Dense	Relatively sparse	Dense
Undergrowth	Dense	Relatively dense	Dense	Relatively sparse
Herbaceous ground cover	Undisturbed	Locally disturbed	More or less absent	Patchy
Lianes, climbers, epiphytes	Abundant	Abundant	Abundant	Locally abundant
Ferns, bryophytes	Abundant	Abundant	Ferns abundant Bryophytes sparse	Locally abundant

trees were standing dead or dying but the cause of death was not determined; there were no signs of biotic interference. Heart rot of *Nothofagus* has been recorded by forestry officers elsewhere in the region (Cavanaugh, 1957).

The dominant canopy species is *Nothofagus* sp.2 (6294) with an estimated density of 190 trees per hectare and a basal area content of 61506 sq.cm per 0.2 hectare. Other minor canopy species include *Syzygium* sp.2 (6285), *Pandanus* sp.1, *Weinmannia* sp. (6278), *Elaeocarpus ?sayeri*, and *Cryptocarya* sp.1 (6426). Of these, *Elaeocarpus ?sayeri* has the largest basal area content, 10102 sq.cm per 0.2 hectare. Less frequently present in the canopy are *Elaeocarpus crenulatus*, *Quintinia* sp. (6360), *Ardisia* sp. (6441), *Syzygium adelphicum*, *Prunus costata*, *Saurauia* sp.1 (6381) and *Drimys* sp.4 (6392).

Figure 4.2 gives the diameter size-class distribution of these canopy species. From this it appears that regeneration is uninterrupted in *Nothofagus* sp.2 (6294), *Elaeocarpus ?sayeri*, *Cryptocarya* sp.1 (6426) and *Pandanus* sp.1 but is disrupted in all others recorded.

The canopy species *Elaeocarpus ?sayeri* dominates the understorey and *?Ardisia* sp. (6441), *Elaeocarpus crenulatus*, *Cryptocarya* sp.1 (6426), *Pandanus* sp.1 are important there also. Understorey taxa of equal or greater density include *Sericolea* sp. (6431), *Kibara* sp.3 (6421), *Acronychia* sp.2 (6430), *Drimys* sp.3 (6374), *Polyosma* sp.1 (6424) and *Streblus urophyllus*, all with densities of over 40 individuals per hectare. Other understorey taxa less densely represented include *Omalanthus* sp.1 (6251), *Casearia* sp. (6311), *Astronia* sp.1 (6244), *Schuurmansia henningsii*, *Prunus pullei*, *Timonius belensis*, *Macaranga ?warburgiana*, *Kibara* sp.2 (6245), *Evodia* sp.5 (6258), Sapindaceae gen.1 (6349), *Drimys* sp.2 (6270), *Olearia* sp. 1/3 (6351), *Spiraeopsis brassii*, *Eurya oxysepala*, *Sphenostemon papuanum*, *Xanthomyrtus* sp. (6345), and *Cordyline* sp.

Sapings and seedlings of the canopy and understorey species dominate the undergrowth. Recorded also from this level are *Schefflera* sp.1 (6352), *Phyllanthus nervosus*, *Piper* sp.5 (6415), *Symplocos* sp.3 (6420), Podocarpus neriifolius, Pittosporum pullifolium, Lauraceae gen.1 (6246), Schizomeria serrata, Cyrtandra sp.1 (6253), Saurauia sp.4 (6256), Elaeocarpus poculiferus and Phaleria ?sogerensis. The small shrubs, Amaracarpus sp.1 (6428) and Amaracarpus sp.3 (6377) are also important in the undergrowth.

Herbaceous taxa are abundant in these forests. Important lianes, climbers and epiphytes are Dimorphanthera denticulifera, Palmeria sp.3 (6271), Psychotria sp. (6287), Piper sp.1 (6408), Rubus moluccanus, Freycinetia spp. and the bamboo Nastus productus. Ubiquitous ground herbs include the Urticaceae, Cypholophus sp. (6422), Elatostema sp.1 (6375), Elatostema sp.3 (6423) and the Zingiberaceae, Alpinia sp.3 (6368), and others remaining unidentified (5975, 6145). The fern families Cyatheaceae and Gleicheniaceae are also well represented.

Site 6 : Beech forest at 2585m (8500 ft) on Mt Hagen

The beech forest at 2585m is relatively more open than that at 2740m due to the lower density of canopy trees and less dense undergrowth. The canopy is discontinuous at 21-24m height, the subcanopy more continuous at 18-21m height. No stratification is obvious (Figure 4.2). Understorey and undergrowth levels are relatively densely stocked with small trees and shrubs and lianes, climbers and epiphytes are abundant. The herbaceous ground cover is locally disturbed by trampling and pig rooting and a number of fallen logs and cut stumps were noted. Schizomeria serrata, Nothofagus, Elaeocarpus ?sayeri, Syzygium sp.2 (6285), Finschia sp. (6289) and Kibara sp.3 (6421) had been selectively cut in this area. Ferns and bryophytes are abundant both as epiphytes on standing and fallen tree trunks and on the ground.

The canopy is again clearly dominated by Nothofagus sp.2 (6294) with a density of 60 trees per hectare and a basal area content of 11938 sq.cm per 0.1 hectare, but Elaeocarpus crenulatus, Elaeocarpus ?sayeri, Pandanus sp.1 and Prunus costata are also important canopy species and all have a basal area content of over 2000 sq.cm per 0.1 hectare. Other canopy species less frequently represented include Schuurmansia henningsii, Cryptocarya sp.1 (6426), Elaeocarpus sp.1 (6247), Weinmannia sp. (6278) and Schizomeria serrata.

Regeneration (Figure 4.2) appears to be occurring evenly only in Cryptocarya sp.1 (6426) and Pandanus sp.1 within these forests. All other canopy taxa show irregular diameter size-class distributions suggesting interrupted regeneration.

The understorey comprises high densities of the canopy taxa Elaeocarpus ?sayeri, Nothofagus sp.2 (6294) and Pandanus sp.1, together with taxa such as ?Ardisia sp. (6441), Syzygium sp.2 (6285), canopy species at 2740m but here only represented in the understorey. Understorey species such as Evodia sp.5 (6258), Kibara sp.2 (6245), Kibara sp.3 (6421), Polyosma sp.1 (6424), Timonius belensis, and Streblus urophyllus are also important. Others, not recorded at 2740m include Lauraceae gen.1 (6246), Turpinea pentandra, Harmsiopanax sp. (6370), Cyrtandra sp.1 (6253), Finschia sp. (6289) and Saurauia sp.4 (6256).

Canopy and understorey species dominate the undergrowth, in particular Elaeocarpus ?sayeri, Kibara sp.3 (6421), Streblus urophyllus, and Drimys sp.2 (6270), all of which have a density of over 1000 per hectare. The undergrowth taxa Elaeocarpus poculiferus, Amaracarpus sp.1 (6428) and Amaracarpus sp.3 (2470) are equally well represented, and Prunus pullei, Drimys sp.4 (6392), Phyllanthus nervosus, Xanthomyrtus sp. (6345) are relatively important.

Herbaceous taxa are even more abundant here than at 2740m. Most of the species recorded there are present, together with Cayratia sp. (6328), among the lianes and Plectranthus sp.1 (6032), Pilea sp.1 (6296) and Zingiberaceae gen.2 (6144) among the ground herbs. Ferns are plentiful in particular Cyatheaceae gen.3, Dicranopteris linearis and a Marattiaceae (6086).

Site 7 : Beech forest at 2410m (7900 ft) on Mt Hagen

At 2410m much of the beech forest has been cut over for timber and some areas cleared previously for use as gardens. The site surveyed has a very broken canopy and subcanopy between 21-24m height, standing above a relatively dense understorey at 9-12m height. Remaining canopy trees are large, however, with individuals of Nothofagus measuring 125-140 cm in diameter, Syzygium sp.2 (6285) 60 cm diameter, Dryadodaphne sp. (6327) 52 cm diameter and Timonius belensis 45 cm diameter. The undergrowth is dense and a wide variety of taxa are present there. Fallen logs are abundant and the undergrowth tangled around them. Ferns and climbing bamboo dominate some open areas. Lianes, climbers and epiphytes are abundant, ferns plentiful but bryophytes sparse. Much of the ground surface is bare, the former cover having been stripped off: in two plots outlines of an old mounded field pattern are evident. Pigs had been rooting over many parts of the site. Cut trunks of Nothofagus sp.2 (6294), Ilex sp.1 (6320), Eurya oxysepala, ?Ardisia sp. (6441), Symplocos sp. (6343), Garcinia sp. (6325), Evodia sp.5 (6258) and Schizomeria serrata were noted.

The main canopy species is Nothofagus sp.2 (6294) with an estimated 45 trees per hectare and a basal area content of 16080 sq.cm per 0.2 hectare. Other canopy species are Syzygium sp.2 (6285), Quintinia sp. (6360), Schizomeria serrata, together with a number of species recorded from the understorey at 2740m and 2585m, namely, Kibara sp.3 (6421), Timonius belensis and Eurya oxysepala. Others not previously recorded in the canopy of beech forest include Ilex sp.1 (6320), Dryadodaphne sp. (6327), Garcinia sp.3 (6325) and Syzygium sp.5 (6314). Most of these have a relatively low basal area content, of around 2000 - 3000 sq.cm per 0.2 hectare.

All the canopy species show disrupted size-class distributions (Figure 4.2), indicating great disturbance or interruption of natural regeneration among them.

The understorey is dominated by Omalanthus nervosus, a soft-wooded, regrowth species; many other species are present in lower numbers. Taxa not recorded in the understorey of the higher altitude beech forests include Endiandra sp.2 (6333), Evodia sp.1 (6486), Elaeocarpus sp.2 (6332), Glochidion sp.4 (6322), Euphorbiaceae gen.1 (6335), Phyllanthus nervosus, Alphitonia incana, Saurauia sp.5 (6324), Symplocos sp.2 (6343), Eurya tigang, Podocarpus imbricatus and Rapanea sp.3 (6354).

Understorey taxa dominate the undergrowth, in particular Omalanthus nervosus and Phyllanthus nervosus with densities of 1300 and 2010 individuals per hectare, and others such as Streblus urophyllus, Evodia sp.5, ?Ardisia sp., Prunus pullei, have densities of over 700 per hectare. Canopy species Garcinia sp.3 (6325), Schizomeria serrata, Nothofagus sp.2 (6294) are important. Also present in relatively large numbers are Spiraeopsis brassii, Astronia sp.1 (6244), Prunus costata, Macranga ?warburgiana, Cinnamomum sp.2, Xanthomyrtus sp. (6345), Piper sp.5 (6415), Cordyline sp., Elaeocarpus poculiferus and Amaracarpus sp.3 (6377). Not recorded from higher altitude sites are Sloanea sp.2/3 (6317), Guioa sp. (6347) and Piper sp.9 (6315), present in relatively high densities and Polyscias sp. (6363), Galbulimima belgraveana, Geniostema sp. (6326), Ficus tonsa, Evodiella sp. (6435), Planchonella macropoda, Discocalyx sp. (6319) Mischocarpus sp. (6331) and Debregeasia sp.1 (6372), present in lower numbers.

High densities are recorded for many of the herbaceous taxa present at this site. As well as most of the 'forest' taxa noted at sites 5 and 6 others, such as Curcurbitaceae gen.1, Rhododendron womersleyi and 'Toowang' are recorded as lianes, 'Kowa' as a very large climbing bamboo and Blumea arnikido, Crassocephalum crepidiodes and Potentilla sp.1 (6393) as forbs. Dense patches of Miscanthus floridulus are common and some areas are covered with Gleichenia hooglandii.

Site 8 : Regrowth forest at 2280m (7500 ft) on Mt Hagen

The plots surveyed at 2280m represent regrowth forest of some years age on land formerly cleared from beech forest for gardens. Physiognomically the forest is open with a low density of canopy trees and patchy undergrowth. The understorey level is densely stocked and forms a more or less continuous layer at 9-12m height. Above this a few trees make up a sparse canopy and subcanopy up to 24m height (Figure 4.2). The only really large trees present are two individuals of Nothofagus sp.2 (6294) with diameters of 80 cm and 158 cm respectively and a single individual of Schizomeria serrata with a diameter of 75 cm. The apparent density of the understorey is increased by many of the taxa being multistemmed, in particular Macaranga ?womersleyi, Phyllanthus nervosus, Geniostema arfakense, Schefflera sp. (6352), Timonius sp. (6436) and Saurauia sp.1 (6381) and Saurauia sp.4 (6256). Fallen logs are plentiful and disturbance of the forest widespread; cut trunks of Nothofagus sp.2 (6294), Elaeocarpus sp.1 (6247), Astronia sp.1 (6244), Evodia sp.1 (6486), Alphitonia incana, Cinnamomum sp.2 (6279) and Spiraeopsis brassii are noted. Lianes, climbers and epiphytes are locally abundant, climbing bamboo ubiquitous. Patches of cane grass occur in most plots and other areas are dominated by ferns. Ground herbs are locally common and bryophytes are abundant on fallen tree trunks and locally on the ground.

Spiraeopsis brassii, Sloanea sp. 2/3 (6317), Macaranga ?womersleyi, Nothofagus sp.2 (6294) and Ficus endochaete are the main canopy species with densities of 15-20 trees per hectare. Others less numerous include Dryadodaphne sp. (6327), Schizomeria serrata and Evodia sp.1 (6486). In basal area content Nothofagus sp.2 (6294) dominates, with Spiraeopsis brassii and Macaranga ?womersleyi also important. They record 6925, 6481 and 5968 sq.cm per hectare respectively. The minor canopy species have basal area contents of 2000 - 3000 sq.cm per hectare.

The diameter size-class distributions of the canopy species (Figure 4.2) suggest uninterrupted regeneration in Spiraeopsis brassii and Macaranga ?womersleyi; the other taxa show disrupted sequences. Nothofagus is regenerating relatively well, however, as shown by the even distribution over the smaller size-classes, the larger trees being regarded as relics.

The canopy species Spiraeopsis brassii and Macaranga ?womersleyi are numerically dominant in the understorey with 205 and 170 individuals per hectare respectively. Nothofagus sp.2 (6294) is also important, together with understorey taxa Timonius belensis, Phyllanthus nervosus, Timonius sp.1 (6436) and Saurauia sp.4 (6256), all of which have densities of 80 or more individuals per hectare. Many others occur in lower densities. Those recorded only in the undergrowth at sites 5, 6 and 7 include Pittosporum pullifolium, Polyscias sp. (6339), Schefflera sp.1 (6352), Macaranga pleiostemona, Galbulimima

Table 4.7 Species composition, species density and plot frequency in the canopy of Beech forests on Mt Hagen.

Site No.			5					6					7					8				
Altitude (m)			2740					2585					2410					2280				
			1*	Density in		*2	Plot		Density in			Plot		Density in			Plot		Density in			Plot
Canopy species			C	U's	U'g	B.A.	Freq.	C	U's	U'g	B.A.	Freq.	C	U's	U'g	B.A.	Freq.	C	U's	U'g	B.A.	Freq.
6320	Aquifoliaceae	Ilex sp. 1											5	25	615	2361	17/20		5	205		10/20
6327	Atherospermaceae	Dryadodaphne sp.											10	30	400	3694	15/20	5		30	859	1/20
6325	Clusiaceae	Garcinia sp. 3											5	5	1285	2807	19/20			270		13/20
6248	Cunoniaceae	Schizomeria serrata			35		1/20	10	20	320	1001	8/10	5	10	715	1670	14/20	5	5	285	2411	7/20
6283	"	Spiraeopsis brassii		5	10		1/20								210		7/20	20	205	750	6481	19/20
6278	"	Weinmannia sp.	10	5	465	3210	13/20	10		420	841	7/10			35		1/20					
6410	Elaeocarpaceae	Elaeocarpus cronulatus	5	40	235	2498	15/20	20	10	660	2554	10/10		15	160		12/20		5	30		2/20
6425	"	Elaeocarpus ?sayeri	10	205	2565	10102	20/20	20	170	1450	4766	10/10		35	665		19/20					
6247	"	Elaeocarpus sp. 1						10		100	887	3/10			195		10/20		5	65		3/20
6317	"	Sloanea sp. 2 & 3													300		11/20	15	20	180	2601	14/20
6360	Escalloniaceae	Quintinia sp.	5	10	340	1685	9/20						10		120	2504	9/20					
6439	Euphorbiaceae	Macaranga ?womersleyi																15	170	645	5968	19/20
6294	Fagaceae	Nothofagus sp. 2	190	35	855	61506	20/20	60	90	550	11938	9/10	45	20	775	16080	19/20	15	80	300	6925	13/20
6426	Lauraceae	Cryptocarya sp. 1	10	55	1565	5415	20/20	10	30	760	1640	9/10		5	465		16/20		15	325		12/20
6421	Monimiaceae	Kibara sp. 3		40	920		20/20		40	1030		9/10	5	10	685	2708	19/20			650		18/20
6440	Moraceae	Ficus endochaete																15	15	165	2271	9/20
6441	Myrsinaceae	?Ardisia sp.	5	70	1080	3021	20/20		120	890		10/10		35	730		19/20		15	695		19/20
6254	Myrtaceae	Syzygium adelphicum	5	15	510	2740	18/20			20		1/10										
6285	"	Syzygium sp. 2	20	30	970	6666	20/20		70	740		9/10	5		490	2637	15/20			80		3/20
6314	"	Syzygium sp. 5											5	5	325	2035	15/20		5	135		5/20
6380	Ochnaceae	Schuurmansia henningsii		10	280		12/20	10	10	140	976	3/10		5	340		12/20		5	45		3/20
6284	Rosaceae	Prunus costata	5	30	900	3253	20/20	20	10	720	2523	10/10			415		18/20		10	20		2/20
6249	Rubiaceae	Timonius belensis		20	840		20/20		40	760		10/10	5	5	370	2530	14/20		125	940		20/20
6486	"	Evodia sp. 1												5	245		11/20	5	25	375	2241	18/20
6381	Saurauiaceae	Saurauia sp. 1	5		15	838	3/20							5	470		12/20		80	345		3/20
6414	Theaceae	Eurya oxysepala		5	330		15/20		20	480		9/10	5	20	475	1834	17/20		70	810		20/20
6392	"	Drimys sp. 4	5	10	680	1621	19/20			410		9/10		5	285		15/20		5	125		8/20
	Pandanaceae	('Um') Pandanus sp. 1	15	40	170	4311	17/20	20	90	320	2292	10/10										

*1 Density i.e. number of individuals per hectare in the canopy (c), understoroy (U's) and undergrowth (U'g).

*2 Basal area in sq. cm. per 0.2 hectare.

Table 4.8 Species composition, species density and plot frequency in the understorey of Beech forests on Mt Hagen.

Site No.			5			6			7			8		
Altitude (m)			2740			2585			2410			2280		
			Density in		Plot	Density in		Plot	Density in		Plot	Density in		Plot
Understorey species			U's	U'g	Freq.	U's	U'g	Freq.	U's	U'g	Freq.	U's	U'g	Freq.
6438	Apocynaceae	Alstonia sp.										5	120	8/20
6280	Aquifoliaceae	Sphenostemon papuanum	5	155	8/20	10	840	10/10		145	8/20		115	6/20
6370	Araliaceae	Harmsiopanax sp.				10	60	3/10					50	2/20
6339	"	Polyscias sp.								130	11/20	10	180	10/20
6352	"	Schefflera sp. 1		280	15/20		280	7/10		20	3/20	45	445	15/20
6351	Asteraceae	Olearia sp. 1/3	5		1/20		80	2/10	15	120	6/20	10	5	1/20
6332	Elaeocarpaceae	Elaeocarpus sp. 2							15	90	5/20			
6431	"	Sericolea sp.	75	475	17/20	20	160	10/10	5	145	8/20	10	70	4/20
6424	Escalloniaceae	Polyosma sp. 1	55	840	20/20	50	920	10/10				20	225	4/20
6322	Euphorbiaceae	Glochidion sp. 4							20	445	18/20		125	5/20
6171	"	Macaranga pleiostemona										10	25	3/20
5530	"	Macaranga ?warburgiana	10	10	3/20					255	10/20	55	425	18/20
6334	"	Omalanthus nervosus							210	1300	13/20	30	590	16/20
6251	"	Omalanthus sp. 1	15	235	10/20		20	2/10						
6282	"	Phyllanthus nervosus		170	6/20		450	6/10	50	2010	20/20	100	1030	20/20
6335	"	Gen. 1							5	270	9/20	25	365	13/20
6311	Flacourtiaceae	Casearia sp.	10	585	16/20	30	700	9/10	10	275	15/20	20	200	10/20
6253	Gesneriaceae	Cyrtandra sp.1		20	5/20	10	750	6/10	5	115	5/20		200	17/20
6337	Himantandraceae	Galbulimima belgraveana								110	8/20	5	5	1/20
6279	Lauraceae	Cinnamomum sp. 2					140	3/10		675	20/20	40	420	16/20
6333	"	Endiandra sp. 2							10	695	20/20	20	375	13/20
6246	"	Gen. 1		20	1/20	10		1/10						
6326	Loganiaceae	Geniostoma sp.								60	4/20	35	515	17/20
6244	Melastomataceae	Astronia sp. 1	20	495	9/20		360	6/10		350	14/20	40	630	18/20
6245	Monimiaceae	Kibara sp. 2	10	640	20/20	90	550	10/10						
6342	Moraceae	Ficus tonsa								10	1/20	10	355	15/20
6427	"	Streblus urophyllus	50	1430	20/20	40	1270	10/10	15	855	20/20	5	440	16/20
6293	Myrsinaceae	Maesa sp.		5	1/20					15	2/20	5	190	13/20
6354	"	Rapanea sp. 3							20	265	10/20		50	3/20
6345	Myrtaceae	Xanthomyrtus sp.	5	915	18/20		420	6/10		395	13/20		5	1/20
6415	Piperaceae	Piper sp. 5		50	4/20		310	9/10		730	20/20	40	665	12/20
6397	Pittosporaceae	Pittosporum pullifolium		10	1/20		180	2/10		10	1/20	35	170	9/20
6289	Proteaceae	Finschia sp.				30	100	3/10						
6434	Rhamnaceae	Alphitonia incana							5	85	5/20	50	80	6/20
6272	Rosaceae	Prunus pullei	20	1875	19/20		780	8/10	5	860	18/20	5	375	17/20
6436	Rubiaceae	Timonius sp. 1										80	875	20/20
6430	Rutaceae	Acronychia sp. 2	50	1735	20/20	20	720	9/10						
6258	Rutaceae	Evodia sp. 5	10	640	20/20	100	900	10/10	15	720	17/20	25	215	11/20
6435	"									10	1/20	10	500	16/20
6347	Sapindaceae	Guioa sp.								330	15/20	5	105	4/20
6349	"	Gen. 1	10	160	10/20		60	2/10		75	3/20	35	530	18/20
6329	Sapotaceae	Planchonella macropoda								120	11/20	10	125	4/20
6256	Saurauiaceae	Saurauia sp. 4		25	2/20	10	60	3/10	5	500	15/20	100	190	13/20
6324	"	Saurauia sp. 5							5	50	5/20	5	15	1/20
6277	Staphyleaceae	Turpinea pentandra				20	500	8/10		30	4/20			
6343	Symplocaceae	Symplocos sp. 2							5	210	17/20	20	205	11/20
6420	"	Symplocos sp. 3		105	7/20				10	540	15/20		80	6/20
6298	Theaceae	Eurya meizophylla										5	20	3/20
6338	"	Eurya tigang							5	85	5/20	45	345	16/20
6270	Winteraceae	Drimys sp. 2	25	995	20/20	10	1030	10/10		50	5/20			
6274	"	Drimys sp. 3	60	915	18/20	20	200	7/10		25	3/20	10	45	4/20
	Liliaceae	Cordyline sp.	5	5	2/20					495	18/20	25	445	14/20
6323	Podocarpaceae	Podocarpus neriifolius							10	220	12/20		5	1/20

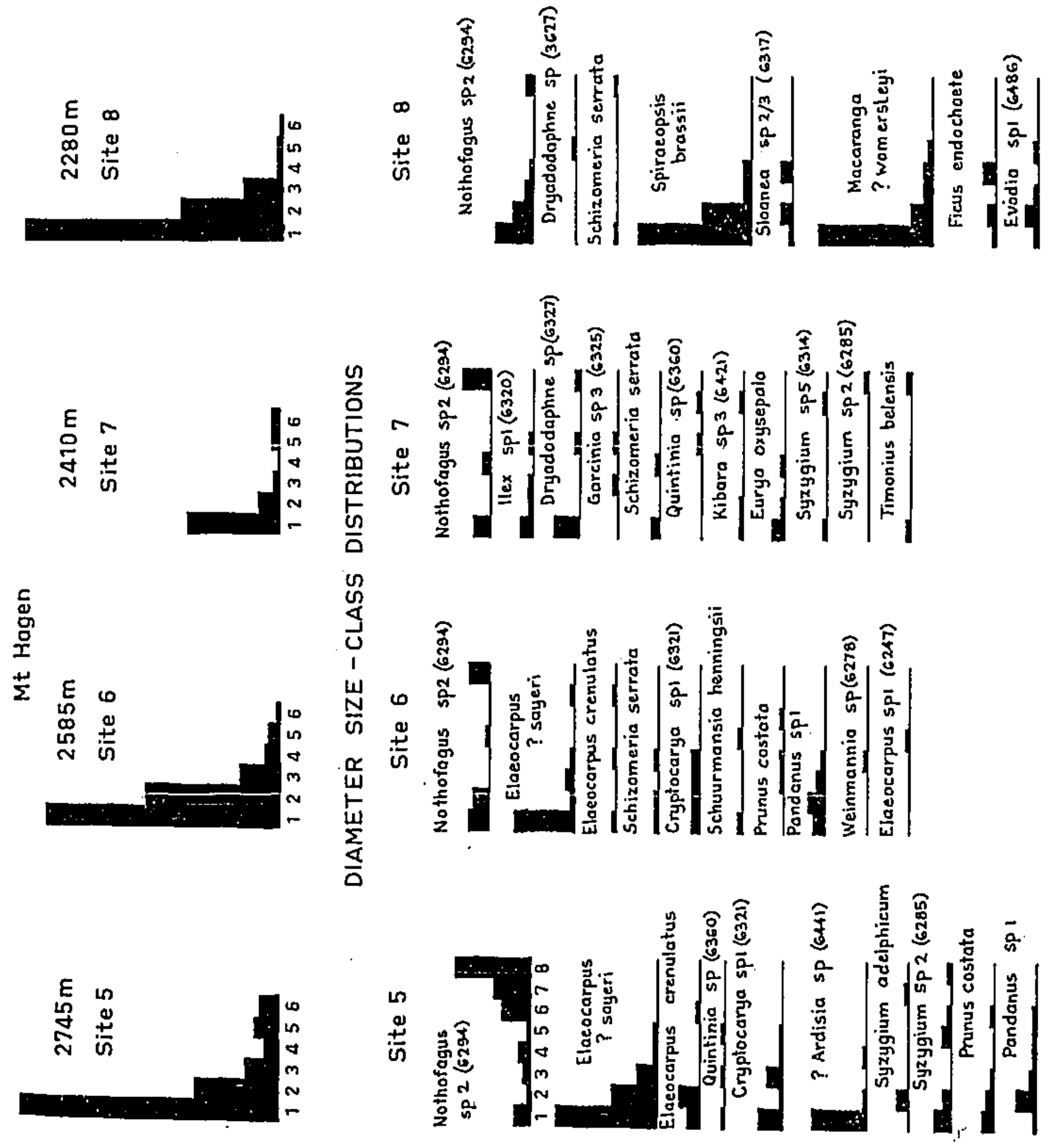
Table 4.9 Species composition, species density and plot frequency in the undergrowth of Beech forests on Mt Hagen.

Site No.			5		6		7		8	
Altitude (m)			2740		2585		2410		2280	
Undergrowth Species			Density U'g	Plot Freq.	Density U'g	Plot Freq.	Density U'g	Plot Freq.	Density U'g	Plot Freq.
6281	Chloranthaceae	Ascarina philippinensis							35	5/20
6348	Elaeocarpaceae	Elaeocarpus poculiferus	1545	20/20	1710	10/10	1155	20/20	950	20/20
5757	Moraceae	Ficus dammaropsis							105	8/20
6319	Myrsinaceae	Discocalyx sp.					115	6/20		
6315	Piperaceae	Piper sp. 9					525	11/20	685	19/20
6428	Rubiaceae	Amaracarpus sp. 1	215	8/20	1150	8/10				
6377	"	Amaracarpus sp. 3	2475	20/20	2470	10/10	930	14/20	1520	19/20
6331	Sapindaceae	Mischocarpus sp.					100	7/20		
6433	Thymeleaceae	Phaleria ? sogerensis	615	16/20	220	8/10			10	1/20
6372	Urticaceae	Debregeasia sp..1					80	6/20	200	11/20
6259	Podocarpaceae	Podocarpus neriifolius	65	6/20	150	1/10	195	11/20	25	2/20

Table 4.10 Species compositions, species density and plot frequency of herbaceous taxa in Beech forests on Mt Hagen

Site No. / Altitude m		Herbaceous species	5 (2740 m) Density	5 (2740 m) Plot Freq.	6 (2285 m) Density	6 (2285 m) Plot Freq.	7 (2410 m) Density	7 (2410 m) Plot Freq.	8 (2280 m) Density	8 (2280 m) Plot Freq.
	Cucurbitaceae	gen.1					1325	19/20	435	12/20
6353	Ericaceae	Dimorphanthera alpina	340	9/20	830	7/10	445	10/20	765	19/20
6376	"	D. denticulifera	1330	20/20	1250	9/10	135	8/20	375	15/20
6384	"	Rhododendron womersleyi					115	6/20		
6271	Monimiaceae	*Palmeria sp. 3*	2315	20/20	2530	10/10	2130	20/20	725	17/20
6408	Piperaceae	Piper sp. 1	790	20/20	1540	10/10	700	14/20	1515	19/20
5573	Rosaceae	Rubus moluccanus	790	18/20	1370	10/10	1300	20/20	675	18/20
6287	Rubiaceae	Psychotria sp.	835	18/20	350	5/10				
6328	Vitaceae	Cayratia sp.			1090	5/10	955	18/20	20	1/20
		'Tropena'	390	16/20	720	10/10	915	20/20	1015	19/20
		'Toowang'					1000	19/20	810	19/20
	Pandanaceae	Freycinetia spp.	1360	15/20	3280	10/10	3535	20/20	1555	18/20
6261	Poaceae	Nastus productus	4000	20/20	4000	10/10	4000	19/20	2960	19/20
	"	'Kowa'					55	3/20	380	8/20
6082	Asteraceae	Blumea arnakidophora					55	2/20	615	19/20
5724	"	*Crassocephalum crepidioides*					40	1/20		
6269	Gesneriaceae	Cyrtandra sp. 3	105	5/20	850	9/10	100	6/20	15	1/20
6032	Lamiaceae	Plectranthus sp. 1			490	6/10	200	7/20	515	11/20
6393	Rosaceae	Potentilla sp. 1					5	1/20	40	1/20
5746	"	Rubus rosaefolius	520	5/20						
6422	Urticaceae	Cypholophus sp.	540	8/20	1390	6/10	60	2/20	290	10/20
6375	"	Elatostema sp. 1	3385	19/20	1720	5/10	540	15/20	635	18/20
6312	"	Elatostema sp. 2					475	4/20	760	6/20
6423	"	Elatostema sp. 3	870	19/20	1160	10/10				
6296	"	Pilea sp. 1			1240	4/10				
6340	Orchidaceae	Glomera sp. 2					200	7/20		
6341	"	Glomera sp. 3					155	6/20		
6066	Poaceae	Miscanthus floridulus					1670	10/20	3000	18/20
6368	Zingiberaceae	Alpinia sp. 3	4000	20/20	4000	10/10	4000	20/20	3180	19/20
5975	"	1.	1545	19/20	1270	10/10	1760	20/20	1805	20/20
6144	"	2.			20	1/10			20	1/20
6145	"	3.	375	9/20	770	9/10	550	17/20	35	1/20
6022	Cyatheaceae	Cyathea sp.					440	9/20	245	11/20
	"	2.	1655	20/20			1215	20/20	160	9/20
	"	3.	1505	20/20	1220	10/10	620	18/20	15	3/20
	"	4.	10	1/20	220	6/10	145	8/20	300	15/20
6026	Gleicheniaceae	Dicranopteris linearis	785	13/20	1930	8/10	40	2/20	3600	18/20
6029	"	Gleichenia hooglandii					1305	9/20	3225	19/20
6086	Marattiaceae				240	7/10	185	11/20	640	20/20
	Lycopodiaceae	Lycopodium spp.					10	1/20		

Figure 4.2 Stratification (as indicated by height-class distributions) and diameter size-class distributions of beech forest species.



belgraveana, Cinnamomum sp.2 (6279), Geniostema sp. (6326), Ficus tonsa, Maesa sp. (6293), Piper sp.5 (6415), Evodiella sp. (6435), Guioa sp. (6347), Planchonella macropoda and Eurya meizophylla.

Understorey taxa dominate the undergrowth, in particular Phyllanthus nervosus, Timonius sp.1 (6436), Timonius belensis and Eurya oxysepala, all with more than 700 individuals per hectare. Omalanthus nervosus, Endiandra sp.2 (6333), Astronia sp.1 (6244), Prunus pullei, Schefflera sp.1 (6352), Macaranga ?warburgiana, Euphorbiaceae gen.1 (6335), Cinnamomum sp.2 (6279), Geniostema sp. (6326), Streblus urophyllus, Piper sp.5 (6415), Evodiella sp. (6435), Sapindaceae gen.1 (6349), Eurya tigang and Cordyline sp. are also abundant with more than 300 individuals per hectare. The canopy species Spiraeopsis brassii, Macaranga ?womersleyi, Evodia sp.1 (6486) and Nothofagus sp.2 (6294) show similar densities.

The herbaceous complement is similar to that at site 7. Piper sp.1 (6408), 'Tropena' and Freycinetia spp. are particularly abundant among the lianes, Alpinia sp.1 (6368) and A. sp.3 (5975) among the ground herbs. Patches of Miscanthus floridulus are present in most plots and other areas are covered with ferns Gleichenia hooglandii and Dicranopteris linearis.

MIXED FOREST (Plate 8 A)

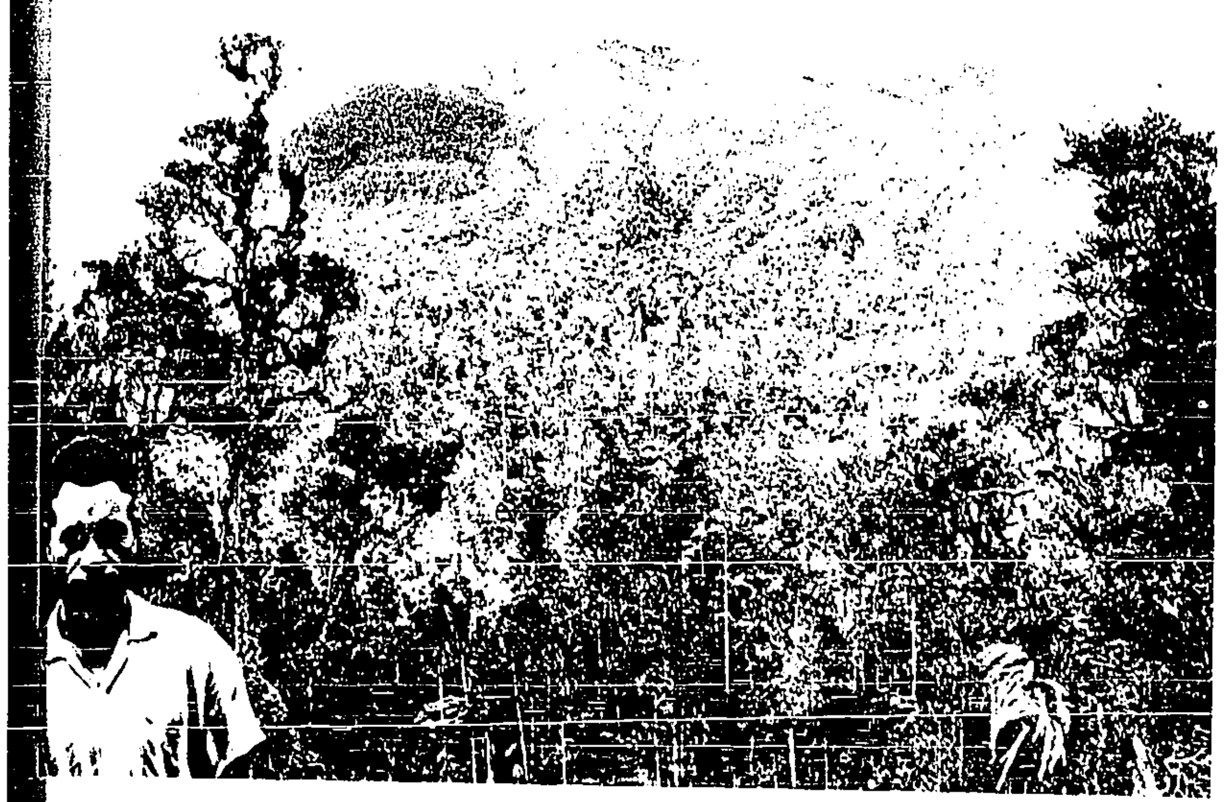
Mixed forest covers an area of ca 11.8 sq.km (4.5 sq.mi.) in the study region (3.3%). It is extensive on Mt Hagen at altitudes above 2740m (9000 ft) and at similar high altitudes in the Kubor Ranges and to the west of the Nebilyer River. In aerial photographs the canopy is characteristically fine-textured and rather uneven; where conifers are emergent, as on the southern slopes of Mt Hagen, the roughness of the canopy is accentuated. Preliminary ground survey suggests that the families Elaeocarpaceae, Cunoniaceae, Escalloniaceae, Lauraceae and Myrtaceae share canopy dominance in these forests. At the upper limit of continuous forest on Mt Hagen Ericaceae, Podocarpaceae and Myrsinaceae are important canopy components also. Small areas of stunted mixed forest occur at the upper limit of the

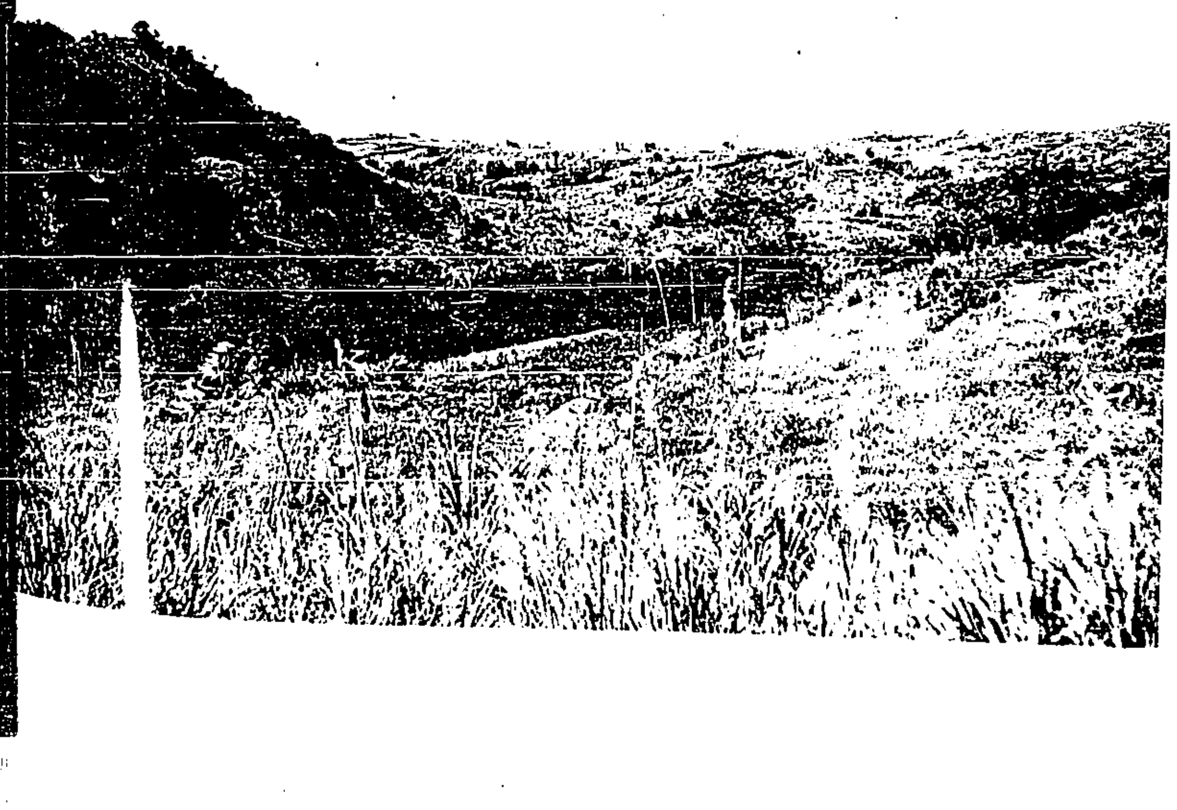
PLATE 8A

Looking towards the summit and southern slopes of Mt Hagen from the Wabag road. Mixed forest with emergent conifers is the main vegetation.

PLATE 8B

Regrowth shrubs in grassland just below the forest margin on Mt Hagen (2300m) altitude.





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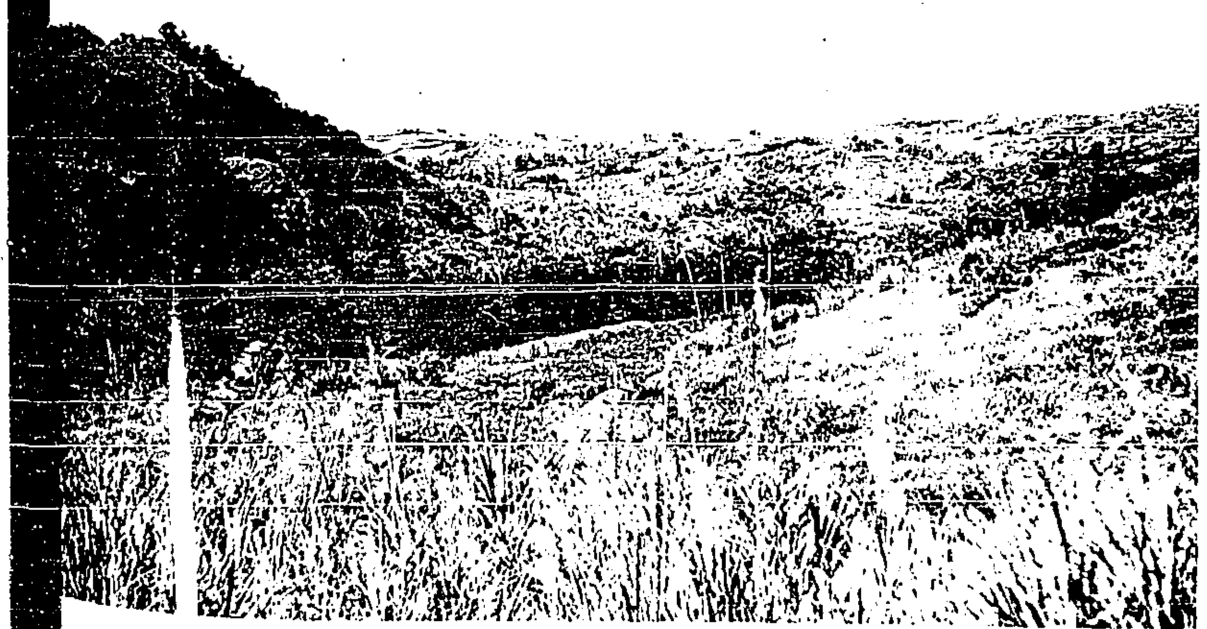

continuous forest and other areas are degraded through cutting of timber for various purposes

Altogether four sites were surveyed in mixed forest on the slopes of Mt Hagen. One site appeared undisturbed, two others showed local disturbance and the fourth site was largely regrowth vegetation, the forest having been cleared previously for commercial timber. Table 4.11 gives habitat data and describes general features of the four sites and Tables 4.12 to 4.15 outline species composition, species density and species plot frequency for the canopy, understorey and undergrowth. Basal area content is included in Table 4.12 for the canopy taxa.

Site 1 : Mixed forest at 3345m (11000 ft) on Mt Hagen (Plate 9 A)

The high altitude mixed forest is usually covered with cloud; it appears dense, dark and is always wet. The canopy is uneven at 15-17m height and emergent trees of Quintinia sp. (6360) reach 18m. There is no stratification apparent (Figure 4.3) and all levels are relatively densely stocked with trees, shrubs and herbs. Some trees, in particular, Quintinia sp. (6360) and ?Ardisia sp. (6441), have twisted and gnarled trunks, while others are multistemmed, for example, Eurya oxysepala, Sericolea sp. (6431) and Schefflera sp. (6352). All are thickly covered with mosses, liverworts and filmy ferns. A number of canopy gaps are recorded and fallen logs litter the ground. Stumps of Syzygium adelphicum, Ilex sp.3 (6262), Pittosporum pullifolium, Drimys sp.3 (6374), Saurauia sp.1 (6381) and Polyosma sp. (6255) are noted; the Ilex appears to have been cut. Lianes and climbers are well represented, tree ferns abundant. The ground is covered with thick leaf litter, mosses, ferns and lycopods and biotic disturbance is not apparent.

The dominant canopy species is Quintinia sp. (6360) with an estimated density of 110 trees per hectare and a basal area of 22902 sq.cm per 0.2 hectare. However, Elaeocarpus crenulatus, Vaccinium apiculatum, Polyosma sp. (6255) and Syzygium adelphicum are also very important with between 45-70 trees per hectare and basal area contents of between 11371 and 22306 sq.cm per 0.2 hectare. Other minor canopy species are Ilex

Table 4.11 Characteristics of Mixed forest sites on Mt Hagen

Site No.	4	1	2	3	4
No. plots recorded	10	20	20	20	10
Altitude	3345	3345m	3040m	2900-2740m	2710m
Landform		Ridge side	Ridge side	Ridge crest & side	Ridge side
Aspect		NE	NE	N - NE	SE - S
Slope		Medium	Steep to medium	Steep to medium	Steep to medium
Drainage		4	4	4	4
Soil		Deep, dark brown loam leaf litter to 8cm, soil to 70cm, brown clay below.	Dark brown loam, surface litter 5-8cm soil to 75cm, brown clayey loam below.	Dark brown loam litter to 10cm, soil to 25cm, mixed brown clay below.	Dark brown clayey loam, litter patchy to 5cm, brown clay 30cm.
pH		5.0 - 6.0 at base	6.0 - 6.5	5.0 - 6.5	6.0
Disturbance		Not obvious Fallen logs plentiful, some cut stumps.	Local disturbance, cut stumps, trampling, some pig rooting.	General disturbance, cutting, trampling.	General disturbance cutting, trampling pig rooting.
Canopy & subcanopy		Uneven, continuous, dense	Even, continuous, dense.	Broken, sparse.	Broken, sparse.
Canopy height		15-17m - 18m	20 - 21m	22 - 24m	22 - 24 m
Understorey		Dense	Relatively sparse	Dense	Relatively sparse
Undergrowth		Dense	Dense	Dense	Relatively sparse
Herbaceous ground cover		Continuous, thick	Discontinuous	Discontinuous, patchy	Patchy
Lianes, climbers		Locally abundant	Locally abundant	Locally abundant	Locally abundant
Ferns, bryophytes		Dense	Abundant	Common	Ferns common Bryophytes sparse

continuous forest and other areas are degraded through cutting of timber for various purposes

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Landform	Ridge side	Ridge side	Ridge crest & side	Ridge side
Aspect	NE	NE	N - NE	SE - S
Slope	Medium	Steep to medium	Steep to medium	Steep to medium
Drainage	4	4	4	4
Soil	Deep, dark brown loam leaf litter to 8cm, soil to 70cm, brown clay below.	Dark brown loam, surface litter 5-8cm soil to 75cm, brown clayey loam below.	Dark brown loam litter to 10cm, soil to 25cm, mixed brown clay below.	Dark brown clayey loam, litter patchy to 5cm, brown clay 30cm.
pH	5.0 - 6.0 at base	6.0 - 6.5	5.0 - 6.5	6.0
Disturbance	Not obvious Fallen logs plentiful, some cut stumps.	Local disturbance, cut stumps, trampling, some pig rooting.	General disturbance, cutting, trampling.	General disturbance cutting, trampling pig rooting.
Canopy & subcanopy	Uneven, continuous, dense	Even, continuous, dense.	Broken, sparse.	Broken, sparse.
Canopy height	15-17m - 18m	20 - 21m	22 - 24m	22 - 24 m
Understorey	Dense	Relatively sparse	Dense	Relatively sparse
Undergrowth	Dense	Dense	Dense	Relatively sparse
Herbaceous ground cover	Continuous, thick	Discontinuous	Discontinuous, patchy	Patchy
Lianes, climbers	Locally abundant	Locally abundant	Locally abundant	Locally abundant
Ferns, bryophytes	Dense	Abundant	Common	Ferns common Bryophytes sparse

PLATE 9A

Mixed forest at 3345 m (11,000 ft) altitude on Mt Hagen. Emergent trees are *Quintinia* sp. (6360). The other main species are *Vaccinium apiculatum*, *Syzygium adelphicum* and *Cyathea* spp. Subalpine tussock grassland is in the background.

PLATE 9B

Pandanus sp. in mixed forest at 2900 m on Mt Hagen. Other species with it are *Saurauia* sp., *Drimys* sp. and the climbing bamboo, *Nastus productus*.

sp.3 (6262), Rapanea sp.2 (6265), Syzygium sp.2 (6285), Eurya oxysepala, Drimys sp.4 (6392), Podocarpus neriifolius, Drimys sp.3 (6374), Saurauia sp.1 (6381), Prunus pullei, Rapanea sp.3 (6354) and ?Ardisia sp. (6441).

Figure 4.3 gives the diameter size-class distribution of a number of these taxa. Regeneration appears to be occurring fairly evenly in the main canopy species but some of the minor taxa show disrupted sequences. Whether this is due to biotic or natural causes will be considered after the other mixed forest sites have been described.

The canopy taxa Polyosma sp. (6255), ?Ardisia sp. (6441), Eurya oxysepala and Drimys sp.3 (6374) dominate the understorey with densities of between 230 and 365 individuals per hectare, and many other canopy species are important also. Schefflera sp. (6352), Drimys sp.2 (6270), Pittosporum pullifolium and Sericolea sp. (6431) are common understorey taxa with densities of over 40 individuals per hectare, while Timonius belensis, Polyosma sp.1 (6424), Piper sp.5 (6415) and Evodia sp.5 (6258) are recorded in lower numbers.

Canopy taxa dominate the woody undergrowth also with Polyosma sp. (6255), ?Ardisia sp. (6441), Rapanea sp.3 (6354), Syzygium adelphicum and Drimys sp.3 (6374) recording over 1100 individuals per hectare. Schefflera sp. (6352), and Drimys sp.2 (6270) record similar densities as understorey taxa. Undergrowth taxa include Symplocos sp.3 (6420), Olearia sp. 1/3 (6351), Harmsiopanax sp. (6370), Ilex sp.1 (6320), ?Senecio sp. (6357), and Schuurmansia henningsii. The small divaricating shrubs Trochocarpa papuana, Coprosma papuensis and Amaracarpus sp.3 (6377) are common.

Herbaceous species are well represented. Dimorphanthera denticulifera, Diplocosia sp. (6268), Piper sp.1 (6408), Loranthaceae gen.4 (6264) and Rubus moluccanus are important lianes and climbers, Hebe ?albiflora, Elatostema sp.1 (6375) and Elatostema sp.3 (6423), Potentilla sp.1 (6393) and Blumea arnakido are common forbs. Members of the Zingiberaceae, in particular Alpinia sp.3 (6368) and 'Pugar' (5975) form dense patches. Tree ferns, Cyatheaceae, are abundant together with ground ferns such as Dicranopteris linearis and Gleichenia hooglandii. Lycopodium spp. are also abundant.

Site 2 : Mixed forest at 3040m (10,000 ft) on Mt Hagen

At site 2 the canopy is higher and more even at 20-21m, tree trunks are taller and straighter and the forest more open. Some stratification is indicated in Figure 4.3 but was not obvious in the field. However, while the canopy and undergrowth levels are densely stocked the understorey is relatively sparse. Epiphytic mosses, liverworts and ferns, while still abundant, do not grow in the same profusion as at site 1. Tree ferns and ground ferns are plentiful, lianes, climbers and epiphytes locally abundant. Canopy gaps are infrequent but fallen logs are common on the forest floor. In addition cut trunks or stumps of Elaeocarpus crenulatus, Syzygium adelphicum, Vaccinium apiculatum, Cryptocarya sp.1 (6426) and Polyosma sp. (6255) are noted. Some local cutting and trampling of undergrowth is apparent and herbaceous ground cover is patchy. Areas of pig rooting are recorded in four plots.

Canopy composition changes considerably at site 2 with members of the Aquifoliaceae, Myrsinaceae, Rosaceae, Theaceae, Saurauiaceae and Podocarpaceae absent. Quintinia sp. (6360) shares dominance with Schizomeria serrata and Symplocos sp.3 (6420) with densities of 70-75 trees per hectare and basal area contents of 16287-23309 sq.cm per 0.2 hectare. Other canopy species recorded at site 1 remain relatively important or share minor positions with Elaeocarpus sp.1 (6247), Omalanthus sp.1 (6251), Cryptocarya sp.1 (6246), Lauraceae gen.1 (6246), Astronia sp.1 (6244), Kibara sp.3 (6421), Schuurmansia henningsii and Timonius belensis.

Diameter size-classes are shown in Figure 4.3 for the canopy species. Many appear to be regenerating evenly but some, such as Elaeocarpus crenulatus, Vaccinium apiculatum, Syzygium adelphicum, Polyosma sp. (6255), Cryptocarya sp.1 (6426), Drimys sp.3 (6374) and Drimys sp.4 (6392) show interrupted sequences.

Canopy taxa once again numerically dominate the understorey, in particular Schuurmansia henningsii, Symplocos sp.3 (6420), Drimys sp.3 (6374), Acronychia sp.2 (6430), Kibara sp.3 (6421) Astronia sp.1 (6244) and Quintinia sp. (6360) all with 40 or more individuals per hectare. Elaeocarpus ?sayeri, Polyosma sp.1 (6424), Streblus urophyllus and Evodia sp.5 (6258) are important understorey taxa with similar densities. Claoxylon nubicola, Harmsiopanax sp. (6370) and Olearia sp.1/3 (6351) are also recorded in lower densities.

Canopy taxa dominate the woody undergrowth; Cryptocarya sp.1 (6426) and Quintinia sp. (6360) have 2350 and 1955 individuals per hectare, while Vaccinium apiculatum, Polyosma sp. (6255), Kibara sp.3 (6421), Syzygium adelphicum, Schuurmansia henningsii and Symplocos sp.3 (6420) all record over 100 individuals per hectare. Many other canopy and understorey taxa show lower densities. Undergrowth taxa not recorded at site 1 include Cyrtandra sp.1 (6253), Phaleria ?sogerensis, Macaranga ?warburgiana, Kibara sp.2 (6245), Evodia sp.2 (6432) and the shrub Amaracarpus sp.1 (6428). Trochocarpa papuana, Coprosma papuensis and Ilex sp.1 (6320) are absent.

The herbaceous complement is similar to that at Site 1. In addition Palmeria sp.3 (6271) is important as a liane, Nastus productus as the common climbing bamboo and Cypholophus sp. (6422) as a ground herb. Two members of Cyatheaceae were recorded as abundant.

Site 3 : Mixed forest at 2900m - 2740m (9500-9000 ft) on Mt Hagen (Plate 9 B)

The forest canopy at Site 3 is broken and sparse at 22-24m height; canopy and subcanopy trees are widely spaced and only a few individuals measured over 48cm diameter at breast height. A tall Pandanus species appears at 2900m and gives a characteristic appearance to the forest. Layering of the forest is apparent (Figure 4.3) with a dense understorey developed at 12-15m height. Undergrowth is relatively dense also and lianes, climbers and epiphytes locally abundant. Tree ferns and ground ferns are common. Disturbance of the forest is fairly general, a number of trees having been cut (Prunus costata, Syzygium adelphicum and Cryptocarya sp.1) and the undergrowth trampled near Pandanus trees. The herbaceous ground cover is patchy.

Timonius belensis dominates the canopy with an estimated density of 60 trees per hectare and a basal area content of 17603 sq.cm per 0.2 hectare. Other common canopy species are Schizomeria serrata, Elaeocarpus crenulatus, Sericolea sp. (6431), Quintinia sp. (6360), Syzygium adelphicum and Schuurmansia henningsii. Minor species, not recorded at Sites 1 and 2 are Endiandra sp.2 (6333), Prunus costata, Turpinea pentandra and Pandanus sp.1.

Diameter size-class distributions (Figure 4.3) suggest that relatively regular regeneration is occurring in Timonius belensis, Quintinia sp. (6360), Schuurmansia henningsii, Sericolea sp. (6431) and Turpinea pentandra but in all other taxa it has been interrupted.

The understorey is dominated here by Phyllanthus nervosus and Polyosma sp.1 (6424) with 270 and 245 individuals per hectare. Other important understorey taxa are Elaeocarpus ?sayeri, Streblus urophyllus, Drimys sp.2 (6270), Astronia sp.1 (6244) and Drimys sp.3 (6374). Canopy taxa of equal density are Sericolea sp. (6431), Quintinia sp. (6360), Cryptocarya sp.1 (6426), Schuurmansia henningsii, Timonius belensis and Turpinea pentandra. Taxa not recorded in the understorey at Sites 1 and 2 include Sphenostemon papuanum, Ascarina philippinensis, Spiraeopsis brassii, Cinnamomum sp.2 (6279) and Casearia sp. (6311).

Canopy and understorey saplings and seedlings dominate the undergrowth. Cryptocarya sp.1 (6426), Syzygium sp.2 (6285), Elaeocarpus ?sayeri, Phyllanthus nervosus and Streblus urophyllus all record densities of between 1100 and 1630 individuals per hectare and many others are present in lower densities. Undergrowth taxa which are equally well represented are Cyrtandra sp.1 (6253), Amaracarpus sp.1 (6428) and Amaracarpus sp.3 (6377). Others, present in lower numbers include Macaranga ?warburgiana, Elaeocarpus poculiferus, and Schefflera sp. (6352).

Most of the herbaceous taxa recorded at Sites 1 and 2 remain important at Site 3. In addition Solanum ?belense, Freycinetia spp. and 'Tropena' are common lianes and climbers, Cyrtandra sp.3 (6269), Gunnera macrophylla, Rubus rosifolius, Elatostema sp.2 (6312) and Pilea sp.1 (6296) as forbs and fleshy ground herbs. Members of the Zingiberaceae are particularly abundant, forming large dense patches in many plots.

Site 4 : Mixed forest and regrowth vegetation at 2710m (8900 ft) on Mt Hagen

Site 4 includes an area of mixed forest from which most of the large trees have recently been removed for commercial timber. The canopy, understorey and undergrowth levels are ill-defined (Figure 4.3) and density varies from plot to plot. In general the canopy is uneven and fairly open at 22-24m height; canopy trees are widely spaced and few record over 48cm diameter. Climbers and lianes are locally common, tree ferns abundant. Tree trunks and limbs litter parts of the site and climbers and scramblers are tangled over them. The original ground cover is disturbed in most places and few ground ferns and mosses are present. Large areas are covered, however, with wild gingers (Zingiberaceae) or with the fleshy scramblers and ground herbs of the family Urticaceae.

Turpinea pentandra and Schizomeria serrata are the dominant canopy species with an estimated 60 and 50 trees per hectare respectively and basal area contents of 9505 and 6609 sq.cm per 0.1 hectare. Many other mixed forest canopy taxa are present in low numbers, together with Olearia sp. 1/3 (6351), Omalanthus nervosus and Nothofagus sp.2 (6294), species not recorded from the canopy at other mixed forest sites..

The diameter size-class distributions plotted in Figure 4.3 show that interrupted sequences are present in all taxa except Olearia sp.1/3 (6351). Little or no regeneration appears to be occurring at present in Elaeocarpus sp.1 (6247), Symplocos sp.3 (6420), Nothofagus sp.2 (6294), Endiandra sp.2 (6333), Pandanus sp.1 or Schuurmansia henningsii. The understorey is dominated by the canopy taxa Olearia sp. 1/3 (6351), and Drimys sp.3 (6374) and others such as Turpinea pentandra, Cryptocarya sp.1 (6426), Lauraceae gen.1 (6246) and Astronia sp.1 (6244) are also important.

Table 4.12 Species composition, species density and plot frequency in the canopy of Mixed forests on Mt Hagen

Sits No.			1					2					3					4				
Altitude (m)			3345					3040					2900 - 2740					2710				
			Density in			Basal	Plot	Density in			Basal	Plot	Density in			Basal	Plot	Density in			Basal	Plot
Canopy species			C	U's	U'g	Area	Freq.	C	U's	U'g	Area	Freq.	C	U's	U'g	Area	Freq.	C	U's	U'g	Area	Freq.
6262	Aquifoliaceae	Ilex sp. 3	20	130	645	7917	20/20															
6351	Asteraceae	Olearia sp. 1 & sp. 3			375		13/20		10	30		4/20		10	95		4/20	10	110	270	2379	7/10
6248	Cunoniaceae	Schizomeria serrata						75	35	995	23309	20/20	25	20	485	6790	16/20	50	30	230	9505	6/10
6410	Elaeocarpaceae	Elaeocarpus crenulatus	70	165	655	22306	20/20	35	35	335	10503	13/20	25	25	510	7210	18/20		10	120		3/10
6247	"	Elaeocarpus sp. 1						15	25	675	4835	18/20	5		240	1153	14/20	10		160	2063	3/10
6431	"	Sericolea sp.		65	515	2486	19/20	10	15	845	3702	18/20	35	45	435	6499	17/20		30	130		4/10
6356	Ericaceae	Vaccinium apiculatum	50	25	250	14272	15/20	30	30	1150	12926	20/20										
6255	Escalloniaceae	Polyosma sp	50	365	1180	17299	20/20	10	20	1045	3881	15/20		10	405		6/20					
6360	"	Quintinia sp.	110	75	745	22902	19/20	70	40	1955	16287	19/20	35	40	760	10673	19/20			70		1/10
6334	Euphorbiaceae	Omalanthus nervosus																10	20	40	1237	3/10
6251	"	Omalanthus sp. 1						10	20	30	2028	9/20			55		3/20					
6294	Fagaceae	Nothofagus sp. 2																10		10	1958	2/10
6311	Flacourtiaceae	Casearia sp.												10	360		14/20	10	10	30	737	2/10
6426	Lauraceae	Cryptocarya sp. 1						30	25	2350	9955	20/20	5	45	1630	5268	20/20	10	60	550	2918	7/10
6333	"	Endiandra sp. 2											15		350	2995	10/20	10		110	2028	4/10
6246	"	gen.1						5	30	50	1091	6/20			55		4/20	10	40	220	2727	6/10
6244	Melastomataceae	Astronia sp. 1						10	50	400	3074	10/20		70	535		12/20	20	40	300	5471	5/10
6421	Monimiaceae	Kibara sp. 3						5	70	1025	4240	20/20		10	940		20/20			380		4/10
6441	Myrsinaceae	?Ardisia sp.	5	310	1270	8915	19/20												10	200		3/10
6265	"	Rapanea sp. 2	10	55	640	4011	16/20															
6354	"	Rapanea sp. 3	5	130	1150	4877	20/20												20	490		7/10
6254	Myrtaceae	Syzygium adelphicum	45	45	1205	11371	20/20	10	5	1120	4505	20/20	20		410	5300	13/20					
6285	"	Syzygium sp. 2	15	5	615	3103	16/20						15	15	1390	4850	20/20			90		2/10
6380	Ochnaceae	Schuurmansia henningsii			5		1/20	30	115	1200	8417	20/20	25	80	720	8661	19/20	20		180	1220	3/10
6397	Pittosporaceae	Pittosporum pullifolium		45	240	1425	14/20	5		100	2091	4/20			15		2/20					
6284	Rosaceae	Prunus costata											5	5	215	909	11/20			110		4/10
6272	"	Prunus pullei	5	5	95	1119	6/20						5	5	900		18/20			70		3/10
6249	Rubiaceae	Timonius belensis		5	65		1/20	5	5	715	1879	19/20	60	40	825	17603	20/20		20	410		6/10
6430	Rutaceae	Acronychia sp. 2						10	45	740	3651	19/20		20	690		20/20			100		1/10
6381	Saurauiaceae	Saurauia sp. 1	5	105	690	4684	20/20			205		9/20		10	30		5/20		70	800		6/10
6277	Staphyleaceae	Turpinia pentandra											5	55	440	3238	14/20	60	50	460	6609	8/10
6420	Symplocaceae	Symplocos sp. 3			1075		20/20	70	95	1060	16295	19/20	5	25	315	1509	20/20	10	10	120	1070	3/10
6414	Theaceae	Eurya oxysepala	10	230	625	8015	20/20			85		6/20		10	95		6/20		10	40		3/10
6374	Winteraceae	Drimys sp. 3	5	235	1190	7348	20/20	15	45	385	5753	18/20		120	710		19/20	30	120	620	3725	10/10
6392	"	Drimys sp. 4	10	55	820	3029	20/20	15		465	5370	18/20		15	345		8/20					
	Pandanaceae	Pandanus sp. 1 ('Um')											5	15	20	1244	3/20	10		70	866	2/10
6259	Podocarpaceae	Podocarpus neriifolius	20	20	365	6723	18/20			35		5/20			25		3/20					

1 * Density i.e. number of individuals per hectare.

2 * Basal area in sq. cm per 0.2 hectare.

Table 4.13 Species composition, species density and plot frequency in the understorey of Mixed forests on Mt Hagen

Site No.			1			2			3			4		
Altitude (m)			3345			3040			2900 - 2740			2710		
			Density in		Plot	Density in		Plot	Density in		Plot	Density in		Plot
Understorey species			U's	U'g	Freq.	U's	U'g	Freq.	U's	U'g	Freq.	U's	U'g	Freq.
6280	Aquifoliaceae	Sphenostemon papuanum							50	610	14/20	20	190	4/10
6370	Araliaceae	Harmsiopanax sp.		145	11/20	5	135	7/20		5	3/20	30	260	5/10
6352	"	Schefflera sp.	140	1195	20/20		475	18/20		170	11/20		240	5/10
6281	Chloranthaceae	Ascarina philippinensis							5	60	5/20		20	2/10
6283	Cunoniaceae	Spiraeopsis brassii							5	90	7/20			
6348	Elaeocarpaceae	Elaeocarpus ?sayeri				40	1040	19/20	95	1140	20/20	10	350	4/10
6424	Escalloniaceae	Polyosma sp. 1	15	480	19/20	55	660	20/20	245	945	20/20	30	440	10/10
6429	Euphorbiaceae	Claoxylon nubicola				20	205	9/20						
6282	"	Phyllanthus nervosus							270	1295	20/20			
6253	Gesneriaceae	Cyrtandra sp. 1					265	5/20		1460	18/20	20	1510	9/10
6279	Lauraceae	Cinnamomum sp. 2							15	190	9/20			
6427	Moraceae	Streblus urophyllus				55	895	19/20	45	1180	20/20	10	170	6/10
6415	Piperaceae	Piper sp. 5	5	25	3/20									
6258	Rutaceae	Evodia sp. 5	25	295	16/20	45	335	16/20	15	375	18/20	50	250	7/10
6256	Saurauiaceae	Saurauia sp. 4										40	400	5/10
6433	Thymelaeaceae	Phaleria ?sogerensis					510	17/20	5	200	10/20		70	3/10
6372	Urticaceae	Debregeasia sp. 1										20	40	2/10
6270	Winteraceae	Drimys sp. 2	85	1860	20/20		715	15/20	60	715	18/20	50	590	7/10

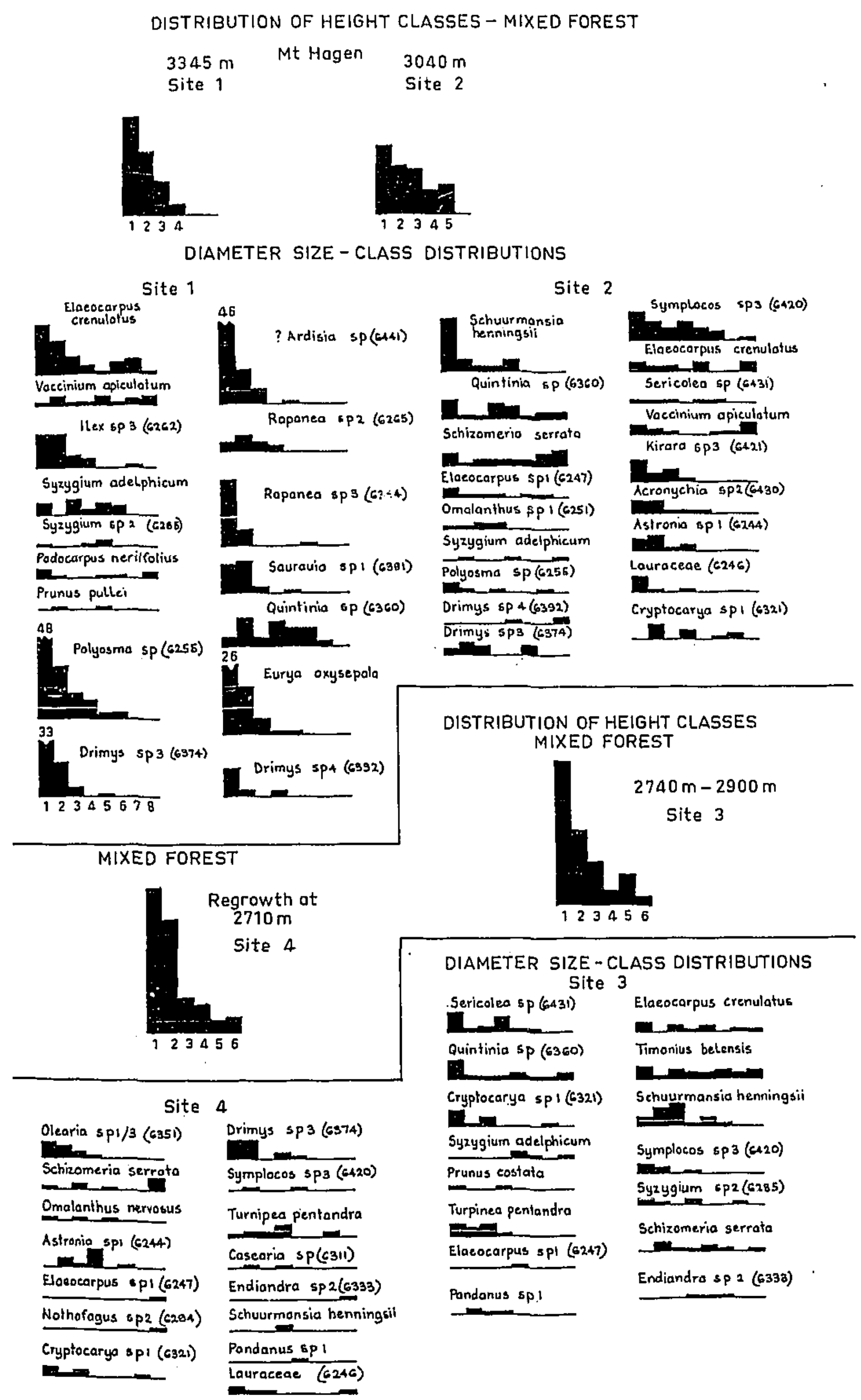
Table 4.14 Species composition, species density and plot frequency in the undergrowth of Mixed forests on Mt Hagen.

Site No.			1		2		3		4	
Altitude (m)			3345		3040		2800		2710	
Undergrowth species			Density U'g	Plot Freq.	Density U'g	Plot Freq.	Density U'g	Plot Freq.	Density U'g	Plot Freq.
6320	Aquifoliaceae	Ilex sp. 1	150	3/20						
6357	Asteraceae	?Senecio sp.	5	4/20	10	2/20				
6278	Cunoniaceae	Weinmannia sp.							140	2/10
6348	Elaeocarpaceae	Elaeocarpus poculiferus					960	17/20	2220	10/10
6267	Epacridaceae	Trochocarpa papuana	70	6/20						
5530	Euphorbiaceae	Macaranga ?warburgiana			15	2/20	75	5/20	80	2/10
6245	Monimiaceae	Kibara sp. 2			65	2/20			670	9/10
6293	Myrsinaceae	Maesa sp.							10	1/10
6428	Rubiaceae	Amaracarpus sp. 1			3430	18/20	1900	19/20	1030	8/10
6377	"	Amaracarpus sp. 3	3280	17/20	3180	19/20	3235	20/20	2930	9/10
6365	"	Coprosma papuensis	1220	12/20						
6432	Rutaceae	Evodia sp. 2			185	3/20				

Table 4.15 Species composition, species density and plot frequency of herbaceous taxa in Mixed forests on Mt Hagen.

Site No. / Altitude (m)	Herbaceous taxa		1 (3345) Density	1 (3345) Plot Freq.	2 (3040) Density	2 (3040) Plot Freq	3 (2800) Density	3 (2800) Plot Freq.	4 (2710) Density	4 (2710) Plot Freq.
	Cucurbitaceae	'Kobug'							430	3/10
6376	Ericaceae	Dimorphanthera denticulifera	1475	20/20	600	20/20	1860	20/20	1240	10/10
6268	"	Diplycosia sp.	915	14/20						
6264	Loranthaceae	gen.4	165	10/20						
6271	Monimiaceae	Palmeria sp. 3			1515	19/20	2150	20/20	2550	10/10
6408	Piperaceae	Piper sp. 1	3045	20/20	935	19/20	2105	20/20	3660	10/10
5573	Rosaceae	Rubus moluccanus	2180	20/20	1145	19/20	1610	19/20	296	10/10
6287	Rubiaceae	Psychotria sp.							400	1/10
6291	Solanaceae	Solanum ?belense					980	14/20	2250	6/10
	?Vitaceae	'Tropena'					445	13/20	730	6/10
	Pandanaceae	Freycinetia spp.					1970	14/20	100	1/10
6261	Poaceae	Nastus productus			2770	19/20	3320	20/20	1620	5/10
6082	Asteraceae	Blumea arnakidophora	50	3/20						
6269	Gesneriaceae	Cyrtandra sp. 3					670	13/20	2430	10/10
6379	Haloragaceae	Gunnera macrophylla					20	1/20		
6393	Rosaceae	Potentilla sp. 1	700	15/20	965	11/20	120	3/20		
5746	"	Rubus rosifolius					10	1/20		
6366	Scrophulariaceae	Hebe ?albiflora	1680	19/20						
6422	Urticaceae	Cypholophus sp.			4735	20/20	2790	19/20	2620	7/10
6375	"	Elatostema sp. 1	1945	16/20	4000	20/20	3460	19/20	4000	10/10
6312	"	Elatostema sp. 2					1330	9/20	2000	5/10
6423	"	Elatostema sp. 3	960	9/20	3700	20/20	2460	15/20	4000	10/10
6296	"	Pilea sp. 1					1200	6/20		
	Cyperaceae	Carex spp.					90	2/20		
6394	Poaceae	Deyeuxia brassii	1275	17/20						
6368	Zingiberaceae	Alpinia sp. 3	1170	16/20	3195	20/20	4000	20/20	1610	7/10
5975	"	gen.1	3065	20/20	1390	20/20	1505	20/20	450	8/10
6144	"	gen.2					775	14/20	590	8/10
6145	"	gen.3					435	14/20	550	10/10
	Cyatheaceae	gen.1	365	13/20	595	16/20	365	11/20		
	"	gen.2	1205	18/20	2170	20/20	1025	19/20	640	8/10
	"	gen.3			1415	18/20	1830	19/20	590	8/10
	"	gen.4			115	9/20			270	3/10
6026	Gleicheniaceae	Dicranopteris linearis	2290	17/20			1800	14/20	1900	6/10
6029	"	Gleichenia hooglandii	900	13/20						
6086	Marattiaceae						310	15/20	390	8/10
	Lycopodiaceae	Lycopodium spp.	1640	14/20	2165	14/20	470	7/20		

Figure 4.3 Stratification (as indicated by height-class distributions) and diameter size-class distributions of mixed forest species.



The main understorey taxa present are Saurauia sp.1 (6381), Evodia sp.5 (6258), Saurauia sp.4 (6256), and Drimys sp.2 (6270). Many others recorded previously are also common.

The small shrubs, Amaracarpus sp.1 (6428) and Amaracarpus sp.3 (6377) and Elaeocarpus poculiferus dominate the undergrowth with estimated densities of 1030 to 2930 individuals per hectare. Schefflera sp. (6352), Phaleria ?sogerensis, Weinmannia sp. (6278), Kibara sp.2 (6245) and Maesa sp. (6293) are recorded in lower numbers. Many seedlings and saplings of canopy and understorey taxa are present also.

The herbaceous species present are essentially the same as at the other mixed forest sites. Piper sp.1 (6408), Palmeria sp.3 (6271) and Solanum ?belense are important lianes, Nastus productus, the climbing bamboo, is plentiful and the Elatostema species and Zingiberaceae abundant.

SUBALPINE FOREST

The small patches of forest present within tussock grassland above 3345m (11000 ft) on Mt Hagen are distinguished as subalpine forest. They occupy an estimated 0.1 sq.km (0.04 sq.mi.) within the study region and grow mainly in sheltered aspects of the rugged terrain of the Mt Hagen summit area. The canopy is at 5-6m height with Pittosporum pullifolium and Vaccinium apiculatum dominant. Other associated taxa include Drimys, Olearia, Styphelia, Rapanea and Symplocos.

DISCUSSION

The different forest types of the Mt Hagen area have been distinguished on the basis of species composition and dominance. Those studied in detail were as follows:

1. Mixed forest, dominated by Quintinia, Elaeocarpus, Schizomeria, Polyosma, Syzygium and Symplocos species, and covering an estimated 7.8 sq.km between 2585m and 3345m altitude.
2. Beech forest, dominated by Nothofagus species and covering an estimated 19.9 sq.km between 2130m and 2745m altitude.
3. Oak forest, dominated by Castanopsis and Schizomeria species and covering an estimated 7.3 sq.km between 1820m and 2130m altitude.

The subalpine forest, occurring within sheltered areas of the summit plateau was not studied in detail. From aerial photographs it appeared to cover about 0.1 sq.km at altitudes above 3345m.

The sites described may be considered as fairly representative of the forests of the Mt Hagen region as a whole, although the aerial photographs do suggest considerable mixing of the forest types in some areas.

Species distribution cannot be correlated directly with environmental parameters as the relevant data are lacking. However, a number of factors are more or less constant over the whole area. Thus the basement rock over much of the region is the same and soils are of the humic grey brown clay type, slightly acid and usually well drained. Similar variations in landform, aspect and slope occur throughout the region; they do not appear to play a prominent part in determining vegetation distribution. Variations in rainfall are slight and all areas receive adequate moisture.

The main factor that varies in the region is altitude. Forest covered areas range from 1820m to more than 3345m and species distribution appears to be correlated with this, at least in part. Since temperature decreases at a rate of 0.6°C per 100m increasing elevation this is possibly the altitudinally correlated factor of physiological significance although the high incidence of cloud at high altitudes, reducing insolation may also be important.

Biotic disturbance was noted at many sites and its intensity seems to affect the species composition of the forests.

Altitudinal Trends

Table 4.16 lists the canopy species, their distribution and calculated density (number of individuals per 0.1 hectare) in the least disturbed sites of each forest type. From this it can be seen that some species, such as *Ilex* sp.3 (6262), *Vaccinium apiculatum*, *Polyosma* sp. (6255), *Podocarpus neriifolius* and *Drimys* sp.3 (6374) seem restricted to high altitudes whilst others, such as *Nothofagus* sp.2 (6294), *Prunus costata*, *Pandanus* sp.1, *Weinmannia* sp. (6278) and *Castanopsis acuminatissima* grow only at lower altitudes. Many others show wide

Table 4.16 Canopy species distribution and density in Mixed forest, Beech forest and Oak forest.

Site No.	1	2	5	6	9	10
Altitude (m)	3345	3040	2745	2585	2000	2200
Species						
Ilex sp. 3 (6262)	2					
Sphenostemon papuanum						2
Schizomeria serrata		8		1	6	8
Weinmannia sp. (6278)			1	1		
Elaeocarpus crenulatus	7	4	1	2		
Elaeocarpus sayeri			1	2		
Elaeocarpus sp. 1 (6247)		2		1		
Sericolea sp. (6431)		1				
Vaccinium apiculatum	5	3				
Polyosma sp. (6255)	5	1				
Quintinia sp. (6360)	11	7	1			
Omalanthus sp. 1 (6251)		1				
Castanopsis acuminatissima					42	20
Nothofagus sp. 1 (6485)					4	2
Nothofagus sp.2 (6294)			19	6		
Cryptocarya sp. 1 (6426)		3	1	1		2
Cryptocarya sp.4 (6459)					4	
Lauraceae gen. 1 (6246)		1				
Kibara sp. 3 (6421)		1				
?Ardisia sp. (6441)	1		1			
Rapanea sp. 2 (6265)	1					
Rapanea sp. 3 (6354)	1					
Syzygium adelphicum	5	1	1			
Syzygium sp. 2 (6285)	2		2			2
Schuurmansia henningsii		3		1		
Pittosporum pullifolium		1				
Prunus costata			1	2		
Prunus pullei	1				2	
Timonius belensis		1				2
Acronychia sp. 2 (6430)		1				
Saurauia sp. 1 (6381)	1		1			
Symplocos sp. 3 (6420)		7				
Eurya oxysepala	1					
Drimys sp. 3 (6374)	1	2				
Drimys sp. 4 (6392)	1	2	1			
Pandanus sp. 2			2	2		
Podocarpus neriifolius	2					

altitudinal tolerance, for example, Schizomeria serrata, Cryptocarya sp.1 (6426), Syzygium sp.2 (6285), Prunus pullei and Timonius belensis.

Diameter size-class distributions, if accepted as records of the course of regeneration, may also be affected by altitude. Figures 4.4 and 4.5 suggest that some species are regenerating better at the upper levels of their distribution (for example, Elaeocarpus crenulatus, Quintinia sp. (6360), Eurya oxysepala, Schuurmansia henningsii and Drimys sp.4 (6392)), while others (Cryptocarya sp.1 (6426), Nothofagus sp.2 (6294), Pandanus sp.1 and Timonius belensis) regenerate more actively and regularly at their lower level sites. The pattern of Nothofagus sp.2 (6294) suggests that it is not regenerating as well today at that altitude as it was in the past. Schizomeria serrata shows a similar trend at 3040m and Castanopsis acuminatissima in the Wurup-Mt Oga forests. These data may indicate instability in the forests today. But there are many other possible interpretations of these data; indeed they may not reflect regeneration very accurately as many of the species are known to be selectively cut for timber and household purposes. The facts that, no consistent pattern is shown for all taxa and that disruption of size-class distributions for individual taxa varies from site to site (even at similar altitudes) suggests the overriding importance of biotic interference.

Human disturbance

Within each forest type the plots can be arranged in a sequence of increasing disturbance and clearance. Thus in the Mixed forest sites 1 and 2 are largely undisturbed, site 3 shows general disturbance and site 4 regrowth after clearance in parts. In the Beech forest areas, site 5 is relatively undisturbed, site 6 shows some disturbance, sites 7 and 8 regrowth after at least partial clearance. The Oak forest is disturbed throughout its range; site 9 is the least disturbed, sites 10 and 11 show increased disturbance and site 12 regrowth after clearance.

Table 4.17 gives the species numbers and density within each stratum of the forest for each site. From

Figure 4.4 Diameter size-class distributions of individual species from various Mt Hagen forest sites.

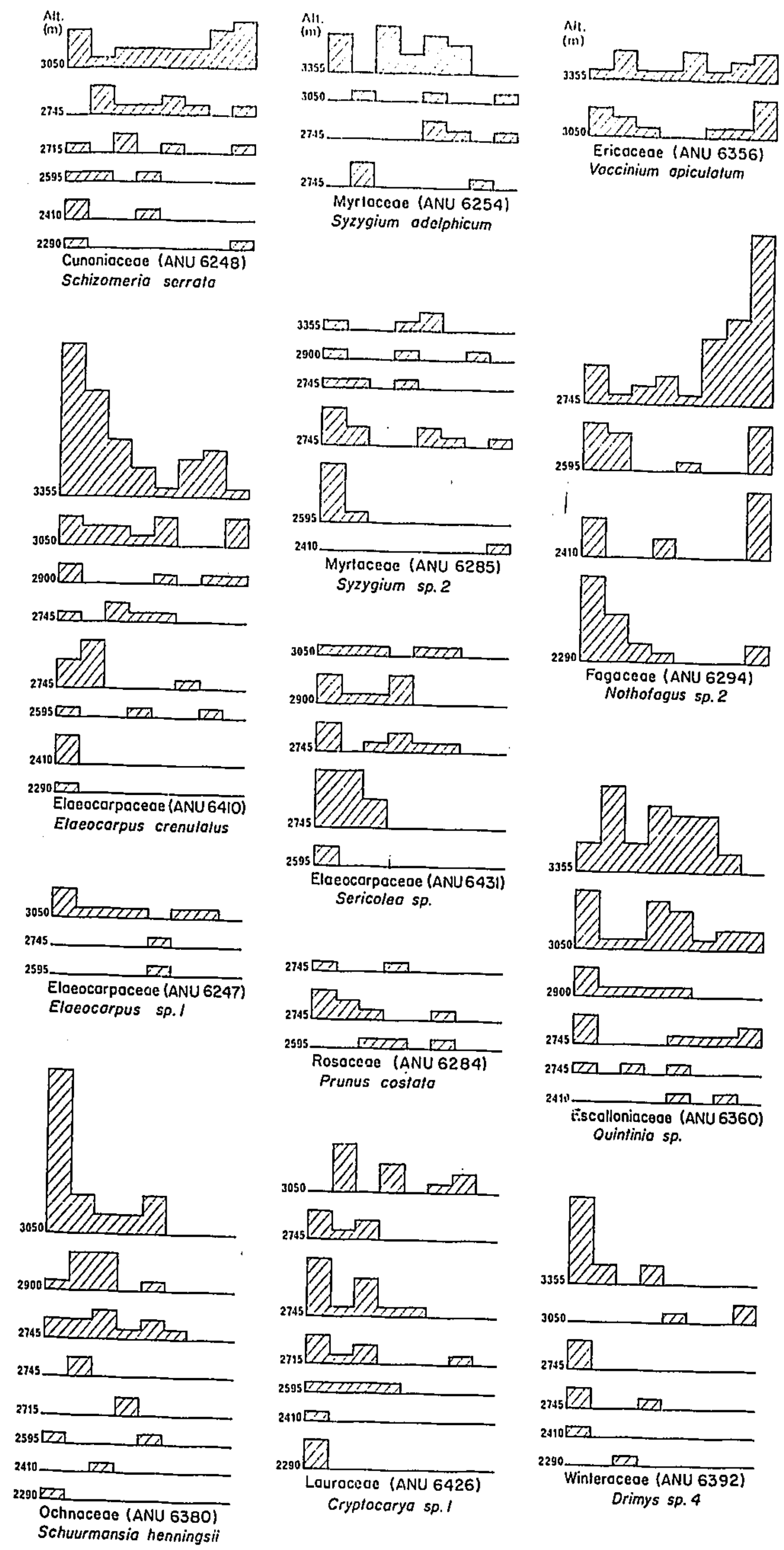
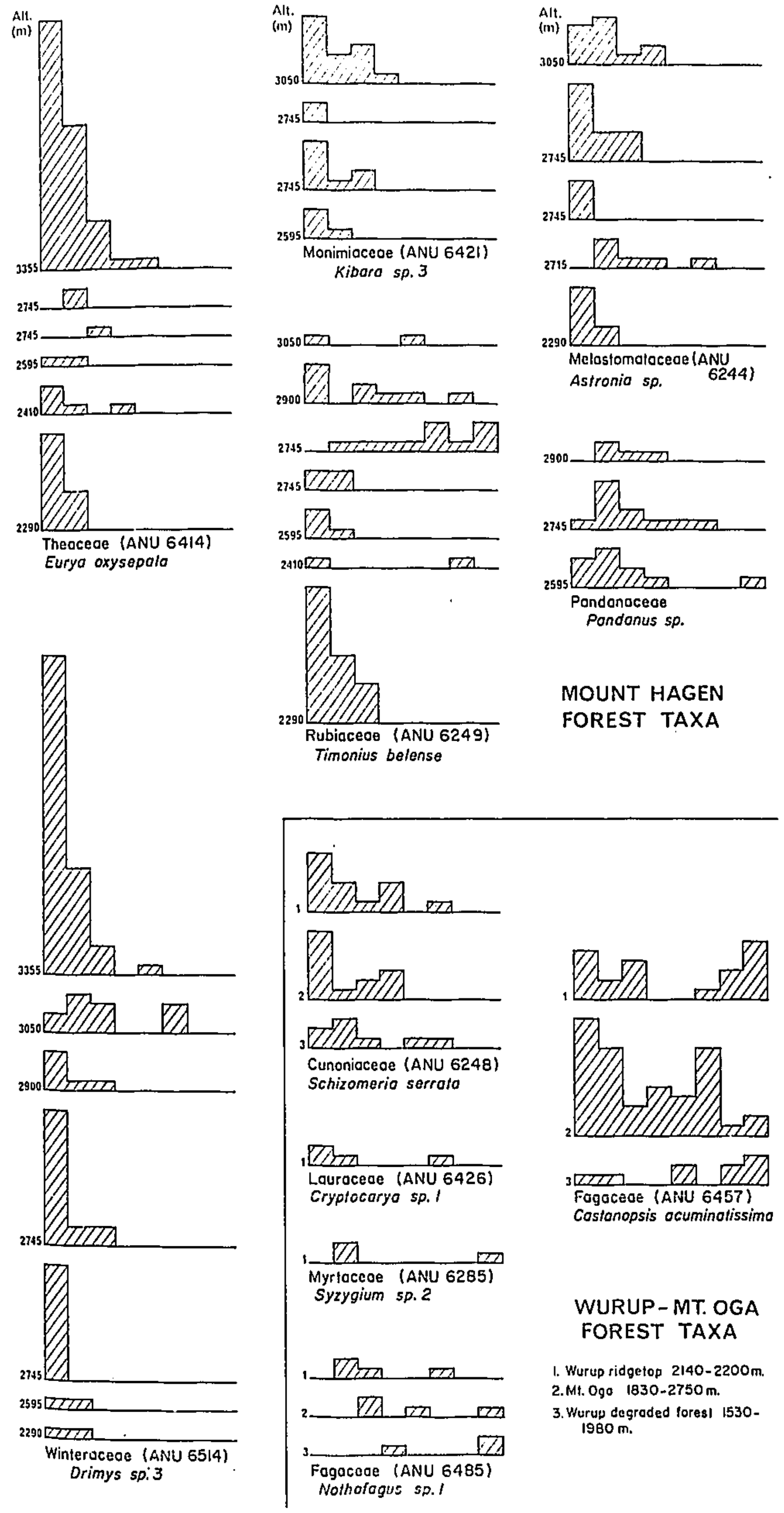


Figure 4.5 Diameter size-class distributions of individual species from various Mount Hagen and Wurup-Mt Oga forest sites.



this and from comparison of species composition within sites from each forest type (Tables 4.2-4.5, 4.7-4.10, 4.12-4.15) certain general features associated with disturbance may be detected. With increased disturbance the composition of the canopy may not change but the density of the canopy is reduced and the canopy species no longer dominate the understorey and undergrowth. The number and density of understorey species increases and usually the total number of woody species present as well. Herbaceous species composition also changes.

It is likely that in most of the disturbed plots some of the large canopy trees have been cut down and the resultant gaps filled with fast-growing, light-demanding species, mixed with seedlings and saplings of the canopy trees. At the same time many of the forest lianes and climbers may disappear or are greatly reduced in numbers. Ruderal forbs appear in their place.

In other cases, where an area has been largely cleared for gardening purposes and then left to regenerate, as at site 12, the following features are apparent:

a) the forest canopy species are absent,
b) the canopy is reduced in height and in density,
c) the density of understorey taxa is increased although the number of species present there may be reduced,
d) the number and density of undergrowth species is reduced,
e) the total number of woody species is greatly reduced,
f) the herbaceous composition has changed radically.

In fact a few, fast-growing, light-demanding species dominate the present structure and composition of the forest.

The data are not detailed enough to allow successions to be established with any degree of certainty. However, certain species which are always associated with regrowth situations can be distinguished.

Indicator Species

Comparison of species composition at different sites permits the recognition of 'indicator species' for each forest type which should be useful in

Table 4.17 Number of woody species and density within each forest stratum.

Site No.	1	2	3	4	5	6	7	8	9	10	11	12
Forest type	MF	MF	MF	MFR	BF	BF	BFD	BFR	OF	OF	OFD	OFR
Location	Mt Hagen				Mt Hagen				Mt Oga - Wurup ridge and slopes			
No. tree species in canopy	15	20	15	15	13	10	11	8	5	7	6	5
Density of trees in canopy	435	465	285	280	290	190	105	95	580	380	300	350
Density canopy trees in understorey	1955	705	410	490	545	430	130	520	780	680	380	1230
Density canopy trees in undergrowth	12140	16640	8745	3370	10350	5440	6255	2730	2620	3540	1460	460
*No. species in understorey	8	7	21	17	23	20	29	49	17	23	22	12
Density trees in understorey	385	230	1100	450	520	770	555	1350	420	700	800	700
Density understorey trees in undergrowth	4675	3300	11905	6390	14485	12720	13215	15255	6240	7480	5240	3780
**No. species in undergrowth	9	13	11	16	15	18	33	19	36	29	36	24
Density in undergrowth	6325	9175	7955	8230	5635	9110	8295	5160	6850	7700	8750	4010
Total number of woody species	32	40	47	48	51	48	73	76	58	59	64	41
Total density in canopy	435	465	285	280	290	190	105	95	580	380	300	350
Total density in understorey	2340	935	1510	940	1065	1200	685	1870	1200	1380	1180	1930
Total density in undergrowth	23140	29115	28605	17990	30470	27270	27765	23145	15710	18720	15450	8250

* Exclusive of canopy species
** Exclusive of canopy and understorey species

MF = Mixed forest BF = Beech forest OF = Oak forest
R = Regrowth D = Degraded

Density = No. individuals per hectare

intrepreting pollen spectra. Indicator species are those which occur within a single forest type or which are much more frequently represented in one than in any other. The canopy species are considered the most important as their pollen would be more widely dispersed than that of the understorey and undergrowth taxa. They also show a more restricted distribution. Table 4.18 gives the indicator status of canopy species for the different forest types.

Some of the small trees and shrubs show restricted distribution and can be used as indicators but most are ubiquitous. Trochocarpa papuana, Coprosma papuensis and Claoxylon nubicola are indicative of Mixed forest, Kibara sp.2 (6245), Finschia sp. (6289) and Eurya tigang of Beech forest and Croton sp. (6491), ?Litsea sp. (6502), Geniostema arfakense, Pandanus sp.2, Palmae gen.1, and Trimenia papuana of Oak forest. The herbaceous taxa are widely distributed and therefore of limited value as indicators.

The apparent altitudinal restriction of certain species and forest types is also of value in interpreting pollen spectra. Not only may certain pollen taxa be used to suggest the presence of certain forest types but also to suggest altitudinal tolerances and extrapolated temperature conditions.

Comparison of the species composition of the biotically disturbed sites suggests indicator species for light-demanding, regrowth vegetation. These are listed in Table 4.19. Other forest taxa known to be used selectively by the native people may be particularly important in indicating disturbance of the forests in pollen diagrams and are listed in Table 4.20. Many of the species listed in these tables are important also in the non-forest woody vegetation; their indicator value for forest situations will be considered further in Chapter 5.

Table 4.18 *The indicator status of canopy species for the different forest types.*

Indicators of Mixed Forest

Ilex sp.3 (6262)
Vaccinium apiculatum
Polyosma sp. (6255)
Rapanea sp.2 (6265)
Rapanea sp.3 (6354)

Pittosporum pullifolium
Acronychia sp.2 (6430)
Symplocos sp.3 (6420)
Podocarpus neriifolius
Drimys sp.3 (6374)
Sericolea sp. (6431)
Astronia sp.1 (6244)

If occurring in relatively high numbers:

Elaeocarpus crenulatus
Quintinia sp. (6360)
Syzygium adelphicum
Eurya oxysepala

Indicators of Beech Forest

Nothofagus sp.2 (6294)
Weinmannia sp. (6278)
Elaeocarpus ?sayeri

If occurring in relatively high numbers:

Pandanus sp.1
Prunus costata

Indicators of Oak Forest

Castanopsis acuminatissima
Sphenostemon papuanum
Nothofagus sp.1 (6485)
Cryptocarya sp.4 (6459)

Wide-ranging taxa

Schizomeria serrata
Cryptocarya sp.1 (6426)
Syzygium sp.2 (6285)
Prunus pullei
Timonius belensis
Saurauia sp.1 (6381)
Drimys sp.4 (6392)
Elaeocarpus sp.1 (6247)
Schuurmansia henningsii
?Ardisia sp. (6441)
Kibara sp.3 (6421)

Table 4.19 Probable indicators of regrowth within forests

Rhus taitensis	*Ficus endochaete*
Polyscias sp. (6339)	*Ficus gul*
Spiraeopsis brassii	*Ficus tonsa*
Carpodetus sp. (6488)	*Artocarpus vriesceanus*
Acalypha sp.1 (6075)	*Alphitonia incana*
Glochidion sp.1 (6081)	*Gynotroches axillaris*
Glochidion sp.4 (6322)	*Wendlandia* sp. (6218)
Macaranga ?warburgiana	*Discocalyx* sp. (6319)
Macaranga ?womersleyi	*Mischocarpus* sp. (6331)
Omalanthus nervosus	*Saurauia* spp.
Phyllanthus nervosus	*Symplocos* sp.2 (6343)
	Trema amboinensis
	Debregeasia sp.1 (6372)

Table 4.20 Forest species used by the native people

Rhus taitensis	*Alphitonia incana*
Ilex sp.1 (6320)	*Nothofagus* sp.1 (6485)
Ilex sp.3 (6262)	*Nothofagus* sp.2 (6294)
Garcinia sp. (6325)	*Castanopsis acuminatissima*
Schizomeria serrata	*Cinnamomum* sp.2 (6279)
Spiraeopsis brassii	*Cryptocarya* sp.1 (6321)
Weinmannia sp. (6278)	*Cryptocarya* sp.4 (6459)
Elaeocarpus crenulatus	*Astronia* sp.1 (6244)
Elaeocarpus ?sayeri	*Kibara* sp.3 (6421)
Elaeocarpus sp.1 (6247)	*Ficus gul*
Sericolea sp. (6431)	*Ficus tonsa*
Vaccinium apiculatum	*Streblus urophyllus*
Polyosma sp.1 (6424)	*?Ardisia* sp. (6441)
Polyosma sp. (6255)	
Finschia sp. (6289)	*Mischocarpus* sp. (6331)
Prunus costata	*Symplocos* sp. (6343)
Prumus pullei	*Eurya oxysepala*
Wendlandia sp. (6218)	*Quintinia* sp. (6360)
Evodia sp.1 (6486)	*Syzygium adelphicum*
Evodia sp.5 (6258)	*Syzygium* sp.2 (6285)

CHAPTER 5

NON-FOREST VEGETATION

By far the greatest part of the study region (ca 90%) is covered with non-forest vegetation; woody and herbaceous communities occupy an altitudinal range from 1520m (5000 ft) to 1760m-2430m (5800-8000 ft), the present lower limit of continuous forest. They occur on all types of topography and grow under various soil and drainage conditions. Above 3345m (11,000 ft) on Mt Hagen subalpine shrubby grassland and bog communities grow on shallow mineral soils and peats.

Different types of non-forest vegetation are described below; for some, site data are available, for others, only species lists (Tables 5.1, 5.2).

WOODY VEGETATION

2.1 Patches of trees and shrubs associated with settlement areas (Plate 10).

2.1.1 Oak patches (Traverse 20, Plate 11A)

Small patches of Castanopsis acuminatissima are frequently associated with settlement areas and are used as burial places by the local people. The canopy is at 20-22m height and in aerial photographs the dense rounded crowns of the Castanopsis trees appear characteristically rough-textured. Other trees and shrubs growing with Castanopsis acuminatissima include Elaeocarpus crenulatus, Maesa sp. (6293), Pittosporum pullifolium, Evodia spp., Eurya meizophylla, Trimenia papuana, Schefflera sp. (6352), Glochidion sp. 1 (6081), Macaranga pleiostemona, Omalanthus nervosus, Ficus gul, Alphitonia incana, Wendlandia sp. (6218), Saurauia spp. and the ubiquitous settlement area plants Cordyline sp., Casuarina spp., Acalypha sp.1 (6075), Ficus dammaropsis, Dodonaea viscosa, Trema amboinensis and Debregeasia sp.2 (5771).

These patches cover an estimated 15% of the settlement area land, ca 7sq km (2.7 sq miles or 2%) of the study region as a whole.

PLATE 10

Part of Weylk settlement area on the Baiyer river divide, 1885 m altitude, showing stands of Casuarina trees and mixed shrubs (centre), sweet potato gardens and included grass fallow. Short grassland (Themeda - dominated) is shown on the left centre and right foreground; tall cane grasses and bananas are shown on the left in the foreground.

2.1.2 Mixed garden regrowth (Traverses 14, 15, Plate 11B)

Woody regrowth develops rapidly on abandoned mixed crop garden sites and important trees and shrubs recorded there include Dodonaea viscosa, Casuarina spp., Acalypha sp.1 (6075), Macaranga ?womersleyi, Macaranga warburgiana, Omalanthus nervosus, Alphitonia incana, Trema amboinensis and Debregeasia spp. Others occurring in lower densities, or less frequently present, include Rhus taitensis, Polyscias sp. (6339), Schefflera sp., Spiraeopsis brassii, Claoxylon sp. (6444), Phyllanthus nervosus, Ficus spp., Syzygium spp. and Althoffia sp. (6496). Small forbs, such as Adenostemma hirsutum, Bidens pilosa, Crassocephalum crepidioides, Desmodium repandum and Crotalaria anagyriodes may be present, together with grasses such as Imperata cylindrica, Miscanthus floridulus, Ischaemum polystachyum and Sacciolepis indica and the ferns Dicranopteris linearis, Gleichenia hooglandii and Sphenomeris chinensis.

Even-aged stands of Dodonaea viscosa are clear in aerial photographs and mixed regrowth stands are distinguished from oak groves by their finer canopy texture and lower canopy height, namely 6-10m. Early stages of regrowth are considered in more detail in section 2.4.2. Mixed gardens and regrowth occupy ca 20% of the settlement area, an estimated 9.4 sq. km (3.6 sq. mi. or 2.6%) of the study region as a whole.

2.1.3 Other settlement area vegetation (Traverse 21).

Small groves of Pandanus, clumps of bamboo (Bambusa spp.) and stands of Casuarina spp. are planted in settlement areas and ceremonial grounds are bordered by various shrubs and trees such as Cordyline spp., Casuarina spp., Croton spp., Graptophyllum pictum as well as numerous self-sown species. These include Schefflera spp., Elaeocarpus crenulatus, Maesa sp. (6293), Alphitonia incana, Wendlandia sp. (6218), Evodia spp., Evodiella sp. (6435), Eurya meizophylla, Dodonaea viscosa, Saurauia spp., Ilex sp. (6497), many Euphorbiaceae and Moraceae. Specimen trees of Araucaria cunninghamiim, Papuacedrus papuanus and Podocarpus imbricatus also occur.

2.2 Patches of forest and shrubs within grassland.

PLATE 11A

An oak stand (*Castanopsis acuminatissima* within the Weylk settlement area. *Casuarina* and a variety of shrubs are associated. In the foreground a grass fallow of former sweet potato gardens has been cut and left to dry.

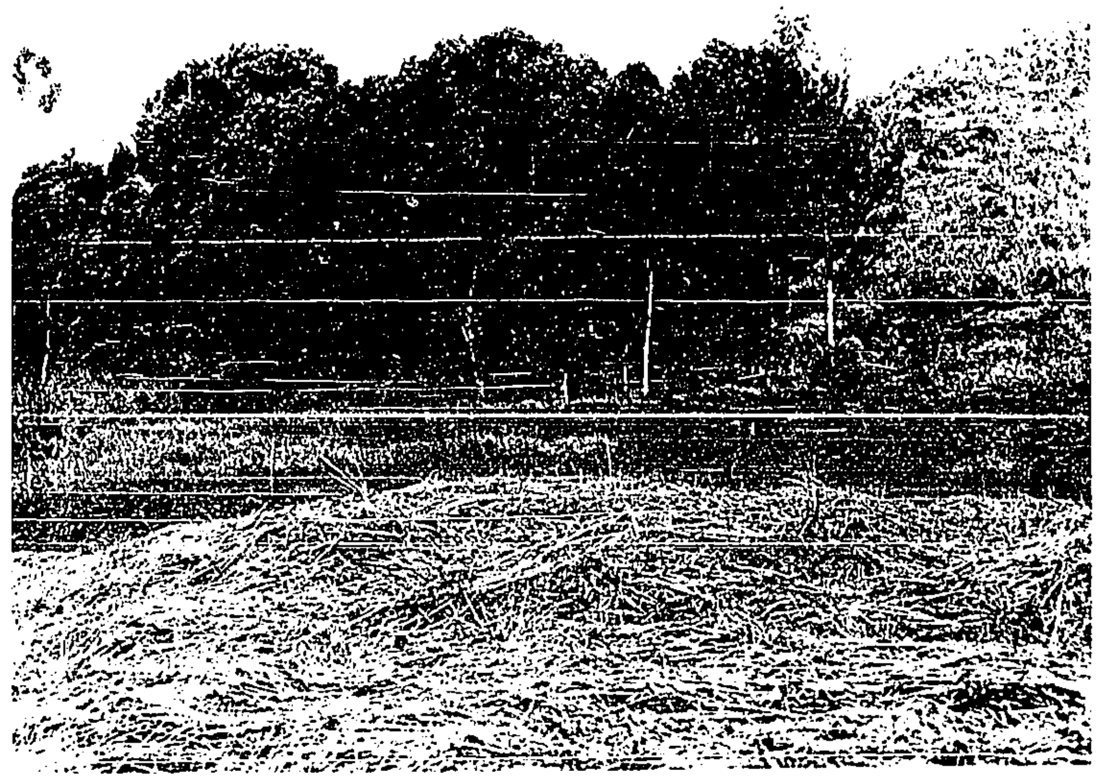


PLATE 11B

Mixed crop garden regrowth. *Casuarina* sp. are the tall trees, *Alphitonia incana* is on the right hand side and *Ficus dammaropsis* the central large-leaved shrub.

Traverses in the Wurup-Mt Oga area:

1. Forest remnant near top gardens - 2130m altitude.

2. Forest remnant below top gardens - 1975-2130m.

3. Disturbed forest - 1975m.

4. Disturbed forest - 1760m.

5. Forest edge - 1760m.

6. Disturbed forest - 1670m.

7. Regrowth within grassland - 1640-1760m.

8. Burnt over grassland area - 2250m.

9. Grass clearing surrounded by disturbed forest - 2130m.

10. Track side near ridgetop forest - 2220m.

11. Track side, steep slope - 1825-1975m.

12. Track side, gentle slope near settlement area - 1610m.

13. Stream bank, steep slope - 1610m.

14. Native subsistence gardens and fallow area - 2130m.

15. Native gardens and fallow area - 1975-2070m.

Traverses in the Draepi - Kwip area:

16. Stream bank, moderate slope - 1825m.

17. Steep gully bank - 1825m.

18. Roadside - 1885m.

19. Grassland regrowth - 1885m.

20. Forest patch at Weylk settlement area - 1855m.

21. Other settlement area vegetation - 1855-1885m.

22. Shrub regrowth in grassland near Kwip - 2220m.

23. Mixed remnant forest and regrowth near Kwip - 2280m.

Table 5.1 Species lists collected on traverses of different vegetation types in the Mt Hagen region - trees and shrubs.

		Traverse No.	20	14	15	21	1	2	13	16	17	7	8	9	19	22	23	18	10	11	12	5	3	4	6
6494	Acanthaceae	Graptophyllum pictum		x	x	x				x	x				x						x				
6489	Anacardiaceae	Rhus taitensis			x				x			x									x	x	x		
6428	Apocynaceae	Alstonia sp.					x		x			x													
6497	Aquifoliaceae	Ilex sp.				x			x			x									x	x			
6479	"	Sphenostemon papuanum																	x						
6370	Araliaceae	Harmsiopanax sp.					x					x			x			x				x	x	x	
6339	"	Polyscias sp.			x		x	x						x								x		x	
6352	"	Schefflera sp.	x		x	x	x		x	x		x				x		x	x		x	x		x	x
	Casuarinaceae	Casuarina spp.	x	x	x	x			x	x					x		x	x							
6281	Chloranthaceae	Ascarina philippinensis																	x				x		
6417	Cunoniaceae	Spiraeopsis brassii		x			x		x				x					x	x	x		x		x	
6248	"	Schizomeria serrata											x							x					
6410	Elaeocarpaceae	Elaeocarpus crenulatus	x		x	x										x	x				x	x	x		x
6431	"	Sericolea sp.											x												
6317	"	Sloanea sp. 2 & 3												x											
6012	Ericaceae	Rhododendron macgregoriae										x						x							
6488	Escalloniaceae	Carpodetus sp.								x		x			x			x				x	x	x	x
6476	"	Polyosma sp.													x										
6075	Euphorbiaceae	Acalypha sp. 1	x	x	x	x			x	x	x	x						x			x	x	x	x	
6444	"	Claoxylon sp.	x		x	x																			
6483	"	Euphorbia plumerioides		x		x			x									x							
6081	"	Glochidion sp. 1	x			x	x		x	x		x	x	x	x	x			x	x	x	x	x	x	x
6171	"	Macaranga pleiostemona	x			x			x	x	x	x				x					x		x		
5530	"	Macaranga ?warburgiana		x	x	x	x		x			x		x							x	x	x		x
6439	"	Macaranga ?womersleyi		x						x			x					x							
5551	"	Omalanthus ?nervosus	x	x	x	x	x	x	x	x		x		x	x	x		x		x			x		x
6282	"	Phyllanthus nervosus			x															x				x	x
6311	"						x												x						
6335	"																			x			x		
6457	Fagaceae	Castanopsis acuminatissima	x	x		x	x		x	x			x	x		x	x	x	x			x	x	x	
6485	"	Nothofagus sp. 1		x			x	x												x			x	x	
6321	Lauraceae	Cryptocarya sp. 1					x													x					
4659	"	Cryptocarya sp. 4					x	x	x				x			x	x	x					x	x	
6279	"	*Cinnamomum sp. 2*																				x			
6333	"	Endiandra sp. 2																		x					
	Liliaceae	Cordyline spp.	x	x	x	x				x	x			x	x										
6482	Loganiaceae	Geniostoma arfakense					x												x	x					
6264	Loranthaceae	gen. 4							x						x			x					x		
6244	Melastomataceae	Astronia sp. 1																		x					
6460	Mimosaceae	Albizia fulva					x	x																x	
6487	Moraceae	Artocarpus vriesenus			x							x													
5759	"	Broussonetia papyifera		x		x																			
6499	"	Ficus adenosperma			x		x		x	x						x									
6456	"	Ficus gul	x		x	x			x	x	x	x			x	x						x	x	x	
5757	"	Ficus dammaropsis	x	x	x	x			x	x					x	x	x	x				x	x		
6440	"	Ficus endochaete																	x					x	
6454	"	Ficus ?novoguineensis																						x	
6342	"	Ficus tonsa			x				x	x								x							
6319	Myrsinaceae	Discocalyx sp.																		x				x	
6293	"	Maesa sp.	x		x	x			x	x	x														
6285	Myrtaceae	Syzygium sp. 2					x													x				x	x
6469	"	Syzygium sp. 3			x																			x	x
6314	"	Syzygium sp. 5																	x					x	
6380	Ochnaceae	Schuurmansia henningsii					x		x	x		x	x		x	x		x		x	x	x			
	Pandanaceae	Pandanus sp. ('Um')			x				x					x					x			x			
6409	Pittosporaceae	Pittosporum pullifolium	x		x			x	x	x		x			x			x						x	
6269	Proteaceae	Finschia sp.					x																		
6434	Rhamnaceae	Alphitonia incana	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x		x	x			
6473	Rhizophoraceae	Gynotrochea axillaris											x												
6284	Rosaceae	Prunus costata					x												x			x		x	
6477	Rubiaceae	Amaracarpus sp. 2																	x						
6249	"	Timonius belensis					x																		
6218	"	Wendlandia sp.	x		x	x			x	x		x			x			x			x	x	x	x	x
6430	Rutaceae	Acronychia sp.							x															x	
6432	"	Evodia sp. 2											x							x					
6458	"	Evodia sp. 6	x		x'	x		x	x			x										x	x	x	v
6435	"	Evodiella sp.				x	x	x	x			x			x	x				x					
6172	Sapindaceae	Dodonaea viscosa	x		x	x			x	x	x	x		x	x		x				x	x	x		
6347	"	Guioa sp.					x												x					x	
6331	"	Mischocarpus sp.					x												x						
6349	"																							x	
6462	Saurauiaceae	Saurauia sp.3			x	x	x		x	x	x	x						x			x	x		x	
6324	"	Saurauia sp. 5	x			x				x	x				x	x	x	x	x						
6467	"	Saurauia sp. 11	x			x				x						x		x						x	
6360	Saxifragaceae	Quintinia sp.																	x						
6490	Sterculiaceae	Commersonia bartramia			x							x													
6343	Symplocaceae	Symplocos sp.																	x	x					
6298	Theaceae	Eurya meiaophylla	x		x	x	x	x		x	x	x		x			x	x		x		x	x	x	
6414	"	Eurya oxysepala							x					x							x				
6496	Tiliaceae	Althoffia sp.		x	x																				
6481	Trimeniaceae	Trimenia papuana	x						x	x	x	x						x	x	x				x	x
6463	Ulmaceae	Trema amboinensis	x	x	x	x		x		x	x			x				x			x		x	x	x
6372	Urticaceae	*Debregeasia sp. 1*		x	x				x	x		x		x	x					x		x		x	x
5771	"	Debregeasia sp. 2	x	x	x	x																			
6374	Winteraceae	Drimys sp. 3					x												x						
6450	Araucariaceae	Araucaria cunninghamii				x										x									
6448		Papuacedrus papuanus				x										x	x								
6323	Podocarpaceae	Podocarpus imbricatus				x																			

Table 5.2 Species lists collected on traverses of different vegetation types in the Mt Hagen region - herbs.

		Traverse No.	20	14	15	21	1	2	13	16	17	7	8	9	19	22	23	18	10	11	12	5	3	4	6
	Cucurbitaceae	'Gwoimunga'				x																			
6202	Philesiaceae	Geitonoplesium cymosum																						x	
6408	Piperaceae	Piper sp. 1																							x
6415	"	Piper sp. 5			x		x		x	x	x	x			x			x			x		x	x	x
•	Poaceae	Bambusa sp. 1																						x	
6261	"	Nastus productus				x												x							x
5573	Rosaceae	Rubus moluccanus					x		x										x			x		x	
6328	Vitaceae	Cayratia sp.																						x	
6470	Acanthaceae	Dicliptera sp.		x																					x
5740	"	Rungia klossii		x																					
	Araceae	Colocasia esculenta			x																				
	"	Xanthosoma sagittifolium			x																				
	"	gen. 1																						x	
5510	Asteraceae	Adenostemma hirsutum		x																					
5726	"	Bidens pilosa			x					x		x			x						x				
6082	"	Blumea arnakidophora					x		x	x		x	x		x				x						
5724	"	Crassocephalum crepidioides		x	x					x		x			x						x				
6019	"	Emilia prenanthoidea										x	x												
6047	"	Erigeron sumatrensis		x																	x				
5553	Balsaminaceae	Impatiens sp.								x					x									x	
6077	Boraginaceae	gen. 1			x																				
6603	Cyperaceae	Carex ?baccans			x																			x	
6014	"	Fimbristylis sp.										x	x												
5753	Fabaceae	Crotalaria anagyroides			x	x				x		x									x	x			
5575	"	Desmodium repandum			x	x	x			x				x				x							
6269	Gesneriaceae	Cyrtandra sp. 3													x				x						
6002	Hypericaceae	Hypericum sp. 1										x													
6032	Lamiaceae	Plectranthus sp. 1					x					x							x			x		x	
6205	*Malvaceae*	*Hibiscus sp.*			x				x													x			
6009	Melastomataceae	Osbeckia chinensis										x												x	
6480	"	Poikilogyne sp.										x		x					x						
5803	Poaceae	Anthraxon hispidus											x												
6007	"	Arundinella setosa								x		x	x		x										
	"	Bambusa sp. 2		x						x	x				x										
6016	"	Capillipedium parviflorum										x			x										
5848	"	Eragrostis sp.										x													
6013	"	Imperata cylindrica		x						x				x							x				
5743	"	Ischaemum polystachyum			x					x		x													
6066	"	Miscanthus floridulus	x	x	x	x	x		x	x	x	x	x	x					x	x	x	x	x	x	
5539	"	Paspalum conjugatum				x															x				
5782	"	Phragmites karka	x			x			x	x	x														
6011	"	Sacciolepis indica			x								x		x						x				
	"	Saccharum officinarum		x																					
6447	"	Saccharum spontaneum							x																
6006	"	Themeda australis								x		x	x					x							
5746	Rosaceae	Rubus rosifolius		x	x		x								x			x							
6233	Rubiaceae	Hedyotis sp.										x													
5723	Solanaceae	Nicotiana tabaccum		x																					
5847	"	Physalis sp.		x	x																				
6422	Urticaceae	Cypholophus sp.					x		x										x						x
6375	"	Elatostema sp. 1				x													x						
6312	"	Elatostema sp. 2																	x						
6051	Violaceae	Viola arcuata										x													
6144	Zingiberaceae						x	x		x	x	x			x										x
6022	Cyatheaceae	gen. ?	x		x	x	x		x	x		x	x	x					x			x			x
6026	Gleicheniaceae	Dicranopteris linearis		x					x			x	x	x					x		x	x		x	
6029	"	Gleichenia hooglandii	x	x		x				x		x		x								x			
6086	Marattiaceae	gen. 1					x		x		x														x
6015	Lycopodiaceae	Lycopodium spp.						x				x	x		x										
6023	Pteridaceae	Sphenomeris chinensis		x		x						x		x					x						
		'Pint'		x	x	x			x	x	x	x		x	x							x			
		'Pug'			x					x		x	x		x						x	x			

2.2.1 Forest patches on steep slopes (Traverses 1,2).

Small patches of forest surrounded by grassland occur mainly on steep valley slopes in the Kubor range area and on the highly dissected country at the base of Mt Hagen. Castanopsis acuminatissima or Nothofagus spp. or both dominate the canopy, 20-22m high and various other species are associated with them. These include Alstonia sp. (6438), various Araliaceae and Euphorbiaceae, Spiraeopsis brassii, Cryptocarya spp., Geniostema arfakense Albizia fulva, Ficus adenosperma, Syzygium sp.2 (6285), Finschia sp. (6289), Schuurmansia henningsii, Prunus costata, Timonius belense, Evodiella sp. (6435), Guioa sp. (6437), Mischocarpus sp. (6331), Saurauia sp.3 (6432), Eurya meizophylla, Trema amboinensis and Drimys sp.3 (6374). Piper sp.5 (6415), Rubus moluccanus, Blumea arnakidophora, Plectranthus sp.1 (6032), Desmodium repandum and Rubus rosifolius are often present, together with a few grasses and ferns. The estimated areal extent of this type of vegetation within the study region is 7.8 sq. km (3 sq. mi. or 2.2%) of the total area.

2.2.2 Stream bank vegetation (Traverses 13,16,17; (Plate 12A and B)

Bordering many of the fast-flowing streams of the region are mixed stands of trees, shrubs, tall grasses and ferns. Castanopsis acuminatissima is frequently present together with Pittosporum pullifolium, Maesa sp. (6293), Eurya meizophylla, Trimenia papuana and occasionally Cryptocarya sp.4 (6459), Carpodetus sp. (6488), Evodia sp.6 (6458), Ilex sp. (6497), Evodiella sp. (6435) and Acronychia sp. (6430) as large trees. Many light-demanding trees and shrubs are there too, such as Schefflera spp., Acalypha sp.1 (6075), Glochidion sp.1 (6081), Macaranga pleiostemona, Omalanthus ?nervosus, Schuurmansia henningsii, Wendlandia sp. (6218), Dodonaea viscosa, Trema amboinensis and Alphitonia incana. Ficus and Saurauia species are particularly abundant. Bamboo is often present and stands of Miscanthus floridulus border the water. Phragmites karka may also be present and tree ferns and ground ferns are abundant. This type of vegetation merges into that described above in many instances; in areal extent it covers about 4.8 sq. km (2.3 sq. mi.), about 1.3% of the total study area.

PLATE 12A

Streambank and steep gully vegetation, Baiyer river divide. Castanopsis acuminatissima Eurya meizophylla and Saurauia spp. are mixed with tall Miscanthus and short grasses and ferns.

PLATE 12B

Streambank vegetation, Kuna river near Wurup. Ficus adenosperma is the main shrub.

2.2.3 Regrowth shrubs in grassland (Plate 13A)

This type of vegetation is readily separated from those described above by the much greater proportion of grassland associated with the shrubs and small trees. Its estimated areal extent is 26.3 sq. km (9.7 sq. mi.), covering about 7.2% of the total study area. The scattered shrubs and small trees reach 5-6m height, standing well above the occasional tree ferns (1.5 m high) and patches of Miscanthus floridulus (1.5-2.0m high). The vegetation is typified, however, by the 1m high grasses and sedges and by large patches of ground ferns. Lianes and climbers are frequently present and forbs are abundant.

Site 13: Regrowth shrubs in grassland on the Wurup slopes:

Table 5.3 gives the habitat data and cover-density values for species recorded at this site, located on the Wurup slopes above the Manton pollen-analytical site. The area was gardened 30-40 years ago, according to informants, and since then had been used as a pig-grazing area and occasionally burnt over. It had been left undisturbed, however, for about the last 8-10 years. The transect was placed across and up the hill-slope and may also cross secondary vegetation of different ages and successional status from earlier regrowth at the bottom to late regrowth at the top.

On the lower slopes Arundinella setosa dominates the grasses with cover density values of 5-8, but Capillipedium parviflorum and Imperata cylindrica are also very important with cover-densities of 4-6 and 3-6 respectively. Ischaemum polystachyum, Leersia hexandra and Sacciolepis indica are present in lower numbers and the sedges Fimbristylis sp. (6014), Rhynchospora rugosa and Carex ?beccans are common. Many forbs are present; the most important are Centella asiatica, Crassocephalum crepidioides and Hedyotis sp. (6233) whilst others, such as Emilia prenanthoidea, Erechthites valerianifolia, Erigeron sumatrensis, Desmodium heterocarpon, Viola betonicifolia and Crotalaria ferruginea, are common. Lianes and climbers recorded include Ipomoea fibriosepala, Rubus fernandi-muelleri and Maoutia sp. Sphenomeris chinensis is the main fern present and Lycopodium cernuum is abundant.

Schuurmansia henningsii dominates the shrubs with cover-density values of 1-5. Also frequently present are Macaranga pleiostemona and Melastoma ?polyanthum, and occasionally Ilex sp. (6213), Glochidion sp.1 (6081), Hibiscus sp. (6205), Osbeckia chinensis, Ficus gul, Dodonaea viscosa, Commersonia bartramia and Callicarpa sp. (5590).

On the higher slopes the shrub cover is much denser; Macaranga pleiostemona, Stephania montana, Ficus gul, Schuurmansia henningsii, Dodonaea viscosa, Saurauia sp.10 (5525) and Eurya meizophylla are all important. Omalanthus ?nervosus, Macaranga ?warburgiana and Glochidion sp.1 (6081) are present in lower numbers.

Ischaemum polystachyum is the dominant grass but Arundinella setosa, Capillipedium parviflorum and Imperata cylindrica are well represented; Miscanthus floridulus, Paspalum conjugatum and Saccharum spontaneum are also recorded. The sedges and forbs are less abundant, only Plectranthus sp.1 (6032), Emilia prenanthoidea and Crassocephalum crepidioides show cover-density values of 2-3. Among the lianes Cucurbitaceae gen.1 (6224) is important and Geitonoplesium cymosum, Loranthaceae gen.1 (6072), Rubus moluccanus are recorded as well as those noted above. The tree ferns Cyatheaceae gen.1 (6018) and Cyatheaeceae gen.2 (6022) occur occasionally while ground ferns ('Pug' and 'Pint') are abundant.

Traverses 7, 8, 9, 19, 22, 23 cross areas of regrowth scrub in grassland. The Saurauiaceae, Moraceae, Euphorbiaceae and Theaceae are particularly important in early regrowth while others, such as Alphitonia incana, Cryptocarya spp., Castanopsis acuminatissima, Pittosporum pullifolium and members of the Araliaceae, Cunoniaceae and Elaeocarpaceae may indicate later stages of regrowth towards secondary forest. A few grasses, sedges, forbs and ferns are associated.

HERBACEOUS VEGETATION

2.3 Grassland

Areas of grassland cover ca 225.6 sq.km (87.1 sq.mi.) of the study region (ca 60 per cent of the total area) between altitudes of 1580m (5200 ft) and 2430m (8000 ft).

Table 5.3 Shrubby regrowth in grassland : species composition and cover-density at site 13.

Location : Wurup area, Kubor range
Altitude : 1640 - 1700m
Landform : Ridge side
Aspect : NE
Slope : Medium to steep
Drainage : 4

Soil : Dark grey brown friable topsoil (25cm thick) overlying mottled yellow brown clay.
pH : 6.0

ANU No.	Family	Genus & Species	49	50	51	52	53	54	55	56	57	58	59	60	61
5805	Poaceae	Apluda mutica				2	x				x			x	1
6007	"	Arundinella setosa	7	6	8	8	6	5	5	6	6	1	1	3	3
6016	"	Capillipedium parviflorum	5	5	5	5	5	5	4	6	5	2	4	4	3
6013	"	Imperata cylindrica	5	6	6	5	3		5	6		4	3	4	5
5743	"	*Ischaemum polystachyum*		4		3	6	4	5	5	6	8	7	6	6
6041	"	Leersia hexandra		x	1		x	1	x	x			1		
6066	"	Miscanthus floridulus										1			
5819	"	Ophiuros exaltatus					1								
5539	"	Paspalum conjugatum												x	1
6447	"	Saccharum spontaneum										1	1	2	1
6011	"	*Sacciolepis indica*	x	x	2	1	2	1	2	2	1			x	
6003	Cyperaceae	Carex ?baccans			2	2	2	2		2	2	x			1
6014	"	Fimbristylis sp.	2	1	2	2	2			x	x	x			x
6010	"	Rhynchospora rugosa	x	3	2	2	1	3	2	1	2				
6004	Apiaceae	Centella asiatica	2	2	5	2	3	3	4	3	2				1
5841	Asteraceae	Adenostemma hirsutum										x			
5543	"	Crassocephalum crepidioides	2	4	4	3	3	3	4	4			3		3
6019	"	Emilia prenanthoidea	x	1	1	1		x	2	3	1	1	3	2	2
5797	"	Erechthites valerianifolia		3		3	2	1	1	2		x			
6047	"	Erigeron sumatrensis	x	1		x	1	x	1	1	x				
6017	"	Lactuca		1	1	1									
6067	"	Vernonia sp.			x									x	1
5687	Begoniaceae	Symbegonia sp.										2			
5615	Euphorbiaceae	?Flueggia sp.									3				
5836	Fabaceae	Crotalaria ferruginea	x	x	1	x	x				2			x	
6209	"	Desmodium heterocarpon	x			2	2	2			x	3			x
6033	"	Desmodium microphyllum								x	x				
5575	"	Desmodium repandum										x	x		
6032	Lamiaceae	Plectranthus sp. 1		x								4	3	3	2
6008	Polygalaceae	Polygala sp. 1					x	x							
6233	Rubiaceae	Hedyotis sp.	2	1	2	2	1	2	3	3	2	2	2	x	x
6051	Violaceae	Viola arcuata												1	3
5828	"	*Viola betonicifolia*	1	2		x	1	1	1	1	2				
6025	Orchidaceae	Spathoglottis sp.	x			3	x	x							
6211	Convolvulaceae	Ipomoea fibriosepala				x				1	1				
6224	Cucurbitaceae	gen.1										6	4	4	3
6072	Loranthaceae	gen.1													2
6202	Philesiaceae	Geitonoplesium cymosum												3	4
6108	Rosaceae	Rubus fernandi-muelleri		x			4	2						x	
5573	"	Rubus moluccanus										3	x		
6208	Urticaceae	Maoutia sp.	x	3				1	3	1	5				
6213	Aquifoliaceae	Ilex sp.		x											
6081	Euphorbiaceae	Glochidion sp.1						1	1			1			1
6171	"	Macaranga pleiostemona		1			2	1	2	1	x	3	6	4	3
5530	"	Macaranga ?warburgiana												1	1
5581	"	Omalanthus ?nervosus								1		x			1
6205	Malvaceae	Hibiscus sp.			1						1				
6207	Melastomataceae	Melastoma ?polyanthum	x	1		3			x		1				
6009	"	Osbeckia chinensis					x								
6225	Menispermaceae	Stephania montana											2	3	
6466	Moraceae	Ficus gul				x					1		5	x	4
6027	Ochnaceae	Schuurmansia henningsii	4	5	5	5	1	5	1		6				6
6172	Sapindaceae	Dodonaea viscosa		x			1	4	4	5	3	3		1	2
5525	Saurauiaceae	Saurauia sp. 10													5
6219	Sterculiaceae	Commersonia bartramia				x			1						
6173	Theaceae	Eurya meizophylla												6	
5590	Verbenaceae	Callicarpa sp.				1	x	1	1	1	1	3			
6018	Cyatheaceae	Gen. 1.						4	4	1					
6022	"	Gen. 2.						1							
6005	Dicksoniaceae	Culcita villosa								1					
6023	Pteridaceae	Sphenomeris chinensis	5	6	5	5	5	5	6	4	1				
	Pteridae	'Krandramp'					2			4	3				
		'Pug'									3		4	5	3
		'Pint'										4	5	1	4
6015	*Lycopodiaceae*	*Lycopodium cernuum*	2	x	3	4	2	3							1

PLATE 13A

Shrubby regrowth in grassland on the Wurup slopes. Macaranga pleiostemona, Ficus gul, Schuurmansia henningsii and Eurya meizophylla are present, together with grasses, tree-ferns and forbs.

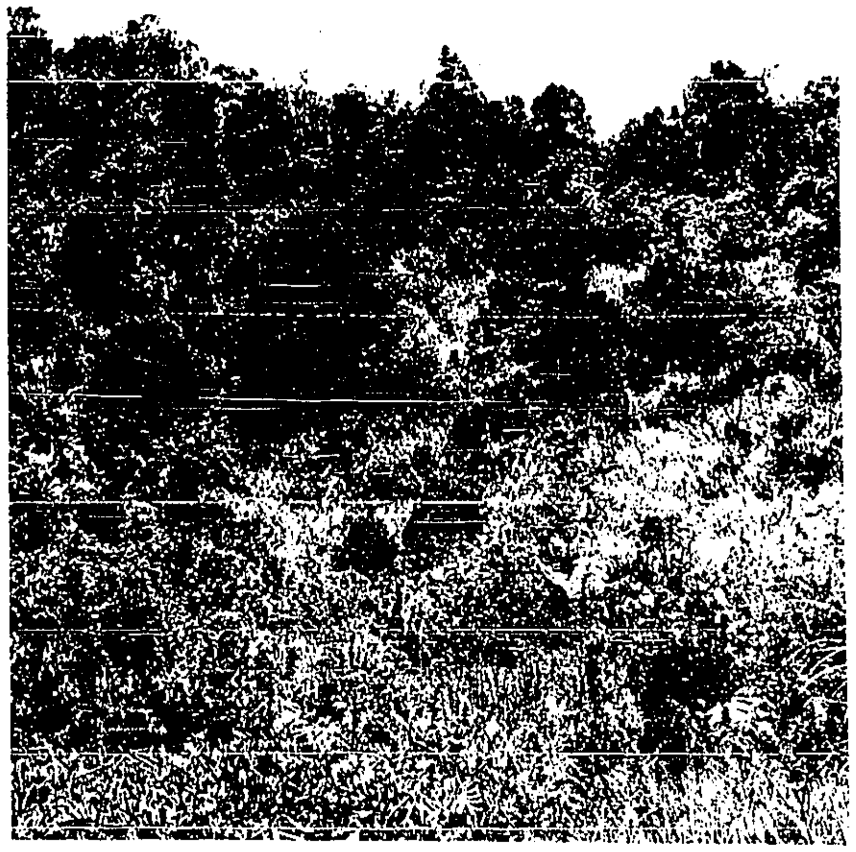


PLATE 13B

Short grassland on the Wurup slopes, dominated by Themeda australis, Arundinella setosa and Ischaemum barbatum. The chequer-board pattern of former sweet potato gardens is still obvious.

2.3.1. Short grassland (Plate 13 B)

Themeda australis dominates much of the grassland on steep, well-drained slopes within the Mt Hagen region, both on the volcanic plain at the base of Mt Hagen and on the foothills of the Kubor ranges. Arundinella setosa and Ischaemum barbatum may share dominance locally with the Themeda. The canopy is relatively dense at 0.5-1m height and on aerial photographs appears smooth-textured. Short grassland covers an estimated 58 per cent of the total grassland area, that is ca 128 sq.km (50.5 sq.mi.) of the study region.

Site 14 : Short grassland on the lower slopes of Mt Oga:

Site 14, near the Manton pollen-analytical site, exemplifies the short grassland found in the Mt Hagen region. The grasses and sedges form a relatively dense layer at about 1m height above which a few shrubs may emerge to 1.5m. Some of the forbs attain 30-40 cm height while others provide a low ground cover. Patches of bare ground occur around and between the bases of the grass tussocks in most plots but there are no obvious signs of disturbance of the ground. The area was gardened 20-30 years ago, according to informants, and burnt over several times since then. Table 5.4 gives the habitat data and cover-density values for the species present.

Arundinella setosa, Themeda australis and Ischaemum barbatum share dominance in these plots with cover-density values greater than 5. Other important grasses include Capillipedium parviflorum, Paspalum conjugatum, Imperata cylindrica and Eragrostis sp. (5848). Minor grasses are Arthraxon hispidus, Ophiuros exaltatus and Sacciolepis indica. The sedges, Fimbristylis sp. (6014), Rhynchospora rugosa, Rhynchospora rubra and Carex ?beccans are present in relatively low numbers. Important forbs are Centella asiatica and Crassocephalum crepidioides, while Emilia prenanthoidea, Desmodium microphyllum and Hedyotis sp. (6233) are usually present in lower numbers. Less frequently recorded are ?Alyxia sp. (5766), Erechthites valerianifolia, Erigeron sumatrensis, Lactuca sp. (6017) and Polygala paniculata. The small shrubs Hibiscus sp. (6205) and Osbeckia

Table 5.4 Short grassland : species composition and cover density at site 14.

Location : Mt Oga
Altitude : 1600m
Landform : *Foothill slope*
Aspect : NW
Slope : Gentle (2-5°)
Drainage : 4

Soil : Dark brown friable topsoil (15cm) over yellow clay.
pH : 5.5

ANU No.	Family	Genus & Species	41	42	43	44	45	46	47	48
5803	Poaceae	Arthraxon hispidus				x	x		3	
6007	"	*Arundinella setosa*	7	6	7	6	6	5	7	5
6016	"	Capillipedium parviflorum	3	1	2	x	2	3	3	3
5848	"	Eragrostis sp.	x	2	2	x	1	2	3	
6013	"	Imperata cylindrica	5	4			4		6	3
6001	"	Ischaemum barbatum	5	5	5	7	5	6	6	7
5819	"	Ophiuros exaltatus			1 -	x	x	1	x	x
5539	"	Paspalum conjugatum	3	2	3	2	1	2	1	1
6011	"	Sacciolepis indica	x		x	x	x		x	
6006	"	Themeda australis	6	6	6	6	6	7	5	5
6003	Cyperaceae	Carex *?beccans*				x	3		x	1
6014	"	Fimbristylis sp.	x	2	x	1	1	2	1	1
6021	"	Rhynchospora rubra	x	x		1		1	1	x
6010	"	*Rhynchospora* rugosa	x	x	1	3	1	3	x	2
6004	Apiaceae	Centella asiatica	x	2	4	3	3	5	3	1
5766	Apocynaceae	?Alyxia sp.				x			4	x
5543	Asteraceae	Crassocephalum crepidioides	2	3	2	3	4	4	3	2
6019	"	Emilia prenanthoidea	x	x	x	x	x	1	x	x
5797	"	Erechthites valerianifolia			x					
5780	"	Erigeron sumatrensis							x	1
6017	"	Lactuca sp.				2	2	2	x	1
6033	Fabaceae	Desmodium microphyllum	1	2	2	x	x	1	x	2
6028	Polygalaceae	Polygala paniculata				1				
6233	Rubiaceae	Hedyotis sp.	2	x	x	2	1	x	x	x
6205	*Malvaceae*	Hibiscus sp.						1	3	
6009	Melastomataceae	Osbeckia chinensis				1		x		x
5025	Orchidaceae	Spathoglottis sp.	x			x				x
6015	Lycopodiaceae	Lycopodium cernuum	1			x	x		x	

chinensis occur sparsely and the orchid Spathoglottis sp. (6205) occasionally. Ferns are absent but Lycopodium cernuum is recorded from some plots.

Site 16 : Slopes above the Draepi pollen-analytical site:

Short grassland also grows on the slopes surrounding Draepi. There tree ferns and shrubs grow to a height of 1.5-2.0m above the grasses and sedges (0.8-1m high) and ground ferns form large patches in some areas, 0.5m high. Table 5.5 gives habitat data and cover-density values for species recorded at this site.

Themeda australis is the sole dominant, with cover-density values of 6-8; Arundinella setosa, Ischaemum barbatum and Capillipedium parviflorum are also important, with cover-density values of x-3. The minor species are similar to those at site 14 but Dimeria dipteros and Eulalia trispicata are also recorded. Many of the same sedges and forbs occur here as at site 14; the sedges are slightly more abundant here. Centella asiatica, Polygala sp.1 (6008), Lactuca sp. (6017) and Viola betonicifolia are the most important forb taxa. Osbeckia chinensis is relatively common and Schuurmansia henningsii is recorded in one plot. Tree ferns are common and the ground ferns Culcita villosa, Dicranopteris linearis, Gleichenia hooglandii and Sphenomeris chinensis are occasionally represented. Lycopodium cernuum is abundant in some plots.

2.3.2. Tall grassland (Plate 4 A, Chapter 2)

Grassland dominated by Miscanthus floridulus is present throughout the region and is distinguished from Themeda grassland in aerial photographs by its much rougher texture. Pure stands of 2-3m high Miscanthus are found in moderately to poorly drained organic soils on lower slopes and valley floors and also sometimes at the margin of the continuous forest where it forms a zone of 'tall grassland' between the forest and adjacent 'short grassland'. Often near settlement areas Miscanthus grassland is used for pig-grazing and few other species then become established in it. In other areas tree-ferns (Cyathea spp.) are plentiful and shrubs such as Saurauia spp., Ficus spp., Acalypha spp. and Schuurmansia henningsii may appear. On well-drained

Table 5.5 Short grassland : Species composition and cover-density at site 16.

Location : Draepi — Drainage : 3-4
Altitude : 1945m — Soil : Dark brown organic topsoil (15cm) overlying brown clay.
Landform : Valley side — pH 5-5. % Bare ground/plot : [illegible]
Aspect : E
Slope : Gentle (2-5°)

ANU No.	Family	Genus & Species	1	2	3	4	5	6	7	8	9	10	11	12
5803	Poaceae	*Arthraxon hispidus*			x									
6007	"	Arundinella setosa	3	[illegible]	[illegible]	3	3	3	3	3	3	3	4	3
6016	"	Capillipedium parviflorum	2	[illegible]	1	3	2	1	2	2	3	2	3	3
6024	"	Dimeria dipteros						3	2	4	3	4	3	1
6020	"	Eulalia triapicata			[illegible]	1					1	1	1	x
6013	"	Imperata *cylindrica*			1	4	3		5	3	5	4	5	5
6001	"	Ischaemum barbatum	3	[illegible]	[illegible]	2	2	2	2	2	x	x	2	1
6011	"	Sacciolepis indica	x	x	[illegible]	x	x		x	x	x		x	x
6006	"	Themeda australis	8	[illegible]	[illegible]	8	7	7	8	8	7	8	6	6
6003	Cyperaceae	*Carex ?beccans*	2	x	1	2	1	x	1	x	1	x		x
6014	"	Fimbristylis sp.		x	[illegible]	x	x				x			
6021	"	Rhynchospora rubra			[illegible]	x	1	3	2	2	2	2	2	x
6010	"	Rhynchospora rugosa	2	[illegible]	[illegible]	3	2	2	2	2	3	3	3	x
6004	Apiaceae	Centella asiatica	3	x	[illegible]	2		1	1	1	1		2	
5724	Asteraceae	Crassocephalum crepidiodes		1								1		
6019	"	Emilia prenanthoidea		x										
6017	"	Lactuca sp.	x	2	[illegible]		x	2	1	1	1	x	x	x
6002	Hypericaceae	Hypericum sp. 1	x					x		x				
6028	*Polygalaceae*	Polygala paniculata								x				
6008	"	Polygala sp. 1	2	1	[illegible]	1	x	x	x	x	2	x	2	2
5828	Violaceae	Viola betonicifolia		[illegible]			x	x	1	1	3	1	3	1
6009	Melastomataceae	Osbeckia chinensis	[illegible]	[illegible]	[illegible]	x	x	2	1	1	2	2	2	x
6027	Ochnaceae	Schuurmansia henningsii								x				
6025	Orchidaceae	Spathoglottis sp. 2								x				
6018	Cyatheaceae	gen. 1		[illegible]		[illegible]						x	4	5
6022	"	gen. 2			1	3	x				2	x		2
6005	Dicksoniaceae	Culcita villosa	[illegible]			[illegible]					4		4	
6026	Gleicheniaceae	Dicranopteris linearis								1	5			2
6029	"	Gleichenia hooglandii									4	1		
6023	Pteridaceae	Sphenomeris chinensis				[illegible]		x		x	1	3	1	4
6015	Lycopodiaceae	Lycopodium cernuum				[illegible]	2	3	3	3	x	4	x	1

slopes Miscanthus may share dominance with a number of other grasses, including Capillipedium parviflorum, Arundinella setosa and Themeda australis.

Small patches of Miscanthus grassland are included in settlement area vegetation and regrowth shrub vegetation estimates; separately mapped areas total 87.4 sq.km (33.8 sq.mi.) for the region as a whole.

2.3.3. Mixed grassland (Plate 10)

Within native garden areas a short fallow stage of grassland is usually associated with the cultivation of the main crop, Ipomoea batatas. Dominance of this fallow is shared by a number of grass species and associated sedges and forbs are abundant. Such grassland accounts for about 15 per cent of settlement area vegetation and is estimated to cover about 7 sq.km (2.7 sq.mi., or 2 per cent) of the study region.

Site 19 : Mixed grassland in sweet potato garden areas at Weylk:

Table 5.6 gives habitat data and cover-density values for species recorded at this site. The area had been used for sweet potato gardens 4-6 years before, according to informants, when it had been created by the clearance and burning of a similar grass fallow. After harvesting the sweet potato tubers the area was left undisturbed. The fallow was about 2-5 years old. Some successional trends may be noted from these plots.

Early grassland fallow is dominated by Ischaemum polystachyum, Imperata cylindrica and Setaria palmifolia, all with cover-density values above 5. Other important grasses are Digitaria sp. (5802), Leersia hexandra and Oplismenis compositus. Arthraxon hispidus, Sacciolepis indica and Panicum paludosum are less often present or represented in lower numbers. Longer fallow results in increasing importance of Arthraxon hispidus and Sacciolepis indica together with the appearance of Apluda mutica, Arundinella setosa, Capillipedium parviflorum, Miscanthus floridulus and Themeda australis.

Among the sedges, Cyperus melanospermus, Bulbostylis densa, Fimbristylis sp. (6014) and Rhynchospora rubra are important throughout the fallow; Carex ?beccans, Carex

?neurochlamys and Lipocarpha chinensis are important in longer fallow stages.

Dominant forbs in early fallow are Bidens pilosa, Crassocephalum crepidioides, Commelina sp. (5738), Polygonum nepalense and Viola betonicifolia. Many others, such as Adenostemma hirsutum, Erechthites valerianifolia, Drymaria cordata and Rubus rosifolius are present in lower numbers. Some are present occasionally in early fallow stages and become more important later on, namely, Centella asiatica, Siegesbeckia orientalis and Plectranthus sp.1 (6032). Many others are recorded only in the later stages of the succession, namely, Lactuca sp. (6017), Euphorbia serrulata, Desmodium microphyllum, Osbeckia chinensis, Polygala sp.1 (6008) and Spathoglottis sp.2 (6025).

Tree ferns and ground ferns also enter in the later successional stages; Cyatheaceae gen.1 (5535), Cyatheaceae gen.2 (5854) are recorded together with Hypolepis sp. (6182), Histiopteris incisa and Gleichenia hooglandii.

2.3.4. Subalpine grassland mires (Plate 9 A)

Subalpine grassland and mire communities grow on the summit plateau of Mt Hagen and the grasslands extend down to 3345m (11000 ft). The summit area was traversed and the following species noted; no description of communities can be given on the basis of these data but certainly several are represented. The areal extent of this vegetation is 3.7 sq.km (1.4 sq.mi.), about 1.5 per cent of the total area.

Divaricating shrubs, such as Coprosma divergens, Drimys sp.4 (6392) and Rhododendron womersleyi, all about 1.5m high and Vaccinium cf evanidinervum, Styphelia suaveolens and Hypericum sp.1 (6390), less than 0.5 high, are common in some areas of tussock grassland. In others a tree fern Cyathea sp. (6412) is abundant and in others, Gleichenia vulcanica forms large patches. Gleichenia bolanica was noted on rocky sites. The main grasses were Deyeuxia brassii, Danthonia archboldii, Deschampsi klossii, Poa nivicola and Hierochloe redolens and the sedges Gahnia javanica, Carex ?capillacea, Carpha alpina and Scirpus

Table 5.6 Mixed grassland : species composition and cover density at site 19.

Location : Veyik Settlement area
Altitude : 1850m
Landform : Valley-side
Aspect : N

Slope : Very gentle (0-1°)
Drainage : 4
Soil : Black organic topsoil (25-30 cm) over orange-brown clay
pH : 5.5

ANU No.	Family	Genus & Species		29	28	5	24	25	20	21	31	30	19	26	27	13	14	15
	Convolvulaceae	Ipomoea batatas	'Toyga'				x		x	2								
	"	" "	'Dombumi			3	x	3	4	4	1	1	2	x	x	4		
	"	" "	Minima				3	1	3	2	3	1	4			3		
	"	" "	Dogarn	2		3	3	x	x		2	2				1		
	"	" "	Koepep					2	2	x								
	"	" "	Konimoy	1	x	x	x	1				1						
	"	" "	Krapkelua							1								
	"	" "	Daralang					x		x								
	"	" "	Karatnoga				3											
5805	Poaceae	Apluda mutica														4	3	3
5803	"	Arthraxon hispidus				1	3	3	1		1		5				5	6
6007	"	Arundinella setosa														3	5	6
6016	"	Capillipedium parviflorum															4	4
5802	"	Digitaria sp.			x	3	3	4	4	5	4				3	5		
6013	"	Imperata cylindrica			x	5	6	6	6	7	7	6	3	4	5	6	4	5
6048	"	Isachne globosa										2			x	2		
5743	"	Ischaemum polystachyum		8	8	6	6	7	7	7	5	7	6	8	8			
6041	"	Leersia hexandra				4	3	5	3	4	5	1						
6066	"	Miscanthus floridulus												x	2		4	5
6063	"	Oplismenus compositus		4	x		2	4			5	5	4			4		
6177	"	Panicum paludosum		5	3						5	6						
6011	"	Sacciolepis indica		x		2	x	x	x	4	4	x	5	1	2	3	1	2
5600	"	Setaria palmifolia		3	4	1	6	5	5	3	5		6	5	4			
6006	"	Themeda australis														4	6	7
6179	Cyperaceae	Bulbostylis densa				3		3	3	3	1		5			2	5	3
6003	"	Carex ?beccana											3	x	1	2	3	
5882	"	Carex ?neurochlamys					x		3	4						2	4	2
5749	"	Cyperus melanospermus		3	4		3	3	4	4	3	4	4	4	3	2	2	3
6014	"	Fimbristylis sp.						x	3	2	3		2			x	1	2
6045	"	Lipocarpha chinensis				3										2	3	2
6021	"	Rhynchospora rubra		x		2	x	x	x		3		1	x			x	
6010	"	Rhynchospora rugosa																2
6004	Apiaceae	Centella asiatica								3	1		2	x		3	4	4
5510	Asteraceae	Adenostemma hirsutum					x	1		2			2	2	x			
5726	"	Bidens pilosa		2	1	4	4	4	3	3	4	3	4	3	1	5	2	2
5724	"	Crassocephalum crepidioides			x	4	4	4	4	4	2		4	x	x	4	4	3
6019	"	Emilia prenanthoidea						x										
5797	"	Erechthites valerianifolia		x	x		x			x					x			
5780	"	Erigeron sumatrensis						1	1	x	2	x	x		x	1	1	1
6017	"	Lactuca sp.														2	2	2
6080	"	Siegesbeckia orientalis					5	1		1			3	x	3	4	1	3
6077	Boraginaceae	Gen. 1					1		3	1						1		
6073	Campanulaceae	Wahlenbergia sp.		x									1					
5754	Caryophyllaceae	Drymaria cordata			x	4						x			x	x		
5738	Commelinaceae	Commelina sp.		3	1	4	2	1	x	3	4	3	3	3	3			
5814	Euphorbiaceae	Euphorbia serrulata															2	2
6033	Fabaceae	Desmodium microphyllum														x	2	x
6032	Lamiaceae	Plectranthus sp. 1			1			1							2	3	3	4
6009	Melastomataceae	Osbeckia chinensis															x	x
6028	Polygalaceae	Polygala paniculata									3							
6008	"	Polygala sp. 1														1		x
5748	Polygonaceae	Polygonum nepalense		x		4	4	4	4	3	1		5				3	2
5573	Rosaceae	Rubus moluccanus																x
5746	"	Rubus rosifolius			x	1		x			4			1	1	3	x	
5730	Solanaceae	Solanum nigrum											x					
5828	Violaceae	Viola betonicifolia		2	2	2	2	2	2	1	3	x	3	3	4	2	x	2
6025	Orchidaceae	Spathoglottis sp. 2															1	2
5535	Cyatheaceae	Gen. 1												5	x			
5854	"	Gen. 2												5				
6182	Dennstaedtiaceae	Hypolepis sp.												3				
6183	"	Histiopteris incisa												4				
6029	Gleicheniaceae	Gleichenia hooglandii												1				
6015	Lycopodiaceae	Lycopodium cernuum																x

crassiusculus. Forbs noted in various situations include Potentilla sp.1 (6393), Anaphalis sp.2 (6389), Tetramolopium sp. (6387) growing below rock outcrops and Astelia papuana, Drapetes ericoides, Rhododendron saxifragoides, Potentilla sp.2 (6402), Trachymene novoguinensis, Ranunculus sp. (6398), Trochocarpa decockii and Eriocaulon brevipedunculatum forming smaller or larger mats in wet situations.

2.4 Gardens

Population densities are relatively high in the Mt Hagen region and native subsistence gardens are dispersed over a wide range of drainage, soil and topographic conditions between 1520m (5000 ft) and 2430m (8000 ft) altitude. Within settlement areas gardens occupy an estimated 50 per cent of the total, about 23.3 sq.km (9 sq.mi. or 6.5 per cent) of the study region as a whole.

2.4.1. Sweet Potato gardens (Plate 14)

Sweet potato (Ipomoea batatas), the basic food plant of the Medlpa, is usually grown in small, individually owned or worked, gardens within a large field area of flat to gently sloping ground. The margin of the field is fenced and the ground within used more or less continuously, newly planted and productive gardens rotating with a short-term (4-5 year) mixed grass fallow. Each garden is bounded by a shallow ditch or by a pathway and the sweet potato plants are grown on composted mounds or in rectangular plots. Their distinctive pattern is readily observed on aerial photographs.

When a new sweet potato garden is prepared, the area to be used is demarcated by a peripheral ditch and the grass inside is cut and left to dry. It is burned some time later, using carefully controlled fires. The surface soil and ash are then mixed and any remaining grass roots are taken out. If a rectangular, level, plot is being prepared, further shallow ditches (20-30 cm wide, 15-20 cm deep) are dug across the area, resulting in a chequer-board pattern of 270-290 cm long x 240-280 cm wide plots. Soil from the small ditches is thrown up onto the top of the plot and spread; there is no further tillage.

PLATE 14A

Mounded sweet potato plots at Weylk.

PLATE 14B

Rectangular sweet potato plots near Wurup. Bamboo and Casuarina mark a house site on the hillcrest, market garden plots (corn and beans) are shown in the foreground.

Sweet potato mounds may be almost circular, with diameters between 160-200 cm, or oblong, usually measuring between 240-270 cm long x 200-250 cm wide but up to 450 cm long x 350 cm wide. The preparation of the sweet potato mounds is mainly women's work. The soil is broken up with a small digging stick, rubbed through the hands until fine and friable, then built up around the perimeter of the mound. Compost materials, including old sweet potato vines, dry grass and weeds, are collected and thrown into the centre together with soil and the whole is covered with soil.

Growing tips, cut from mature sweet potato plants, may be planted, or small tubers are removed from neighbouring mounds and planted in the plots and around the upper parts of the mound. Altogether, about 13 varieties of sweet potato are grown, 2 of which are post-European contact introductions.

The chequer-board pattern appears to be used at Weylk when ground is first brought back into cultivation after some years of grass fallow; after the first harvest the ground is reworked into mounds. However, there is no strict rule governing this and in other areas, including Wurup, mounded gardens are rarely seen. The use of composted mounds may be a relatively recent introduction from the Enga people living further west (Bowers, 1965).

The gardens are tended and weeded almost daily during the first few months after planting and the vines spread across the soil surface. The first tubers are removed after about 6-7 months; in the mounded gardens this is done by 'bandicooting' from the top of the mound. Only the large tubers are taken and the plants continue to produce over a period of several months. When only a few small tubers remain, these are collected for pig food and the plots then left undisturbed, or alternatively, the pigs may be tethered in the gardens and allowed to rootle for themselves. These plots may be reworked almost immediately or left to lie fallow.

Weeding ceases after the first tubers have been removed from the plots and pioneer weeds invade and establish rapidly. If the mounds are left undistrubed after the final harvest, further weed species establish and succession towards grassland begins.

Site 18 : Sweet potato gardens at Weylk:

Table 5.7 gives the habitat data and cover-density of species present in sweet potato gardens at Weylk, from the time of first harvest up to 2 years fallow.

The most important pioneer weeds are Polygonum nepalense and Bidens pilosa which have cover-density values of 2-5 and 3-6 respectively, together with the grasses Digitaria sp. (5802) and Leersia hexandra. Other species, usually present in lower numbers, are Crassocephalum crepidioides, Commelina sp. (5738), Oxalis corniculata, Viola betonicifolia and Wahlenbergia sp. (6073) among the forbs and Arthraxon hispidus, Isachne globosus and Lipocarpha chinensis among the grasses and sedges. Sweet potato vines dominate the cover.

After 3-4 months fallow further species establish, such as Erigeron sumatrensis, Rubus rosifloius and Drymaria cordata among the forbs, Ischaemum polystachyum, Oplisimenus compositus, Sacciolepis indica and Setaria palmifolia among the grasses and Bulbostylis densa, Fimbristylis sp. (6014) and Rhynchospora rubra among the sedges. Others, such as Siegesbeckia orientalis, Cyperus globosus and Cyperus melanospermus are occasionally present.

After about 18 to 24 months fallow the sweet potato vines are no longer plentiful. Ischaemum polystachyum is the main grass present although Arthraxon hispidus, Digitaria sp. (5802), Setaria palmifolia and Sacciolepis indica are also important. Lipocarpha chinensis and Rhynchospora rubra are prominent sedges. Bidens pilosa and Polygonum nepalense remain as important forbs together with Commelina sp. (5738).

The later part of the succession has been described above as 'mixed grassland'.

At any stage in the succession the ground may be reworked for further sweet potato gardens or for a mixed 'market-produce' garden (2.4.4.). Although the value of fallow to the ground is realized it is considered that at any time after 12 months the ground could be reworked profitably and it is mainly other pressures which determine the actual time at which this is done.

Table 5.7 Sweet Potato gardens : species composition and cover-density at site 18.

Location : Weyik settlement area.
Altitude : 1850m
Landform : Valley side
Aspect : N

Slope : Very gentle (0-1°)
Drainage : 4
Soil : Black organic topsoil (25-30cm) over orange-brown clay
pH : 5.5.

ANU No.	Family	Genus & Species	1	2	3	4	12	22	23	6	10	11	7	8	9
	Convolvulaceae	Ipomoea batatas 'Toyga'	5				3			4			5	3	4
	"	" " 'Pora'	6		1	3		3	x		x				
	"	" " 'Torema'	4												
	"	" " 'Bombumi'	5	4	5	6	5		1	6	5	5		5	5
	"	" " 'Minima'	3	5	5	4	4	4	1		2	1		4	
	"	" " 'Degarn'	3	4	3	3	5		2	4	5	6	5	3	4
	"	" " 'Koopop'	4		4		3								
	"	" " 'Koninoy'	3	4		3		3	5	3	1	1	4		
	"	" " 'Kandip'		4	4										
	"	" " 'Krapkelua'		4	4	4				3	1				2
	"	" " 'Baralang'		3		3		2							
	"	" " 'Karatooga'						4	2						
5805	Poaceae	Apluda mutica													4
5803	"	Arthraxon hispidus			1	5	2	3	2	4	x	2	3	4	5
5802	"	Digitaria sp.	3	4	4	5	5	4	4		3	3	3	2	3
6048	"	Isachne globosus		x		1									
5743	"	Ischaemum polystachyum					4	2	4	6	6	6	7	5	5
6041	"	Leersia hexandra	3	4	x		5	5	4	4		5	3		
6063	"	Oplismenus compositus					2	2	3		1	3			
6011	"	Sacciolepis indica				3	x	1	2	1	1	1	1	2	3
5600	"	Setaria palmifolia					3	1	4	4	4	4	2		1
6179	Cyperaceae	Bulbostylis densa					x				1		3		
6038	"	Cyperus globosus											x		
5749	"	Cyperus melanospermus						x							
6014	"	Fimbristylis sp.									x	x			x
6045	"	Lipocarpha chinensis	1	x		x	1			4	3	5	3	4	4
6021	"	Rhynchospora rubra								3	2		1	2	x
6004	Apiaceae	Centella asiatica							1						
5726	Asteraceae	Bidens pilosa	4	3	4	5	6	3	5	4	5	4	5	4	4
5724	"	Crassocephalum crepidiodes	1	2	2	4	3	3	4	2	2			2	1
5780	"	Erigeron sumatensis					x	x	x	x	x	x			x
6080	"	Siegesbeckia orientalis					x	1	1						
6073	Campanulaceae	Wahlenbergia sp.				1									
5754	Caryophyllaceae	Drymaria cordata	1							2	x		1	3	
5738	Commelinaceae	Commelina sp.	1	x		1	1	x		4	4	3	5	5	4
6074	Oxalidaceae	Oxalis corniculata				1		2							
5748	Polygonaceae	Polygonum nepalense	5	3	2	3	3	2	3	4			4	4	4
5746	Rosaceae	Rubus rosifolius					x				x	x		1	1
5828	Violaceae	Viola betonicifolia		1	x	1		1	1		x				x

2.4.2. Mixed crop gardens (Plate 15, 16A, 17A)

. This type of garden is usually located on sloping ground, often around the edges of the sweet potato field. Individual gardens are fenced. The main crops grown include bananas, sugar cane, taro, yams and beans. After 1-2 years use, woody regrowth is permitted and a long fallow period ensues. On aerial photographs newly planted and productive gardens may be distinguished by their open canopy of dead and pollarded trees mixed with bananas and sugar cane, but are less obvious than the dense regrowth vegetation which develops after harvesting is finished.

Site 20 : Mixed crop gardens at Weylk:

Table 5.8 gives the habitat data and cover-density values for species recorded at this site.

Mixed gardens are usually prepared from areas of secondary woody regrowth at the beginning of the 'dry' season (May-June). All the small trees, saplings and seedlings are cut down and branches of larger diameter trees (such as Casuarina spp., Macaranga pleiostemona and Eurya meizophylla) are lopped, the trunks left standing. Debris is left to dry for 1-2 months and then is burned; several fires may be needed to clear the ground completely and these are made in restricted patches. After burning, the ashes are spread over the ground and worked into it to some extent but there is little else done by way of soil preparation. The gardens are usually planted by the beginning of the 'wet' season (November-March). Various crops are planted more or less randomly through the garden area although features such as shade, slope and drainage are often taken into consideration.

Varieties of bananas (Musa spp.) and of sugar cane (Saccharum officinarum) and the shrubs Ficus dammaropsis, Cordyline fruticosa and Casuarina spp. are usually planted first. Taro varieties (Colocasia esculenta), yams (Dioscorea spp.) and beans (Dolichos sp., Psophocarpus tetragonolobus) are then interplanted with a number of smaller herbaceous domesticates, including Rungia klossii, Amaranthus tricolor, Saccharum edule, Setaria palmifolia and Zingiber spp. The shrubs Piper sp. (5783), Ricinus communis and Broussonetia papyrifera may also be included and some of the recent European introductions, such as cucumbers (Cucumis sativa), potatoes (Solanum tuberosum), cabbage (Brassica oleracea), corn (Zea mays) and passionfruit (Passiflora sp.).

The mixed garden starts to produce after about 3-4 months, the first crops harvested being cucumbers and some of the small 'greens' such as Rungia klossii, Amaranthus tricolor and Setaria palmifolia. The beans are the next to mature and after about 6 months the Saccharum edule and the corn are harvested. The small domestic forbs continue to produce and with Setaria palmifolia are harvested over a long period. The self-sown ferns ('Pug' and 'Bugamp') and forbs such as Solanum nigrum, Oxalis corniculata, Hydrocotyle javanica, Commelina sp. (5738) and Oenanthe javanica are gathered intermittently. Taro takes 9-10 months to mature and the yams 10 months or longer. By this time the bananas are bearing fruit and the sugar cane can be cut; both are harvested over a long period of time. The shrub species, Piper sp. (5783), Ricinus communis and Broussonetia papyrifera are selectively harvested as well as other condiments such as ginger (Zingiber spp.). Some of the relatively fast-growing forbs may be replanted after initial harvest, small areas of ground being weeded for the purpose. The whole garden provides produce over a period of 1-2 years and sugar cane and bananas may still be harvested in fallow gardens 3-4 years old.

There is some selective weeding near individual plants during the first 2 months but self-sown ferns and certain forbs are retained. After this there is little weeding; ruderals invade and colonize all bare ground and regrowth vegetation develops rapidly.

Important pioneer forbs are Bidens pilosa, Crassocephalum crepidioides, Drymaria cordata, Polygonum nepalense and Viola betonicifolia, while Adenostemma hirsutum, Erigeron sumatrensis, Siegesbeckia orientalis, Rubus rosifolius and Lactuca sp. (6017) are usually present in lower numbers. Later Adenostemma hirsutum increases in importance and many other forbs establish, including Centella asiatica, Erechthites valeranifolia, Boraginaceae gen.1 (6077), Polygala paniculata and Lysimachia japonica.

Table 5.8 Mixed crop gardens : species composition and cover-density at site 20.

Location : Woyik settlement area
Altitude : 1850m
Landform : Valley side
Aspect : NE
Slope : Medium (5-6°)
Drainage : 4

Soil : Black friable organic topsoil (30cm) over dark brown clay loam; yellow brown clay at 95cm.
pH : 5.5.

ASH No.	Family	Genus & Species	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
	Araceae	Colocasia esculenta 'Gugwimp'							3	1		3				4	5	5	4
	"	" " 'Huglump'			4			1	3										
	"	" " 'Mepim'	3	4	3	4	4	3	3	3	4	5	4	3		4	4	5	4
	"	" " 'Haiguoin'	1	2	3	1	3												
	"	" " 'Pul'		1															
	"	" " 'Gitua'			4	3		4		3	3								
	"	" " 'Kraiongbiliamp'			1	3	2												
	"	" " 'Kitina'					1												
	"	" " 'Barn'										5							
	"	" " 'Gragrumbil'														3	3	3	3
	Musaceae	Musa spp. 'Dekonta'	1					3	3				4			4			
	"	" " 'Tugumamp'		4	4		3		3	4	3	5					3		
	"	" " 'Kumburg'						3											
	"	" " 'Mari'										4							
	"	" " 'Ganinga'												5	4				
	Poaceae	Saccharum officinarum 'Po'	4	4	4	4	3	4	4	4	4	5	5	5	5	6	6	6	4
	"	" " 'Pomitoy'									2								
5740	Acanthaceae	Rungia klossii						3	1	3	3	3							
5729	Amaranthaceae	Amaranthus tricolor		x	1		1	1	1	x	2	1							
5807	Apiaceae	Hydrocotyle javanica				1	2	1											
5732	"	Oenanthe javanica		4				x	3	3		2	1						
"	Brassicaceae	Brassica oleracea		x	3	4													
"	Dioscoreaceae	Dioscorea sp. 'Op'	3	3	1				1										
	Euphorbiaceae	Ricinus communis	3	4	5	4	3	3	3	4	5	4		1			1		
6175	Fabaceae	?Dolichos sp.			2				1			2				5	3	4	5
5825	"	Psophocarpus tetragonolobus	3	3	2			1				3							
6074	Oxalidaceae	Oxalis corniculata	1	1	2	1	1		1	x		x	x	x		x			1
"	Passifloraceae	Passiflora sp.					5	3	2	1	2								
5783	Piperaceae	Piper sp.	1																
	Poaceae	Saccharum edule 'Tropin'	3	3			3			3	4	3	4	5	5				
5737	"	Setaria palmifolia		4	5	5	3	6	6	6	6	6		6				5	5
5730	Solanaceae	Solanum nigrum	1	1	1	x	1	2	1	1	1	3	x	1			1		
	"	S. tuberosum						1											
6004	Apiaceae	Centella asiatica	3					2	2	4	2	4	1	4					
5510	Asteraceae	Adenostemma hirsutum	1	1	2	3	3	5	5	5	3	4	4	2		2	4	3	
5726	"	Bidens pilosa	4	3	3	4	3	3	3	3	3	3	3	3	3	4		3	3
5724	"	Crassocephalum crepidioides	5	6	6	4	3	3	3	3	2	4	3	3	2	3	6	2	3
5797	"	Erechthites valerianifolia							x	2	x	1							
5780	"	Erigeron sumatrensis	1	1	1	1	2	x	x	x	1	x	3	3	2		2	4	3
6017	"	Lactuca sp.	x	x		1			1		2	1	1						
6080	"	Siegesbeckia orientalis	1	1	2	x	1	1		x	1	1	1	1			x		
5918	"	'Nobenavi'						x											
6077	Boraginaceae	gen.1									3		2	3			1	2	3
6073	Campanulaceae	Wahlenbergia sp.			1								1						
5754	Caryophyllaceae	Drymaria cordata	3	4	4	3	2	4	4	4	2	4	2	1					
5738	Commelinaceae	Commelina sp.	4	4	3	3	3	3	3	5	4	4				1	x		
6033	Fabaceae	Desmodium microphyllum									1								3
5575	"	Desmodium repandum							1										
6065	Lamiaceae	Plectranthus sp.										1							
6028	Polygalaceae	Polygala paniculata					3	x			x	x	4	5	5	x			
5740	Polygonaceae	Polygonum nepalense	7	5	4	3	3		3	4	4	3	1	1					
6184	Primulaceae	Lysimachia japonica				2	2	3	x										
5746	Rosaceae	Rubus rosifolius		1	1	x		x	x	1	1	1	3	4	4		1		
6051	Violaceae	Viola arcuata																	3
5828	"	*Viola betonicifolia*	2	2	x	4			1	x	2	2	1	1			1	2	3

Table 5.8 continued

ANU No.	Family	Genus & Species	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
5803	Poaceae	Arthraxon hispidus	1					4			2		x		2	1	6	5	4
5802	"	Digitaria sp.							3	3	2		3	3	3				
6099	"	Eleusine indica													6	1		x	
6013	"	Imperata cylindrica	4	1				x	x	1	4	2	x	1			2	3	4
5743	"	Ischaemum polystachyum	3		x	1	1		1	1	2	1	2	3	6		1		2
6041	"	Leersia hexandra							1		x						1	x	
6066	"	Miscanthus floridulus	3	3	1			x					2	4			2		5
6063	"	Oplismenus compositus				1			4	3	2		6	6	3				
6177	"	Panicum paludosum																5	
5539	"	Paspalum conjugatum	3	5	1	3	3	x	x	x	4	1		1					
6189	"	Paspalum orbiculare													3				
6011	"	Sacciolepis indica	x	x	x				x	x	x		x	x	2				4
5600	"	Setaria palmifolia			4	3	4	5	3	1		2	x				1	x	x
6003	Cyperaceae	Carex ?beccans		2	x			1	1	1		2	1	x					
6238	"	Cyperus globosus							x	x	1	2	x						
5749	"	Cyperus melanospermus	3	3	1	x	3	3	3	3	3	4	2	3	3				
6021	"	Rhynchospora rubra		x			x	x			x	x							
	Casuarinaceae	Casuarina spp.					6	6	3						2				
6075	Euphorbiaceae	Acalypha sp. 1	3	3				2	3	1							x		3
5639	"	Acalypha sp. 2								2									
6081	"	Glochidion sp. 1						4	5										
6171	"	Macaranga pleiostemona		3					2			3	3	1	3		2		
5581	"	Omalanthus ?nervosus	1		2			2			2								
	Liliaceae	Cordyline sp. (3 types)			5	3		3						1					
5759	Moraceae	Broussonetia papyrifera						4	3	3	1	5	3						
5757	"	Ficus dammaropsis	4												6				
6434	Rhamnaceae	Alphitonia incana											3				4		
6172	Sapindaceae	Dodonaea viscosa	2	3	3	3	4	2	4	4	4		5	6	7		1	2	4
6462	Saurauiaceae	Saurauia sp. 3									1	3		1					
5569	Solanaceae	Solanum ?torvum												3					
6298	Theaceae	Eurya meizophylla												4	4		6		
5771	Urticaceae	Debregeasia sp. 2	1	2	1		1	4	5	4	3	5							
6018	Cyatheaceae	Gen. 1.												3					
6022	"	Gen. 2.											5						
6023	Pteridaceae	Sphenomeris chinensis											3				6		
6185	Thelypteridaceae	gen.1					4					1							
	'Pug'		4	4	3				1	3	5	5	1	1					
	'Bugamp'			x	2					3	4	4		2					

PLATE 15A

A mixed crop garden at Weylk. Bananas and sugar cane are prominent, taro, *Ricinus communis* and many forbs form a lower layer.

PLATE 15B

Setaria palmifolia, and sugar cane in a mixed garden at Weylk.

Paspalum conjugatum, Miscanthus floridulus, Imperata cylindrica, Ischaemum polystachyum, and Setaria palmifolia are important grasses throughout the succession while Arthraxon hispidus, Digitaria sp. (5802), Eleusine indica, Leersia hexandra and Oplismenus compositus enter into the later stages. Cyperus melanospermus is the most important sedge throughout the sequence; Carex ?beccans, Cyperus globosus and Rhynchospora rubra are present in lower numbers.

Some of the ferns are utilized ('Pug' and 'Bugamp') and others, such as Cyatheaceae gen.1 (6018), Cyatheaceae gen.2 (6022), Sphenomeris chinensis and Thelypteridaceae gen.1 (6185), are occasionally present.

Seedlings of Dodonaea viscosa, Acalypha sp.1 (6075), Omalanthus nervosus and Debregeasia sp.2 (5771) are common in early fallow stages and after harvesting of the main crops is finished many other woody species become established, including Glochidion sp.1 (6081), Macaranga pleiostemona, Alphitonia incana, Saurauia sp.3 (6462), Solanum ?torvum and Eurya meizophylla. The mixed garden areas are left fallow for 10 years or more, unless social pressures force an earlier re-working of the sites.

Succession in the mixed garden areas appears to proceed towards woody regrowth much more rapidly than in the sweet potato open field. In both cases at Weylk the source of seeds of pioneer species is nearby, in fence lines, other fallow areas and forest patches. The more or less continuous use of the sweet potato garden area, involving intensive weeding and intermittent burning, probably reduces the abundance of seeds in the ground very considerably compared with what happens in mixed gardens. The trees left standing in the mixed gardens, together with those planted, must also provide a certain amount of shade which may be advantageous to later regrowth species.

2.4.3. House gardens (Plate 16B)

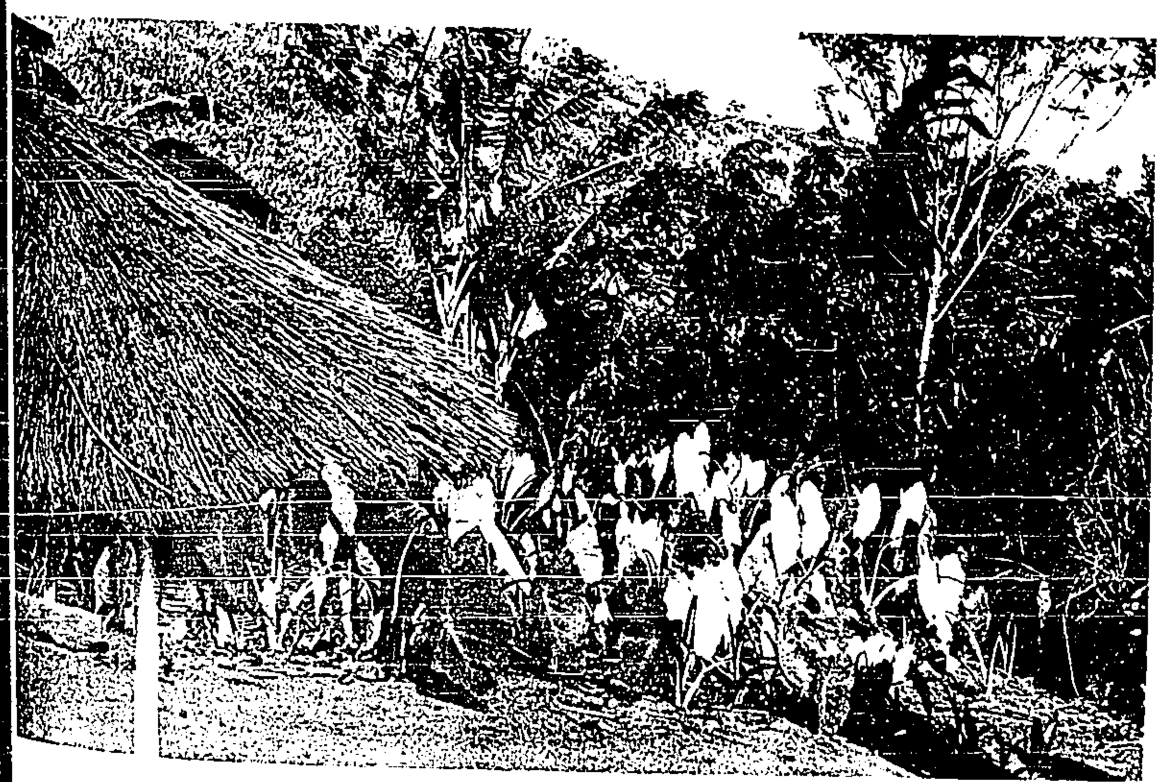
A number of useful shrubs and herbs, ornamentals, 'luxury' food crops and condiments are planted around the house. They include Broussonetia papyrifera, Cordyline spp., Croton spp., Musa sp., Casuarina spp.,

PLATE 16A

Taro replanted in a 2 - 3 year old mixed garden at Weylk. Sugar cane and bananas are present as well.

PLATE 16B

An house garden of Taro at Weylk. Note bananas and Cordyline nearby.



Araceae, Colocasia esculenta, Zingiber sp., Plectranthus spp., Graptophyllum pictum, Nicotiana tabaccum, Lagenaria siceraria, Amaranthus spp. and Oenanthe javanica among others.

2.4.4. Commercial gardens and plantations (Plate 17B)

Marketable vegetables such as cucumbers (Cucumis sativa), corn (Zea mays), beans (Phaseolus sp.), peas (Pisum sativum), potatoes (Solanum tuberosum) and tomatoes (Lycopersicum esculentum) may be grown in the mixed crop gardens or in separate gardens in the sweet potato field area. Peanuts (Arachis hypogaea) and passionfruit (Passiflora sp.) are also grown as cash crops. Coffee (Coffea arabica) is grown in small blocks in the settlement area and tea (Thea sinensis) has been introduced recently. Such plantations have developed since the aerial photographs of the region were taken; no estimate of their areal extent is available but it is certainly very small.

2.5. Swampland

The total area of swampland within the study region approximates 23.3 sq.km (9 sq.mi. or 6.4 per cent). Swamps occur widely on the poorly drained floodplains bordering the Wahgi and Gumants Rivers and their main tributaries and less frequently within the scattered enclosed basins and small valleys of impeded drainage on the Baiyer River divide area.

2.5.1. Cane grass swamp

Swampland dominated by the tall cane grass Phragmites karka occurs on many of the floodplain areas of the Wahgi river and locally in very wet seepages between 1520m (5000 ft) and 1820m (6000 ft) altitude. Phragmites karka is the sole dominant forming dense stands up to 4-5m high. Other grasses, such as Leersia hexandra, Sacciolepis indica and Saccharum spontaneum may be present in lower numbers and Oenanthe javanica, Plectranthus sp.1 (6032) and Polygonum longisetum are recorded as forbs. The ground is always waterlogged and during the wettest months of the year the water-table may rise to 0.5-0.7m above the ground surface (Manton, pers. comm.). A coarse fibrous peat develops under the Phragmites.

PLATE 17A

Clearing woody regrowth for a mixed garden at Wurup. A recent fire, not well controlled, burnt Pandanus plants in the left foreground. Standing trees are Casuarina.

PLATE 17B

A market crop garden at Wurup. Corn, pineapples and beans are grown and some sweet potatoes.

2.5.2. Short-grass swamp

Other areas of the upper Wahgi valley are covered with pure or mixed stands of short grasses up to 1m high; Leersia hexandra may be the sole dominant or may share dominance with Ischaemum barbatum and Capillipedium parviflorum. In other cases it is associated with Phragmites karka. The water table is near or at the surface during most of the year and a fibrous peat develops below the grasses.

Site 15 : Mixed Leersia-Phragmites swamp at the Manton pollen-analytical site:

Table 5.9 gives habitat data and cover-density values for species recorded at this site. Leersia hexandra is the dominant grass over the whole site, with cover-density values of 6-8. Also important in the wetter areas are Phragmites karka, Sacciolepis indica and Ischaemum barbatum. Others, showing patchy distribution or present in lower numbers throughout, include Capillipedium parviflorum, Arthraxon hipidus and Isachne globosus. Only a few sedges are recorded and these are present in low numbers. Among the forbs Oenanthe javanica, Emilia prenanthoidea, Polygonum longisetum and Pouzolzia sp. (5798) are important over the whole site, Plectranthus sp.1 (6032) favours less wet areas and Amaranthus sp. (5826), Adenostemma hirsutum and Viola arcuata are present in lower numbers. The shrubs Melastoma affine and Glochidion sp.3 (6201) and the scrambling Nepenthes sp. (6204) and Geitonoplesium cymosum appear in less wet areas while the fern Dennstaedtia sp. (5501) and Lycopodium cernuum are common in all the plots.

2.5.3. Mixed sedge-grass swamp (Plate 36, 37, Chapter 9)

Mixed sedge-grass swamps often border the small ponds in the volcanic landscape of the Baiyer River divide area. Pure stands, 0.5-1m high, of the sedge Machaerina rubiginosa may form a floating mat of vegetation over several metres of water or, where the water is less deep, dominate a mixed stand of sedges and grasses. A dark peat develops beneath the surface vegetation.

Table 5.9 Short-grass swamp : species composition and cover density at site 15.

Location : Manton pollen analytical site. Soil : Red-brown fibrous peat topsoil (12cm) over yellow brown felted peat.
Altitude : 1580m.
Landform : Alluvial plain pH : 5.0.
Drainage : 0

ANU No.	Family	Genus & Species	9	10	11	12	13	14	19	20	21	23	24	25	26	27	28	22	18	17	16	15	1	2	3	4	5	6	7	8	29	30	31	32	33	34	35	36	37	38	39	40
5803	Poaceae	Anthraxon hispidus			x					5	2	2	x	1	2	1		2									x							1	3	x				x		
5805	"	Apluda mutica																									x															
6016	"	Capillipedium parviflorum								6	3	3	7	7	7	8	8	4						x	5	6	5	6	7	4								1	3			3
6048	"	Isachne globosus	2	2	1	x	1	1	x	x	x	3	2	2	2	1	1	4	x	x	2	1	x	1	2	3	3	2	3	2	x	x	x	x	1	x		x	x	x	x	2
6001	"	Ischaemum barbatum			2	x		3	3	3	3	4	4	3	3	3	3	4	2	3	3	3		2							2	1	1	2	x	3	1	2	1	2	2	3
6041	"	Leersia hexandra	8	8	8	8	8	8	8	8	8	8	8	8	8	6	7	8	8	8	8	8	8	8	8	7	7	8	7	8	6	8	8	8	8	8	8	8	8	8	8	8
6189	"	Paspalum orbiculare																										x														
5782	"	Phragmites karka	3	3	2	3	3	3	3	3	x	2	2	1	1	1	1	1	2	3	3	4	2	1	2	1	1	1	2	1	3	3	1	3	3	1	x	1	3	1	1	1
6011	"	Sacciolepis indica	4	3	1	x	1	x	4	2	6	4	3	3	3	1	2	5	3	1	x	x	2	x	1	x	2	3		x		x	x	x	x	2	x	x	x		x	3
6014	Cyperaceae	Fimbristylis sp.										x		x	x		x						x							x				1	x				x		x	
6045	"	Lipocarpha chinensis							x		x	x	3	3	x		1	3			1																					
6010	"	Rhynchospora rugosa										x																														
6039	"	Scirpus mucronatus																					x																			
5826	Amaranthaceae	Amaranthus sp.	1	x	x		x	1	1			x	x			x		x	x			x						x				x	x		x	1						x
5732	Apiaceae	Oenanthe javanica	5	5	3	5	4	6	5	1	x	1	x	1	x	x	x	1	6	4	4	5	2	1	2	2	2	2	3	4	4	4	5	5	4	5	6	5	5	6	4	5
5841	Asteraceae	Adenostemma hirsutum			1				x		x											1		1				1	3				x					x		4	3	1
6019	"	Emilia prenanthoidea	3	3	3	1	2	2	5				x					x	4	5	3	3	1	1	x	1	2	1	3	x	x		x	x	2	2	x	x	2	2	2	x
5797	"	Erechthites valerianifolia	x	x	x					x												x								x					x							
5780	"	Erigeron sumatrensis	x																																							
6017	"	Lactuca sp.									1																															
5836	Fabaceae	Crotalaria ferruginea											2					x										4	1													
5893	"	Desmodium lasiocarpum								4																																
6032	Lamiaceae	Plectranthus sp. 1	x			2				1	4	4	2	2	1	2	1	4					x	2	x	x	2	2	3	2	3	4	3	5	5	2	x	x	2	1	2	
6200	"	Gen. 1	x																				x																			
6205	Malvaceae	Hibiscus sp.							1																																	
6203	Melastomataceae	Melastoma affine																x		3	3	1	7	8	7	6	6	5	3	5	5	5	4	4	5	3	3	5	4	6	6	3
6201	Euphorbiaceae	Glochidion sp. 3																	x	1	2	1	3	3	4	4	5	4	3	1	x		1	1	x	1	1	2	2	1	2	x
6204	Nepenthaceae	Nepenthes sp.											2	x																		1	1		1		1	1				
6202	Philesiaceae	Geitonoplesium cymosum																					1	4	3	2	3															
5736	Polygonaceae	Polygonum longisetum	4	3	x	2	3	3	3										4	3	3	2	x		x	x	x			x	1		x	1	2	4	4	2	1	2	x	1
5798	Urticaceae	Pouzolzia sp.	1	4	7	5	5	4	5				x	x				1	5	7	5	7	6	5	5	6	6	4	4	3	6	5	6	6	5	6	6	8	7	4	6	2
6051	Violaceae	Viola arcuata	4	1		x	1			3	2	2	1			x		2					1	x			1	1	1												x	
5828	"	Viola betonicifolia																											x													
5501	Dennstaedtiaceae	Dennstaedtia sp.	3	2	2	x	x		1											2	4	4	4	2	4	3	4	x	1	5					x	x	1	2	3	3	3	2
6015	Lycopodiaceae	Lycopodium cernuum									1	2	2	2	2	x	1	2					1	1		x	1	x		x						1		x				

Site 17 : Mixed sedge-grass swamp at Draepi:

Table 5.10 gives habitat and cover-density data for species present at this site. Machaerina rubiginosa dominates the floating mat vegetation with cover-density values of 6-7. Other sedges, such as Cyperus globosus and Juncus cf prismatocarpus also show high values, together with the grasses Dimeria dipteros and Leersia hexandra. Caldesia parnassifolia shows cover density values of 1-4 and Eriocaulon hookerianum and Limnophyla aromatica are also important as aquatics. Other species are present in lower numbers, including Arthraxon hispidus, Isachne globosus, Ischaemum barbatum, Phragmites karka and Sacciolepis indica among the grasses, Cyperus haspan, Eleocharis sp. (6056), Lipocarpha sp. (6045) and Rhynchospora rugosa among the sedges. The forbs, Emilia prenanthoidea, Lactuca sp. (6017), Dysophylla verticillata, Plectranthus sp.1 (6032) and Viola arcuata are present and Xyris sp. (6052) and Thelypteris palustris are also recorded.

With decreasing water-depth, dominance changes somewhat; Leersia hexandra and Ischaemum barbatum become more important among the grasses, Eleocharis sp. (6056), Fimbristylis sp. (6014) and Lipocarpha sp. (6045) amongst the sedges. Oenanthe javanica, Hypericum sp.2 (6055) and Viola arcuata become important amongst the forbs and Plectranthus sp.1 (6032) also becomes more abundant. Most of the species present before are retained in lower numbers but others, such as Caldesia parnassifolia, Lactuca sp. (6017) and Thelypteris palustris disappear.

DISCUSSION

A mosaic of non-forest vegetation types occurs in the Mt Hagen region. The types have been defined for present purposes on the basis of mixed criteria, such as growth form of the main species, species composition and abundance, association with certain landforms or with native settlements, and their areal extent has been estimated. They include:

Patches of trees and shrubs associated with settlement areas occupying ca 16 sq.km within the study region as a whole. (2.1),

Table 5.10 Mixed sedge-grass swamp: species composition and cover-density at Site 17.

Location : Draepi pollen-analytical site
Altitude : 1885m
Landform : Valley floor
Drainage : 0

Soil : Coarse red-brown peat
pH : 6.0

ANU No.	Family	Genus & Species	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21
5803	Poaceae	Arthraxon hispidus	x		1	2	2	x	x			x			1	1	2	1	2	1
6016	"	Capillipedium parviflorum																	x	
6024	"	Dimeria dipteros	3	5	4	5	5	6	2	3	1	3		1	2		2			
6048	"	Isachne globosus	x			x	x								x	x		2	1	2
6001	"	Ischaemum barbatum	x	1	3	2	2	1	3	2	3	3	3	4	3	2	7	6	5	7
6041	"	Leersia hexandra	4	5	2	5	5	5	6	6	6	7	7	8	8	8	4	5	6	4
5782	"	Phragmites karka	1		1	2	2											x	1	
6011	"	Sacciolepis indica	x	x	2	3	3	2	x		1	1	x	1	1	x	2	3	3	2
6038	Cyperaceae	Cyperus globosus	3	5	4	5	5	5	2	2	2	3	2	1	2	1	2	2	3	1
6059	"	Cyperus haspan				x	x		x	1	x	x								
6056	"	*Eleocharis sp.*			x	1	3		4	1	2	2	x		x	2	2	2	4	3
6014	"	Fimbristylis sp.							2	2	4	3	2	3	3	4	6	6	7	7
6045	"	Lipocarpha sp.			1	1	1	3	3	3	2	2	2	1	x	1	x	x	2	2
6044	"	Machaerina rubiginosa	7	7	6	7	7	7	3	4	4	1	3	2	2	1	2	x	3	5
6010	"	Rhynchospora rugosa	1	x	x	x	2		1	x	1	x	1	2	2	x	x	x	x	
6039	"	Scirpus mucronatus	3						2	x	x	x	2	x	x	1				
6037	Juncaceae	Juncus cf. prismatocarpus	1	2	3	2	3	4	2	2	2	2	x	x	2	x	2	x	2	1
6042	Alismataceae	Caldesia parnassifolia	1	3	4	4	4	3												
5732	Apiaceae	Oenanthe javanica									x	x	x	x	x	x	1	1	2	1
6054	Asteraceae	Adenostemma hirsutum																	x	1
5724	"	Crassocephalum crepidioides												x				x		2
6019	"	Emilia prenanthoiden			x	2	x	x								x			x	1
6017	"	Lactuca sp.	1	1	x	2	1	x				1								
6040	*Eriocaulaceae*	Eriocaulon hookerianum	x	x	2	2	3	5	x	1	1	1	x	2	2	1	x	x	x	1
6055	Hypericacene	Hypericum sp. 2									1	1	2	x	2	2	x	x	1	1
6043	Lamiaceae	Dysophylla verticillata	x	x	x	x	x	x			x			x			x	x	x	x
6032	"	Plectranthus sp. 1				x	x	x		x	x	x	x	x	x	1	x	2	2	2
6053	Lentibulariaceae	Utricularia sp. 1				x			2	2	x	1		x					x	x
6061	Orchidaceae	Thelypteris palustris			3	3														
6062	"	gen. 1.	1																	
6049	Scrophulariaceae	Limnophyla aromatica		2	2	2	3	2	3	3	3	3	3	2	2	2	2	2	2	2
6051	Violaceae	Viola arcuata			1	2				x		x	x	1	1	1		x	1	2
6052	Xyridaceae	Xyris sp.	x	x						x	x	x	x							
6015	Lycopodiaceae	Lycopodium cernuum			1			1											x	x

Patches of forest and scrub within grassland, with areal extent ca 39 sq.km (2.2),
Grassland, occupying ca 230 sq.km (2.3),
Gardens, covering about 19 sq.km (2.4),
Swampland, occupying ca 23 sq.km (2.5).

In fact, the types described are rarely separated by distinct boundaries but merge, one into another.

Species Distribution

No detailed observations were made on environmental features and hence direct correlation of species distribution with environmental parameters is impossible. In some cases, however, such as the swamplands, changing species composition is apparently correlated with changes in gross habitat features such as water-depth. Figures 5.1 and 5.2 summarize the swamp zonations at sites 15 and 17 respectively.

Some other vegetation types are anthropogenic; the sweet potato and mixed crop gardens and their associated fallow and regrowth successions are directly correlated with biotic influences and regrowth shrub vegetation within grassland represents a later stage of the succession towards secondary forest. Figures 5.3, 5.4 and 5.5 show the probable successions after gardening.

The oak and other forest patches associated with settlement areas are mixed stands of forest trees and regrowth shrubs; they may be relict forest stands, secondary forest or mixtures of both. The forest patches on steep slopes and on stream banks are similarly mixed stands; the distribution of both is related, at least indirectly, to human influences.

Indicator Species

Indicator species of non-forest vegetation types may be sought by comparison of species composition at different sites and along various traverses. Because many species are wide-ranging the vegetation types have often had to be grouped. In some cases, where a species is far more abundant in one vegetation type than in another, it is included as an indicator of the first type.

Table 5.11 lists probable indicator species for the subalpine grassland and mires. If this is compared with the forest data given in Chapter 4, Drimys sp.4 (6392) is shown to have little indicator value as it is also widespread in the forests. Coprosma, Trochocarpa and Vaccinium are genera common to Mixed forest and sub-alpine grassland; however, they remain valuable indicators of high altitudes (above 3190m).

Table 5.12 lists indicators of swampland. Of these species Oenanthe javanica may occur in gardens and Viola arcuata in grassland but they are not as important there as in swamps.

Most indicators of gardens (Table 5.13) are crop plants or domesticates but some are herbs and woody species which are almost always associated with gardens and garden fallow; their presence in pollen spectra would provide direct evidence of gardening. Casuarina spp. are also relatively common on stream banks.

Some indicators of shrub regrowth are suggested in Table 5.14 but wider experience will probably prove these to be of doubtful value. Most other species are widespread in dry land non-forest vegetation (Table 5.15). Some, such as Ficus dammaropsis, Dodonaea viscosa, Alphitonia incana, Omalanthus nervosus, Acalypha sp.1 (6075), Cordyline spp., Debregeasia sp.2 (5771) and Eurya meizophylla are probable more abundant in settlement area and garden regrowth vegetation than elsewhere but further quantitative data are required to confirm this.

Other taxa have already been considered as forest plants (2 asterisks in Table 5.15) or as indicators of regrowth within forest vegetation (1 asterisk in Table 5.15). These taxa have value in the interpretation of pollen spectra only in relation with others of more restricted occurrence.

Forest species occasionally recorded outside continuous forest areas (for example, in settlement areas, in forest patches on steep slopes or advanced regrowth near the forest margin) are listed in Table 5.16. Their significance in a pollen diagram must once again depend very heavily on the context in which they are found.

Finally, a number of species are found in both dry-land and swampland vegetation (Table 5.17); they only indicate non-forest.

Figure 5.1 Swamp zonation at Site 15, Manton's.

Figure 5.1 Swamp zonation at Site 15

Water table 0.5 - 0.7m above peat Surface at times	-	<u>PHRAGMITES</u> <u>KARKA</u> Leersia hexandra Sacciolepis indica Saccharum spontaneum
↑		
Water table at surface; little or no running water	-	<u>LEERSIA</u> <u>HEXANDRA</u> - <u>POUZOLZIA</u> SP. (5798) Sacciolepis indica Oenanthe javanica Emilia prenanthoidea Polygonum longisetum Viola arcuata
↑		
Water table at 0.25 - 0.5m below surface at most times	-	<u>LEERSIA</u> <u>HEXANDRA</u> - <u>CAPILLIPEDIUM</u> <u>PARVIFLORUM</u> - <u>POUZOLZIA</u> SP.(5796) - <u>MELASTOMA</u> <u>AFFINE</u> Oenanthe javanica Plectranthus sp.1 (6032) Emilia prenanthoidea Polygonum longisetum Dennstaedtia sp. (5501) Glochidion sp.3 (6201)

Figure 5.2 Swamp zonation at Site 17, Draepi.

Figure 5.2 Swamp zonation at Site 17

Water depth	Substrate	Vegetation
3-4m water	Floating mat vegetation 0.5-1.0m thick peat	- <u>MACHAERINA</u> <u>RUBIGINOSA</u> Dimeria dipteros Leersia hexandra Cyperus globosus Caldesia parnassifolia Eriocaulon hookerianum Juncus cf prismatocarpus
0.5-1m water	Floating mat vegetation 1-2m peat	- <u>LEERSIA</u> <u>HEXANDRA</u> Machaerina rubiginosa Eleocharis sp. (6056) Fimbristylis sp. (6014) Limnophyla aromatica
Waterlogged peat		- <u>ISCHAEMUM</u> <u>BARBATUM</u> - <u>FIMBRISTYLIS</u> SP. (6014) Machaerina rubiginosa Eleocharis sp. (6056) Leersia hexandra

Figure 5.3 Succession in sweet potato gardens.

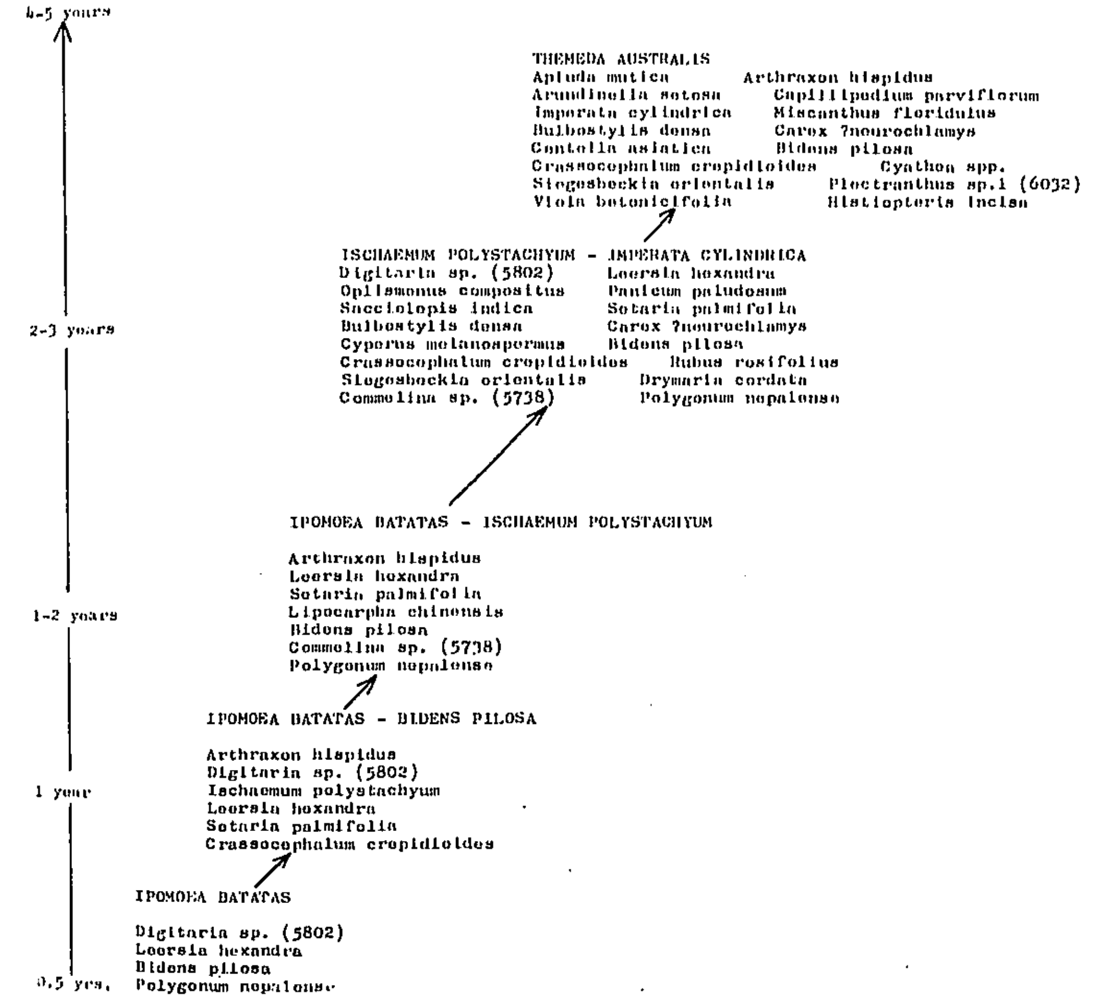


Fig. 5.3. Succession in Sweet potato gardens.

Figure 5.4 Succession in mixed gardens.

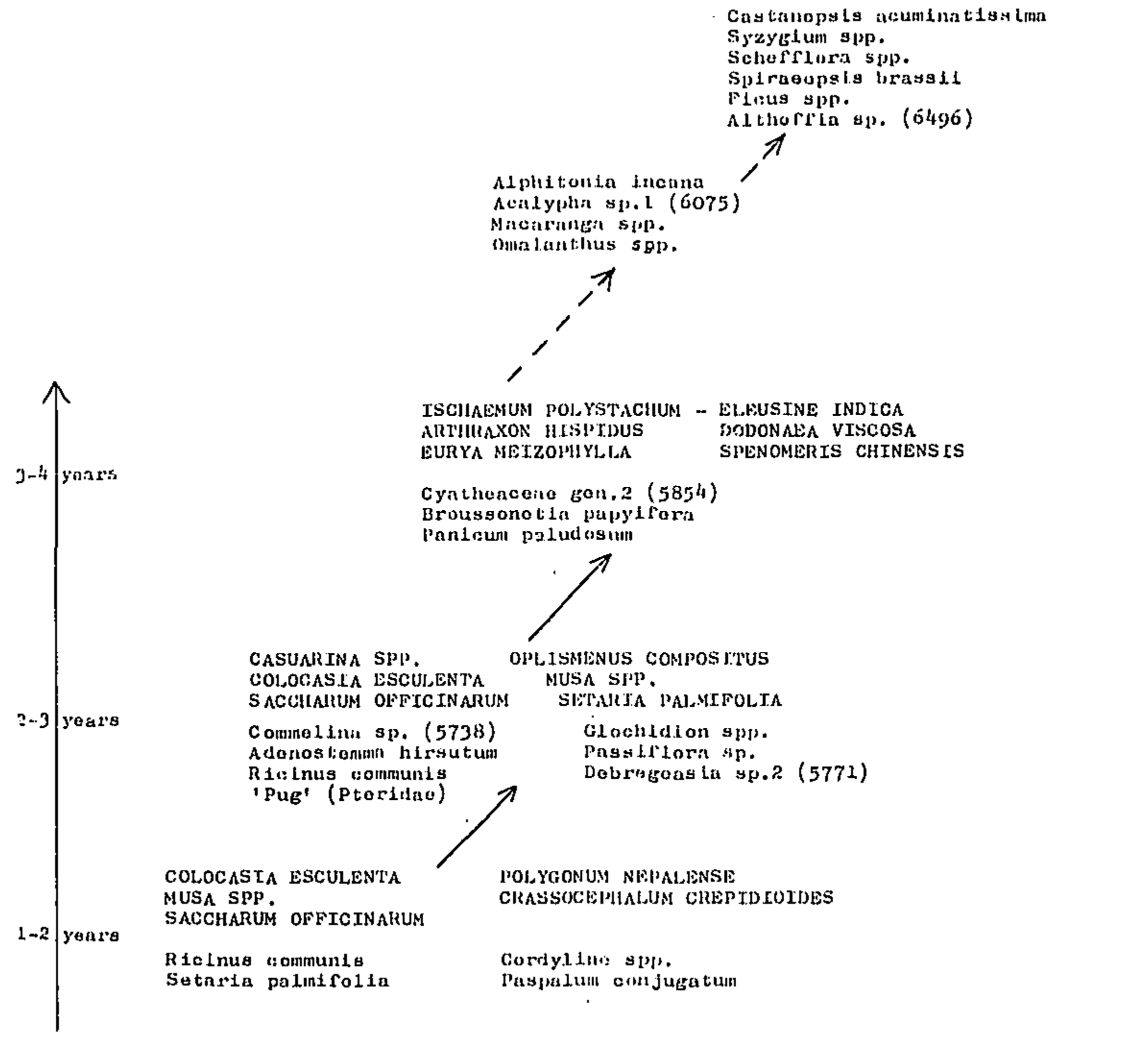


Fig. 5.4 <u>Succession in Mixed gardens.</u>

Figure 5.5 Succession in shrub regrowth in grassland.

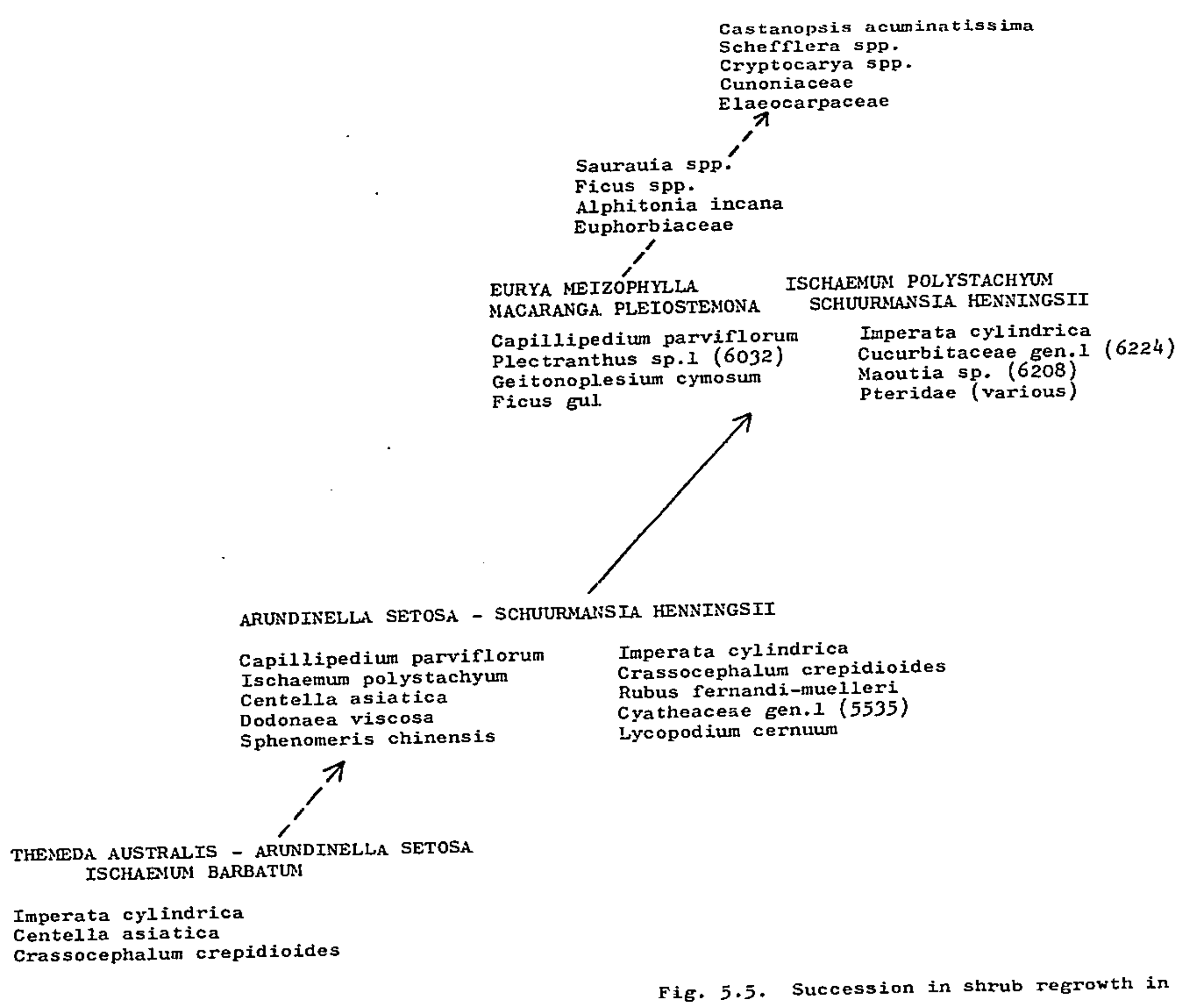


Fig. 5.5. Succession in shrub regrowth in grassland.

Table 5.11 Indicator species of subalpine grassland and mires

Coprosma divergens	Gahnia javanica
Drimys sp.4 (6392)	Carex ?capillacea
Rhododendrom womersleyi	Carpha alpina
Rhododendron saxifragoides	Scirpus crassiusculus
Vaccinium cf evanidinervium	Potentilla sp.1 (6393)
Styphelia suaveolens	Potentilla sp.2 (6402)
Deyeuxia brassii	Anaphalis sp.2 (6389)
Danthonia archboldii	*Tetramolopium sp.* (6387)
Deschampsi klossii	Astelia papuana
Poa nivicola	Drapetes ericoides
Hierochloe redolens	Trachymene novoguinensis
Gleichenia bolanica	Ranunculus sp. (6398)
Gleichenia vulcanica	Trochocarpa decockii
Eriocaulon brevipedunculatum	

Table 5.12 Indicator species of swampland

Phragmites karka	Xyris sp. (6052)
Oenanthe javanica	Eleocharis sp. (6056)
Viola arcuata	Machaerina rubiginosa
Limnophyla aromatica	Scirpus micronatus
Amaranthus sp. (5826)	*Juncus cf prismatocarpus*
Polygonum longisetum	Melastoma affine
Pouzolzia sp. (5798)	Utricularia sp.1 (6053)
Nepenthes sp. (6204)	Eriocaulon hookerianum
Caldesia parnassifolia	

Table 5.13 Indicator species of gardens

Saccharum officinarum	Ipomoea batatas
Saccharum edule	Musa spp.
Colocasia esculenta	Dioscorea spp.
Psophocarpus tetragonolobus	Ricinus communis
Dolichos sp. (6175)	Nicotiana tabaccum
Broussonetia papyrifera	Xanthosoma sagittifolium
Amaranthus tricolor	Hydrocotyle javanica
Rungia klossii	Lysimachia japonica
Oxalis corniculata	Dicliptera sp. (5847)
Commelina sp. (5738)	Solanum torvum
Polygala paniculata	Artocarpus vrieseanus
Boraginaceae (6077)	Adenostemma hirsutum
Drymaria cordata	Siegesbeckia orientalis
Polygonum nepalense	Wahlenbergia sp. (6073)
Solanum nigrum	Viola betonicifolia
Rubus rosifolius	Physalis sp. (5847)

Table 5.14 Indicator species of shrub regrowth in grassland

Melastoma ?polyanthum	Hedyotis sp. (6233)
Stephania montana	Rubus moluccanus
Commersonia batramia	Poikilogyne sp. (6480)
Callicarpa sp. (5530)	Ipomoea fibriosepala
Saurauia sp.10 (5525)	Maoutia sp. (6208)

Rubus fernandi-mulleri

Table 5.15 <u>Ubiquitous dry land non-forest species</u>

* Macarange ?warburgiana	Ficus dammaropsis
Macaranga pleiostemona	* Ficus gul
* Omalanthus nervosus	Cordyline spp.
Piper sp.5 (6415)	* Alphitonia incana
Maesa sp. (6293)	Dodonaea viscosa
** Pandanus sp.1 ('Um')	Eurya meizophylla
* Macaranga ?womersleyi	* Ficus tonsa
Euphorbis plumerioides	Ficus adenosperma
* Carpodetus sp. (6488)	* Acalypha sp.1 (6075)
* Spiraeopsis brassii	* Polyscias sp. (6339)
Schefflera sp. (6352)	Harmsiopanax sp. (6370)
** Castanopsis acuminatissima	Alstonia sp. (6438)
* Rhus taitensis	Graptophyllum pictum
** Pittosporum pullifolium	Evodia sp.6 (6458)
* Wendlandia sp. (6218)	Evodiella sp. (6435)
* Saurauia spp. (6462, 6324, 6467)	Trimenia papuana
* Trema amboinensis	Debregeasia sp.2 (5771)
** Schuurmansia henningsii	* Debregeasia sp.1 (6372)
Arundinella setosa	Miscanthus floridulus
Imperata cylindrica	Ischaemum polystachyum
Themeda australis	Ophiuros exaltatus
Paspalum conjugatum	Digitaria sp. (5802)
Carex ?beccans	Osbeckia chinensis
Rhynchospora rubra	Polygala sp.1 (6008)
Centella asiatica	Bidens pilosa
Cyatheaceae	Crassocephalum crepidioides
Gleicheniaceae	Blumea arnakidophora
Pteridaceae	Crotalaria anagyroides
* Phyllanthus nervosus	Impatiens sp. (5553)

Table 5.16 Forest species occasionally found outside continuous forest areas

Elaeocarpus crenulatus	Geniostema arfakense
Schizomeria serrata	Albizia fulva
Sericolea sp. (6431)	Discocalyx sp. (6319)
Sloanea sp.2/3 (6317)	Prunus costata
Nothofagus sp.1 (6485)	Symplocos sp. (6343)
Cryptocarya sp.1 (6321)	Araucaria cunninghamii
Cryptocarya sp.4 (6459)	Papuacedrus papuanus
Syzygium sp.2 (6285)	Podocarpus imbricatus
Syzygium sp.3 (6469)	Syzygium sp.5 (6314)

Table 5.17 Ubiquitous species of non-forest vegetation

Erigeron sumatrensis	Arthraxon hispidus
Lactuca sp. (6017)	Sacciolepis indica
Desmodium spp.	Fimbristylis sp. (6014)
Emilia prenanthoidea	Rhynchospora rugosa
Erechthites valerianifolia	*Cyperus globosus*
Plectranthus sp.1 (6032)	
Lipocarpha chinensis	Glochidion sp.1 (6081)
Isachne globosus	Hibiscus sp. (6205)
Leersia hexandra	Geitonoplesium cymosum
Apluda mutica	Lycopodium cernuum
Ischaemum barbatum	Hypericum sp.1 (6002)

CHAPTER 6

THE MODERN POLLEN RAIN

Modern pollen rain studies provide information on the production, dispersal, deposition and preservation of pollen grains which may aid interpretation of fossil pollen assemblages. Combined with a knowledge of extant vegetation such studies permit considerations of pollen sources, of pollen spectra produced by different communities and of species representation; together these provide a substantial basis for the reconstruction of past vegetation types.

The lack of a direct relationship between the percentage of a species in the pollen spectrum and any measure of its abundance in the surrounding vegetation was recognised at an early stage in European work and led to studies of pollen production and dispersal and of pollen representation in contemporary surface samples.

Studies on pollen production (per anther, flower, plant etc.), on pollen characteristics important in relation to dispersal (for example, sculpture, size and weight of grains, tendency to stick together etc.) and on breeding system in general (frequency of flowering, pollination mechanism etc.) have been carried out by numerous workers and are reviewed in Erdtman (1943) and Faegri and Iversen (1950, 1964). The differing breeding systems of flowering plants affect the likelihood of their being found in fossil sediments. In some cases the presence of individuals of particular breeding types, such as autogamous and some zoogamous species, may be of great importance as indicating certain vegetation types but nothing can be concluded from their absence. In other cases, such as certain zoogamous species and many anemophilous species, large quantities of pollen may be produced which greatly exagerates the importance of the parent plants in the vegetation.

The realization of differential representation was further investigated by comparing the pollen content of surface layers of living bogs with the composition of adjoining forest areas (Erdtman 1922, Rudolph and Firbas 1925, Hesmer 1933, Aario 1932, cited by Godwin 1934). Some species (for example, Pinus) were found to be overrepresented and others (for example, Quercus and Tilia) under-represented in pollen diagrams due mainly to different magnitudes of pollen production in the various species (Godwin 1933).

Close correlations between relative percentages of pollen types recorded in modern pollen rain spectra and species composition in surrounding vegetation (recorded species frequency, density, basal area, foliage cover, size-classes of trees) were noted by Carrol (1943), Hansen (1949) and Potter and Rowley (1960) in North American studies, although some species showed over and under representation in the pollen spectra. Davis and Goodlett (1960) and Potzger et al (1957), on the other hand, found very little quantitative relation between the frequencies of pollen types in surface samples and frequency of species in the vegetation and this led Davis (1963) to question a number of the basic assumptions of this part of pollen analysis. She emphasized the need for a correction factor (R-value) for each pollen type. Correction of fossil pollen values for differences in representation had been proposed previously by Iversen (1947, cited in Faegri and Iversen 1964) and Fagerlind (1952) both of whom considered it would lead to more accurate interpretation of pollen diagrams. Correction factors have been used for groups of species by Iversen (1952) and Tsukada (1958) and for individual pollen types by Curtis (1959) and Davis (1963).

Further recent comparisons of modern pollen spectra and species composition of vegetation, however, continue to give varying results (compare Bent and Wright 1963, with Terasmae and Mott 1964) and the validity of the use of individual R-values can be questioned (Janssen, 1967).

The main problems of the above quantitative - comparative approach are the lack of knowledge of the areal extent of the vegetation contributing pollen to a particular sampling site and of the mode of pollen transfer to the site. Comparisons are made usually on a local scale (site-specific), although long-distance dispersal has been cited in explanation of discrepancies in a number of cases.

Correlations between modern pollen spectra and vegetation are regional rather than local in the studies of Terasmae and Mott (1964, 1965), Ritchie and

Lichti-Federovich (1963) and King and Kapp (1963) and Lichti-Federovich and Ritchie (1965) propose the use of a geographical unit, rather than the vegetational one commonly used for comparisons with modern pollen rain. They establish a close correlation between pollen spectra and landform-vegetation types for west central Canada at both general and specific levels of comparison and use their data to extend considerably previous interpretations of fossil assemblages. Davis (1967) agrees with this approach and tests it further by using both Canadian and northern United States modern pollen rain data in interpretation of late-glacial pollen diagrams from these areas.

Ignorance of the mode of pollen transfer has added to the problems of interpretation of the relationship between modern pollen rain spectra and vegetation composition. The basic idea expressed by von Post (1916 in Tauber, 1965), Erdtman (1943), Wodehouse (1935) and Faegri and Iversen (1950, 1964) is that parent plants liberate large quantities of pollen which floats in the air, or is carried to high altitudes by thermal convection currents; this spreads and mixes over large areas but eventually falls back to the ground as evenly distributed 'pollen rain'. As well as this there is some direct transfer of pollen from swamp plants and possibly from plants bordering the swamp or lake to the developing peat or organic sediment. Tauber (1965) questions this simple model of pollen transfer, in particular the assumed more or less vertical descent of the pollen rain and replaces it with a composite model based on experimental data. He considers that, for forested areas, deposited pollen will consist of at least three components: pollen carried through the trunk space, pollen carried above the canopy and pollen brought down by rain. Each of these components will derive from vegetation of widely different extent; the trunk space component may originate from within some hundred metres of the site, pollen carried above the canopy from within several kilometres and the rainout component will contain much from even farther afield. In a recent paper he not only provides direct evidence for the transport of pollen in the trunk space but also for strong filtration of pollen by vegetation and for refloatation of pollen of local species within a forested area, thus adding further complexities to the process of pollen transfer (Tauber, 1967a).

Other studies by Andersen (1967) within deciduous forests in Denmark suggest that vertical fall of pollen is as important as horizontal drift in some areas and Turner (1964), studying dispersal of Pinus pollen in Scotland, has emphasized the importance of the forest (plantation) edge as a pollen source. The relatively rapid decrease in pollen frequency which she recorded as distance from the source increased may be a general phenomenon. Janssen (1967) finds that the amount of pollen represented will decrease logarithmically with increasing distance from the source. He uses this to define a local, extralocal and regional component for any sampling point. His local pollen rain component is derived largely from plants growing at or very close to the sampling point, the extralocal component from plants that grow on the slopes and 'upland' adjacent to the site and regional pollen rain from plants 'common far beyond the immediate basin slopes'. Tauber's (1965) trunk space component is correlated with Janssen's extralocal contribution, the canopy and rainout components of Tauber with the regional contribution.

The probability that long distance transport of certain pollen types might have importance for the interpretation of fossil pollen spectra rested for long on more-or-less chance observations of present day behaviour (Gregory 1961, Faegri and Iversen 1964) but Terasmae and Mott (1964), Maher (1964) and Ritchie and Lichti-Federovich (1967) have now conclusively demonstrated its importance in Canada and the U.S.A.

Differential destruction of pollen in fossil sediments may also provide a source of error hindering correct interpretation of pollen spectra. This phenomenon, to which passing recognition is often given (Davis and Goodlett 1960, Lichti-Federovich and Ritchie 1965), has been considered unimportant in both surface and lower samples of organic lake sediments and peats and even in mineral soils, alluvial deposits, archaeological sites and desert deposits (Dimbleby 1957, Martin 1963, Mehringer 1965) it has been largely neglected (Havinga, 1967).

Havinga (1963, 1964, 1967) has classified the types of pollen corrosion found in fossil deposits and investigated the effects of microbial attack and oxidation on pollen in a series of laboratory and field experiments. Together with the results of similar studies by Sangster and Dale (1961, 1964) these data provide valuable information for use in interpretation of modern pollen rain and fossil spectra.

Although a great deal more work remains to be done the value of modern pollen rain studies in clarifying and testing the basic assumptions of pollen analysis and in providing a critical basis for interpretation of fossil pollen assemblages is obvious from the studies considered above. Wright (1967) states that surface sample analyses have become a standard technique in most American historical pollen studies and considers that equal numbers of surface samples and sediment-core samples should be analysed, at least in new areas of investigation.

In New Guinea, Flenley (1967) analysed the pollen content of rainwater caught in a standard rain gauge at Wabag (Western Highlands District) over a period of twelve months and that of six moss polsters collected from different sites within the Wabag and Mt Wilhelm (Eastern Highlands District) regions. The various spectra showed different relative values for forest and non-forest pollen types related to their ecological situation and indications of long-distance transfer were found in tree pollen recovered from altitudes high above the occurrence of the parent plants. In the present study seventeen moss polsters and sixteen surface sediments were analysed in an attempt to gain some idea of the composition of the modern pollen rain of the Mt Hagen region, of local, extralocal and regional pollen sources and of possible differences in species representation which could be used to aid interpretation of the fossil pollen assemblages.

CHOICE OF METHODS

Species composition of modern pollen rain has been studied in a number of ways: by sampling pollen content of the atmosphere, by analysing moss polsters and surface sediment samples. Sampling the atmosphere involves the use of artificial devices of one kind or another. The more sophisticated of these collect pollen by impaction on coated slides, held in a horizontal position and either kept immobile, as in the Durham sampler, or rotated, as in the Hirst Spore Trap. Control of collection time is possible and hence amounts of pollen per unit volume of air can be calculated (Potter and Rowley 1960, Ritchie and Lichti-Federovich 1963, 1967). Other samplers filter a known volume of air, collecting pollen on a suitable surface (Lewis & Ogden, 1965). Such volumetric samplers provide standard information on the hourly, daily, seasonal and yearly pollen content and composition of the atmosphere and, depending on location, can be used to gain information on both local and regional pollen rain. The drawbacks to their use include the need for frequent attention and a power supply, their failure to sample rainout pollen and their only partial analogy with natural sedimentation conditions in terms of position, surface conditions and so on. Lewis and Ogden (1965) believe that the modification of natural aerodynamics around such devices must modify the efficiency with which they sample the air. Most importantly, however, the large short-term variations in atmospheric pollen content require that data from these sources must be collected over many years before they can usefully be applied to the interpretation of fossil spectra.

Simple devices used widely for collection of modern rain samples include rain gauges, stock watering tanks, sunken jars filled with liquid and coated (sticky) surfaces placed at or above ground level (Ranson and Leopold 1962, Flenley 1967, Martin 1963, Lewis 1962, Lichti-Federovich and Ritchie 1965). Problems outlined above, such as inefficient collection in wet or dry conditions and lack of simulation of natural sedimentation conditions, apply to some of these samplers but generally they are more useful than those already described in that they require less attention and collect pollen rain over a longer period of time.

Natural pollen traps used widely to sample modern pollen rain include moss polsters (Carrol 1943, Hansen 1949, Potzger et al 1956, Potter and Rowley 1960, Proctor and Lambert 1961, Turner 1964, King and Kapp 1963, Andersen 1967, Wright et al 1967), surface soil and leaf litter samples (Dimbleby 1957, Bent and Wright 1963, Wright et al 1967) and surface sediments of lakes and ponds (Davis and Goodlett 1960, Maher 1963, Lichti-Federovich 1965, Davis 1967). The greatest advantages in the use of these types of samples is that they are natural sedimentation surfaces and the pollen present represents a number of years of deposition; hence a smoothing out of variations in pollen production and pollen rain composition has occurred. Local pollen rain is the main component of moss polsters and surface soil samples taken from forested and other 'closed' communities, while both local and regional representation is expected in samples from non-forested areas, or 'open' sites. The possibilities of differential pollen migration (Rowley and Rowley 1956), of mixing and other forms of contamination (Maher 1963) and of differential pollen preservation (Andersen 1967) must be taken into account with these samples and chemical extraction of the pollen is necessary.

The advantages and disadvantages of both artificial and natural pollen rain samplers dictate that, for a more or less complete appreciation of the total transfer system, both must be used. In the present study natural sediment, moss and litter samples were combined with a simple direct sampler of the atmospheric pollen content.

FIELD METHODS

Field conditions did not permit the use of mechanical devices or pollen traps requiring frequent attention. Hence, for the collection of samples of atmospheric pollen, 44 gallon drums cut lengthwise were set up on stands 1.5-2.0m above ground level at various points around the pollen analytical sites. Initially these were partly filled with rain water taken from local plantation owner's tanks and the surface covered with ½inch wire mesh to withhold large detritus from the water. Since rainfall per annum averages 2600mm (102 inches) in the Mt Hagen region and no month has less than 25mm (1 inch) it was considered that the tanks would provide adequate samples of atmospheric pollen content and that they could be left untended for relatively long periods of time. However, it was found on returning to the area after an absence of several months that many of the tanks had been interfered with by the local inhabitants (contents tipped out, soil added, stands broken and tanks used elsewhere) and the remaining samples were discarded.

Surface sediment samples, comprising the uppermost 1cm of sediment taken from an area of 10sq. cm, were collected at ca 200m intervals in traverses across the pollen analytical sites and from five subplots within garden and regrowth vegetation plots. Within continuous forests and forest patches small moss polsters were collected in a similar manner, from fallen logs and from the Bryophyte ground cover. Local samples were bulked, labelled and sealed in plastic bags for return to the laboratory.

LABORATORY METHODS

Time permitted the analysis of only a certain number of the surface samples collected and accordingly a choice was made of samples to be treated on the basis of ecological location. For extraction of pollen the moss polsters and surface sediment samples were dispersed firstly in distilled water in an 'Atomix' machine (blender) run at half speed for approximately 30 seconds. The material was transferred to 250ml polyethylene tubes and centrifuged for 5 minutes at 3600 revs per minute. After decanting the supernatant approximately 5 ccs of the remaining sediment was used for pollen analysis. Subsequent treatment followed the standard procedure for fossil samples:

1. Place 1 cc of material on square of terylene muslin and stretch over a waisted glass rod, fasten with a rubber band.
2. Heat for a few minutes (5 to 15) in 10% potassium hydroxide in centrifuge tube in a water bath, press out excess liquid, remove rod, add distilled water, balance and centrifuge.
3. Wash in distilled water, balance, centrifuge.
4. Wash in dilute acetic acid (30%), balance, centrifuge.
5. Wash in glacial acetic acid, balance, centrifuge.
6. Wash in acetic anhydride, balance, centrifuge.
7. Add acetolysis mixture (9 parts acetic anhydride : 2 parts conc. sulphuric acid) in equal quantities

to each sample. Stir.

8. Heat in water bath for about 1 minute, stir, observe pollen under low power microscope, continue process until acetolysis complete - grains should be a light brown colour and have no cell contents.
9. Then add glacial acetic acid to stop the reaction, balance, centrifuge.
10. Wash in dilute acetic acid, balance, centrifuge.
11. Wash in distilled water, balance, centrifuge.
12. Wash in 80% ethyl alcohol, balance, centrifuge.
13. Wash in absolute alcohol, balance, centrifuge.
14. Wash in a mixture of 1 part absolute alcohol : 1 part benzene, balance with benzene, centrifuge.
15. Wash in pure benzene, balance, centrifuge.
16. Add a small quantity of benzene and wash into small phial, add silicon oil AK 2000 (approximately the same volume as the sample) and stir well. Place inside fume cupboard to allow the benzene to evaporate for at least 24 hours.
17. Add further silicon oil if preparation is too dense, mount, seal with nail varnish.

If Hydrofluoric acid treatment is necessary to remove mineral matter then after step 11 above:

1. Wash in 10% hydrochloric acid, balance, centrifuge.
2. Transfer material to nickel crucible using a small amount of 10% hydrochloric acid.
3. Add 40-60% hydrofluoric acid up to 2/3 crucible. Boil for 3-5 minutes or more if sample is largely mineral.
4. Pour contents into 50 ml polypropylene centrifuge tubes containing hot hydrochloric acid (equal volume to that added), put lid on tube. Balance with water into centrifuge bucket, centrifuge.
5. Wash in hot 10% hydrochloric acid, balance, centrifuge. Wash in distilled water, balance, centrifuge.
6. Then continue with steps 12-17 as described above.

<u>Pollen identification in surface and fossil core samples</u>

The pollen and spore content (Pteridophyta and Spermatophyta only considered) of the surface samples and fossil core samples was examined using a Zeiss (Oberkochen) photomicroscope fitted with 10x, 25x, 40x and 100x (oil immersion) plan apochromatic objectives, 8x eyepieces and 2x Optovar lens. Initially identifications of all pollen grains and spores were made at 640x and 1600x magnification; later identification and counting was carried out at 400x magnification with small grains checked at 640x or 1600x magnification. Identification was aided by comparison with pollen reference material collected during the vegetation survey and prepared by a similar method to that of the fossil preparations, with other pollen materials collected previously in New Guinea and with a key to the main types of pollen found in the Wabag region, prepared by Flenley (1967). Many new types were found, however, and to aid identification a simple punch card system was devised using a coded morphological description of the reference material. A more sophisticated coding system has been developed by Walker et al (1968) which involves computer storage and retrieval.

Attempts were made to photograph all pollen taxa recorded and the position of unknown taxa were recorded for future reference. The level of taxonomic identification which can be reached varies with different pollen taxa and the notation of Benninghoff and Kapp (1962) is used to indicate identification of each recorded pollen taxon. A number of pollen taxa remain unmatched so far with the pollen reference material available and these are grouped according to morphological criteria, following the system of Faegri and Iversen (1964). Fossil pollen and reference types are shown together in Plates 18 to 30. They are arranged in mixed ecological-taxonomic groups, namely, forest trees and shrubs, light-demanding forest and non-forest trees and shrubs, forbs, aquatics, sedges and grasses, unidentified taxa (Spermatophyta), ferns and lycopods.

Pollen counting

Counting of the samples was carried out by means of traverses across the slides, spaced at regular intervals (2 - diameters of the field of view), using 400 x magnification. In some samples pollen was sparse and accordingly, traverses were made under 160x magnification with individual grains identified at 400x magnification. Fragments were counted only if they were more than half of a grain, and grains were ignored if they were more than halfway outside of the field of view. Eroded, broken,

PLATE 18

Magnification of pollen in Plates 18-30 is 1250x unless stated otherwise

1/1	Fossil	: Ilex sp. - DR/II/29/524
1/2, 1/3	Type	: Ilex arnhemensis - ref. 159-1-3
1/4, 1/5	Fossil	: Sphenostemon sp. - DR 159/100
2/4, 2/5	Type	: Sphenostemon papuanum - ref. 159-2-1
2/1	Fossil	: Ascarina sp. - M6/61
2/2, 2/3	Fossil	: Ascarina sp. - DR/II/29/484
3/1, 3/2, 3/3	Type	: Ascarina philippinensis - ref. 48-1-1
3/4, 3/5	Type	: Cunoniaceae, Acsmithia sp. - ref. 120-17-1
4/4, 4/5	Fossil	: Cunoniaceae - DR 159/464
4/6	Fossil	: Cunoniaceae - DR 159/344
4/1, 4/2, 4/3	Type	: Elaeocarpaceae, Elaeocarpus sp. - ref. 174-1-3
5/1, 5/2	Fossil	: Elaeocarpaceae - DR 159/464
5/3, 5/4	Fossil	: Elaeocarpaceae - DR 159/540
5/5, 5/6	Type	: Quintinia sp. - ref. 117-3-2
6/3, 6/4, 6/5	Fossil	: Quintinia sp. - DR 159/464
6/1	Fossil	: Nothofagus sp. - DR 159/464
6/2	Fossil	: Nothofagus sp. - DR 159/540
7/1	Fossil	: Nothofagus sp. - M6/4
7/2, 7/3, 7/4	Type	: Nothofagus perryi - ref. 59-3-112
8/1, 8/2, 8/3	Fossil	: Castanopsis sp. - M6/101
8/4	Fossil	: Castanopsis sp. - M6/91
8/5	Fossil	: Castanopsis sp. - M6/61
9/1, 9/2, 9/3, 9/4	Type	: Castanopsis sp. - ref. 59-4-11

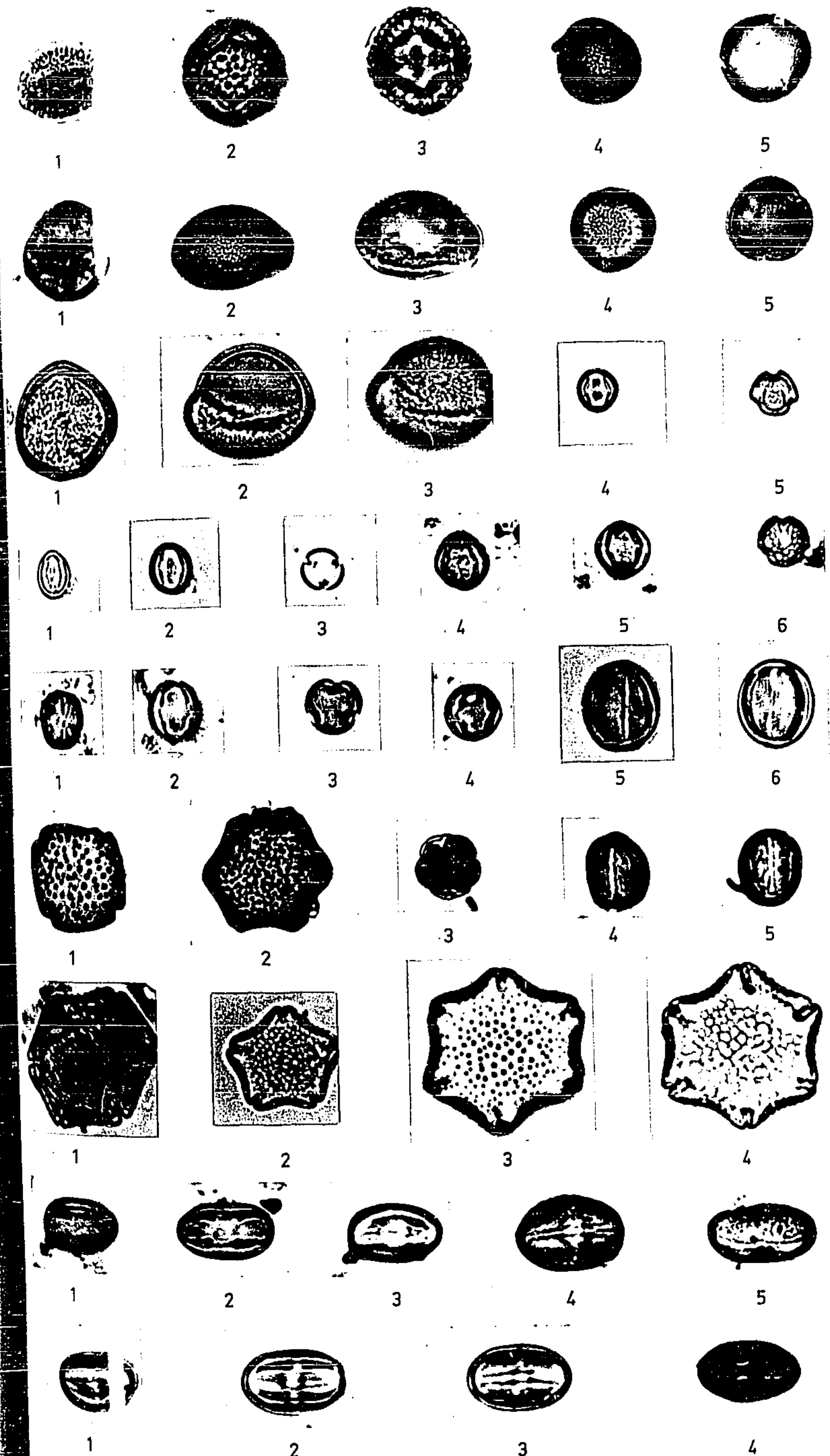


PLATE 19

1/1	Fossil	: Lauraceae, sim. Litsea sp. - HS 12
1/2	Type	: Litsea sp. - ref. 101-6-1
1/3, 1/4	Fossil	: Meliaceae - WUR 3
2/1, 2/2, 2/3	Fossil	: Meliaceae - M1/29
3/2, 3/3	Type	: Meliaceae, Melia azederach - ref. 142-1-1
3/1a, 3/1b, 4/1	Fossil	: Myrsinaceae, sim. Tapeinosperma sp. - DR 159/10
4/2, 4/3, 4/4	Type	: Myrsinaceae, Tapeinosperma sp. - ref. 241-8-1
5/1, 5/2, 5/3	Fossil	: Myrsinaceae, sim. Rapanea sp. - DR 159/10
6/1, 6/2, 6/3	Type	: Myrsinaceae, Rapanea sp. - ref. 241-1-1
4/5	Type	: Myrtaceae, Syzgium sp. - ref. 225-18-6
5/4	Fossil	: Myrtaceae, sim. Syzygium sp. - DR 40/B/124
5/5	Fossil	: Myrtaceae, sim. Syzygium sp. - KW 2
6/4, 6/5	Fossil	: Myrtaceae, sim. Decaspermum sp. - DR/II/29/544
7/5	Type	: Myrtaceae, Decaspermum sp. - ref. 225-22-2
7/1, 7/2	Fossil	: Pittosporaceae, sim. Pittosporum sp. - DR/II/29/464
7/3, 7/4	Type	: Pittosporum ramiflorum - ref. 118-1-2a
8/1, 8/2	Fossil	: Rhamnaceae - M6/91
8/3, 8/4	Type	: Rhamnaceae, Pomaderris apetala - ref. 172-2-3

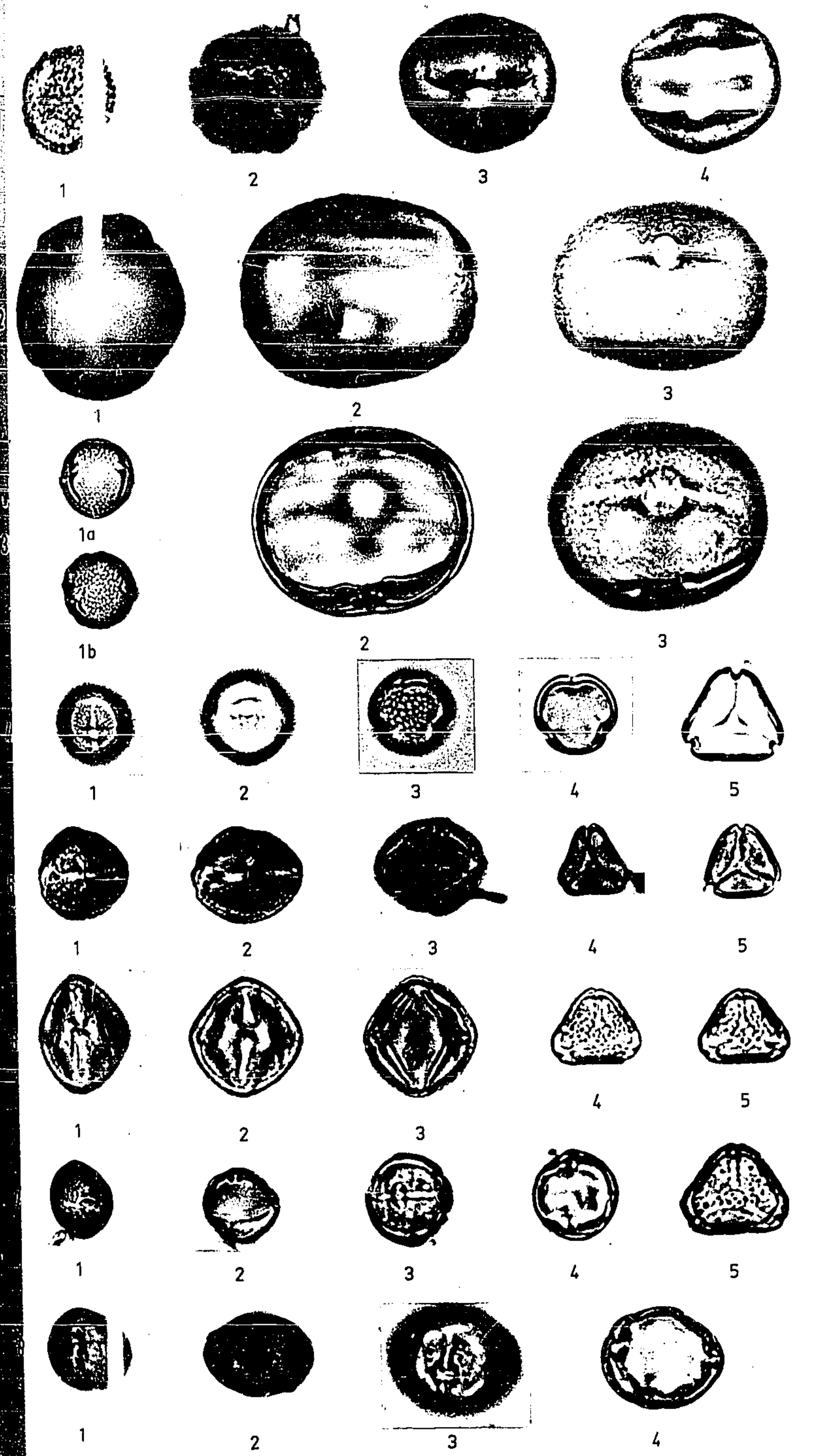


PLATE 20

1/1, 1/2	Fossil	:	Dacrydium sp. - DR 159/254
2/1, 2/2	Fossil	:	Dacrydium sp. - DR/II/29/464
1/3, 2/3	Type	:	Dacrydium sp. - ref. 305-2-4
3/1	Fossil	:	Phyllocladus sp. - DR 159/540
3/2, 3/3	Fossil	:	Phyllocladus sp. - DR 159/464
3/4	Type	:	Phyllocladus hypophyllus - ref. 305-4-1
4/1	Fossil	:	Podocarpus sp., sim. P. pilgeri - M6/141
4/2	Type	:	Podocarpus pilgeri - ref. 305-1-12
5/1	Fossil	:	Podocarpus sp., sim. P. compactus - DR/II/29/704
5/2, 5/3	Type	:	Podocarpus compactus - ref. 305-1-9b
6/1, 6/2	Fossil	:	Podocarpus compactus - M6/31

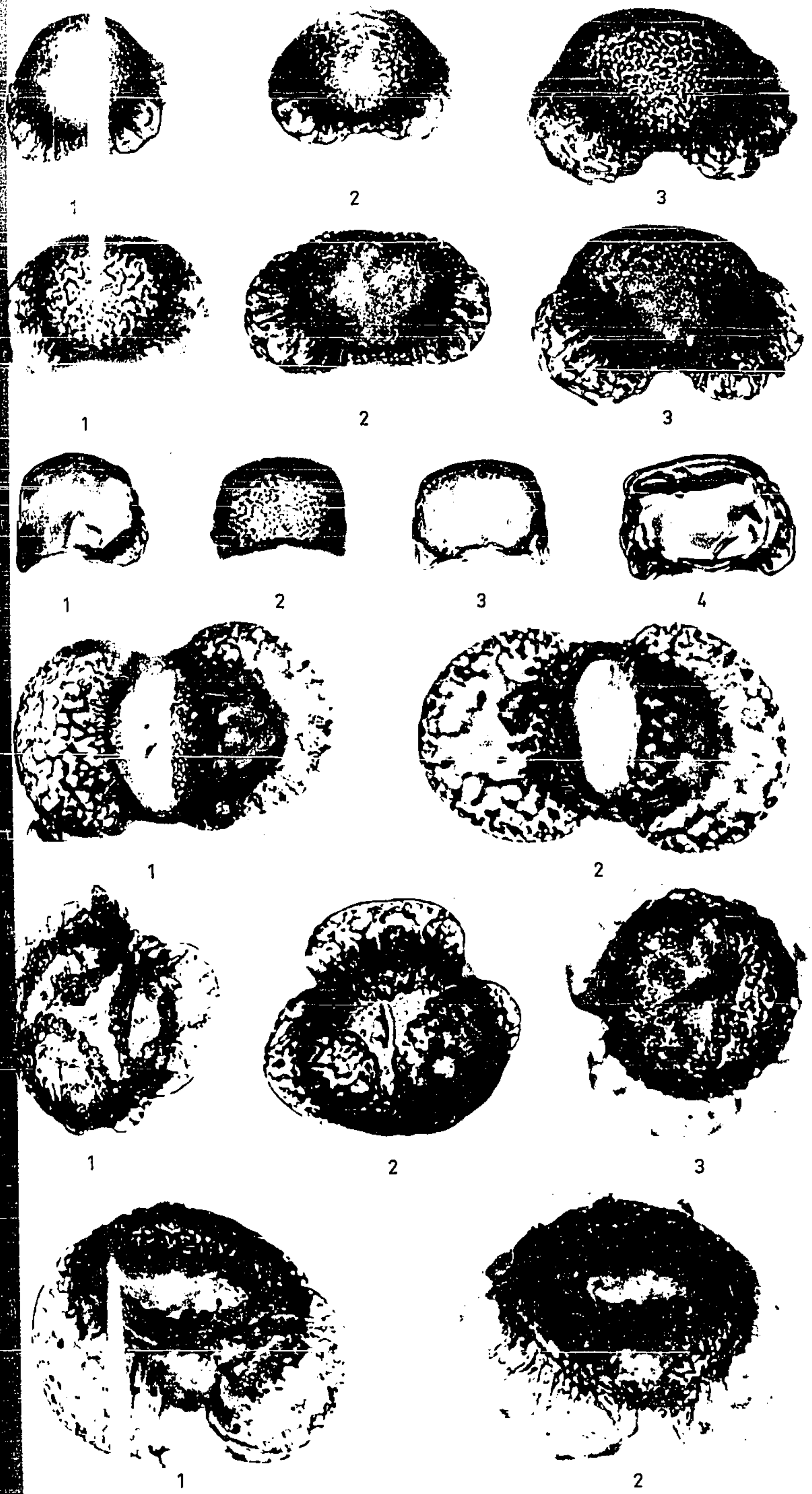


PLATE 21

1/1, 1/2	Fossil	:	Rutaceae, sim. Evodia sp. - M6/43
1/3, 1/4	Type	:	Rutaceae, Evodia sp. - ref. 139-9-2
2/1, 2/2, 2/3	Fossil	:	Sabiaceae, sim. Meliosma sp. - DR 159/511
3/1, 3/2, 3/3	Type	:	Sabiaceae, Meliosma sp. - ref 169-1-1
2/4, 2/5	Fossil	:	Driyms sp. - HF5
3/4, 3/5	Type	:	Drimys sp. - ref. 198-1-40
4/1, 4/2	Fossil	:	Sterculiaceae, sim. Brachychiton sp. - M6/138
4/3, 4/4	Type	:	Brachychiton populneum - ref. 180-1-2a
4/5	Fossil	:	?Sapindaceae - DR 159/70
5/1, 5/2	Fossil	:	?Palmae - M1/0
6/1, 6/2	Fossil	:	Palmae, sim. Calamus sp. - DR/II/29/624
6/3, 6/4	Type	:	Palmae, Calamus sp. - ref. 13-3-1
5/3	Fossil	:	?Proteaceae - DR/II/29/684
5/4	Type	:	Proteaceae, Helicia arguta - ref. 63-15-5
5/5	Fossil	:	?Proteaceae, ?Sapindaceae DR/159/444
7/1	Fossil	:	?Pandanaceae - DR/40A/4
7/2, 7/3	Fossil	:	?Pandanaceae - DR/40B/109
7/4, 7/5	Fossil	:	Pandanaceae, sim. Pandanus sp. - DR/40B/124
8/4, 8/5	Fossil	:	Pandanaceae, sim. Pandanus sp. - DR 159/464
8/1, 8/2	Type	:	Pandanus sp. - ref. 2-1-2
8/3	Type	:	Pandanus pygmaeus - ref. 2-1-4

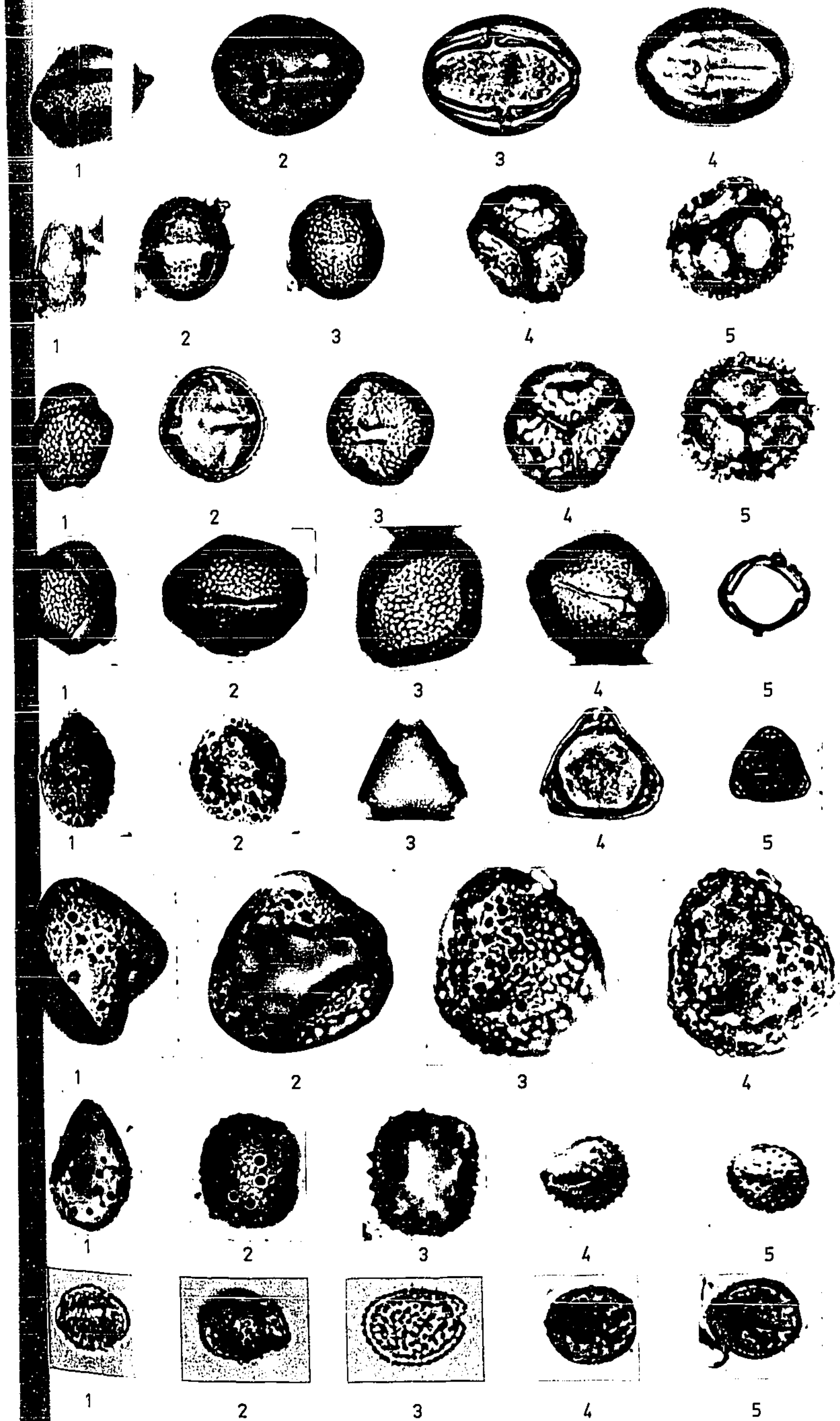


PLATE 22

1/1, 1/2	Fossil	;	Epacridaceae, sim. Styphelia sp. - DR 159/464
1/3, 1/4	Type	:	Styphelia suaveolens - ref. 238-2-1a
2/1, 2/2	Fossil	:	Epacridaceae, sim. Trochocarpa sp. - DR/II/29/484
2/3, 2/4	Type	:	Trochocarpa dekockii - ref. 238-17-4
3/1, 3/2	Fossil	:	Ericaceae, sim. Rhododendron sp. - HS3
3/3	Type	:	Rhododendron sp. - ref. 237-1-10
4/1	Fossil	:	Ericaceae, sim. Vaccinium sp. - HF5
4/2	Type	:	Vaccinium apiculatum - ref. 237-3-11
4/3, 5/3, 5/4	Fossil	:	Rubiaceae, ?Psychotria sp. - DR/II/29/484
5/1, 5/2, 5/3	Type	:	Rubiaceae, Psychotria sp. - ref. 278-8-11
6/1, 6/2	Fossil	:	Coprosma sp. - HS9
6/3, 6/4	Type	:	Coprosma sp. - ref. 275-1-3

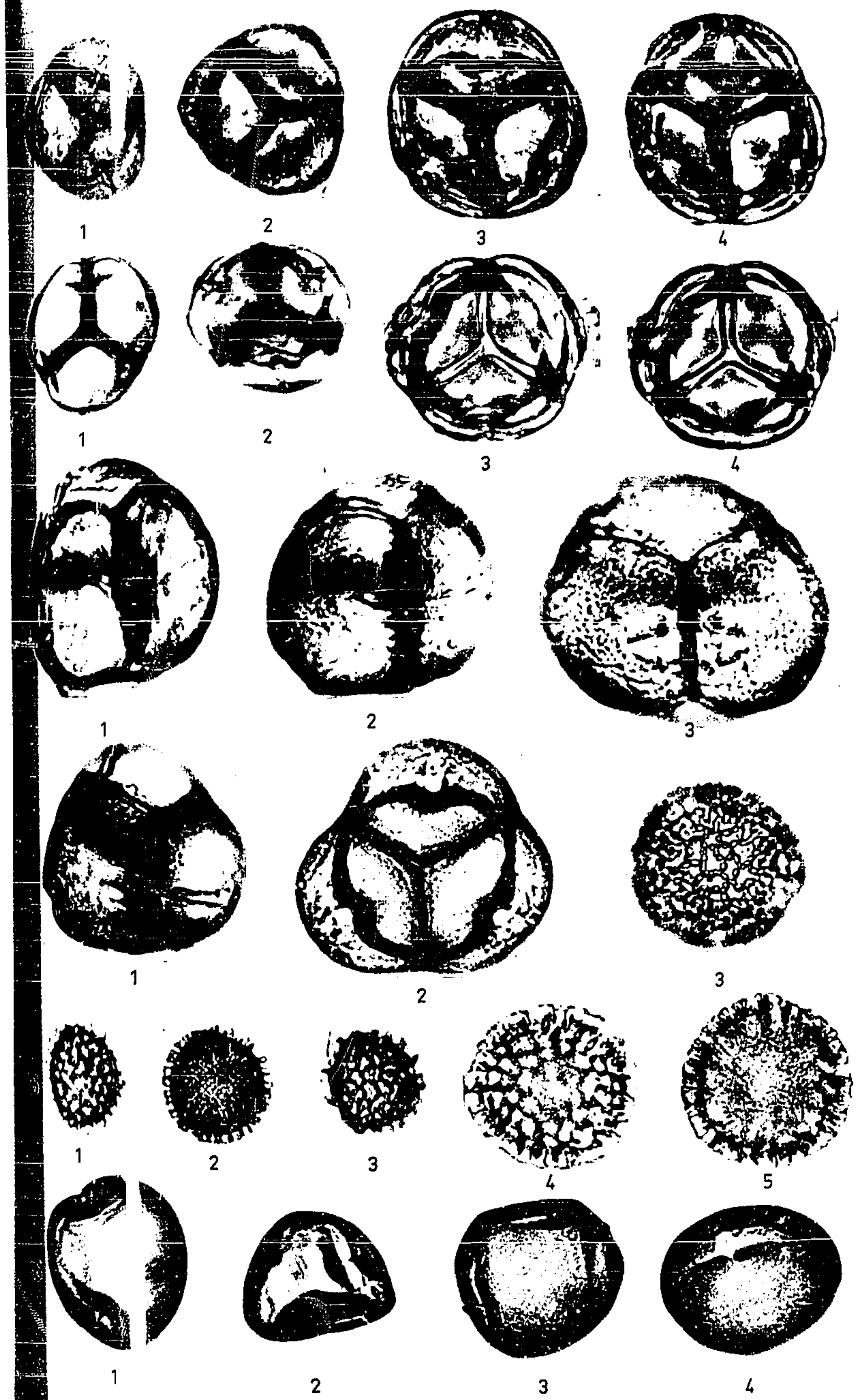


PLATE 23

1/1	Fossil	: Anacardiaceae, sim Rhus sp. - DR/40B/174
1/2	Type	: Rhus sp. - ref. 155-1-3
1/3, 1/4	Fossil	: Araliaceae, cf. Harmsiopanax - DR/II/29/684
1/5	Fossil	: Araliaceae, cf. Harmsiopanax - DR/II/29/664
2/3, 2/4, 2/5	Type	: Harmsiopanax sp. - ref. 231-4-1
2/1; 2/2) 3/1)	Type	: Schefflera sp. - 231-2-8
3/2	Type	: Schefflera sp. - ref. 231-2-7
3/3, 3/4) 3/5, 3/6)	Fossil	: Araliaceae, cf. Schefflera sp. M6/61
4/1, 4/2	Fossil	: Acalypha sp. - M6/160
4/3, 4/4, 4/5	Fossil	: Acalypha sp. - M6/141
5/1, 5/2, 5/3	Type	: Acalypha sp. - ref. 149-9-1
5/4, 5/5	Type	: Acalypha lindheimeri - ref. 149-9-2
6/1	Fossil	: Claoxylon sp. - HF2
6/2	Type	: Claoxylon sp. - ref. 149-7-1
6/3	Fossil	: Macaranga sp. - DR 159/464
6/4	Fossil	: Macaranga sp. - DR 159/10
6/5	Type	: Macaranga sp. - ref. 149-19-3
7/1, 8/1	Fossil	: Melastomataceae, sim. Melastoma sp. - DR 159/100
7/2, 7/3	Fossil	: Melastomataceae, sim. Melastoma sp. - DR 159/294
7/4, 7/5	Type	: Melastoma ?affine - ref. 226-4-3a
8/2, 8/3	Fossil	: Moraceae, sim. Paratrophis sp. - DR 159/464
8/4, 8/5	Type	: Paratrophis glabra - ref. 61-3-1
9/1	Fossil	: ?Moraceae - M6/37
9/2, 9/3	Fossil	: Ulmaceae, sim. Celtis sp. - DR 195/70
9/4, 9/5	Type	: Ulmaceae, Celtis paniculata - ref. 60-1-3a.

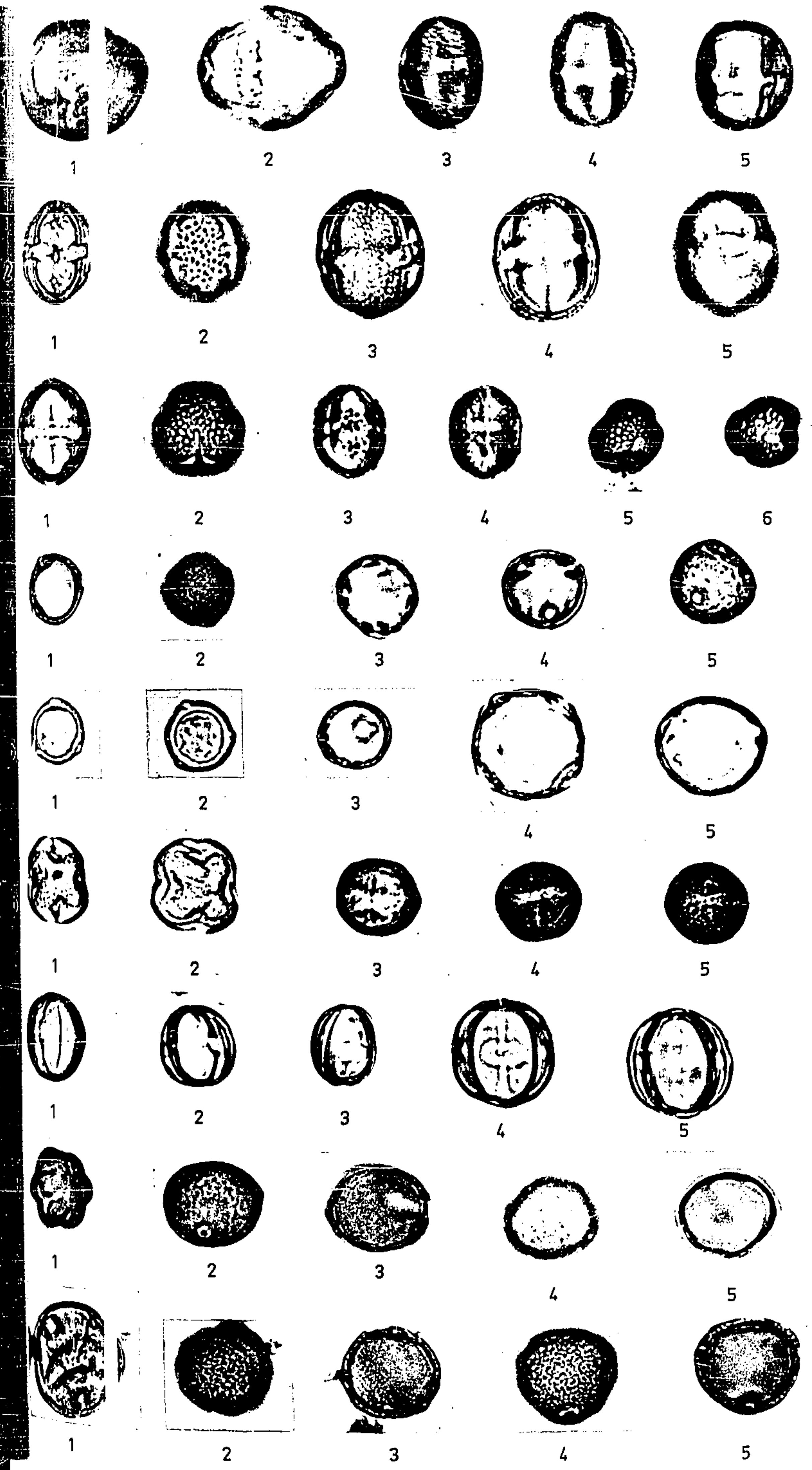


PLATE 24

1/1, 1/2	Fossil	:	Dodonaea sp. - WK8
1/3, 1/4	Type	:	Dodonaea viscosa - ref. 168-5-1c
2/1	Fossil	:	Casuarina sp. - WK8
2/2, 2/3	Type	:	Casuarina oligodon - ref. 45-1-10
1/5	Fossil	:	Trema sp. - KW2
2/4, 3/6	Type	:	Trema sp. - ref. 60-2-9
3/1, 3/2, 3/3	Fossil	:	?Saurauia sp. - DR/II/29/544
3/4, 3/5	Type	:	Saurauia sp. - ref. 182-2-11
4/1	Fossil	:	Urticaceae - DR 159/464
4/2, 4/3	Fossil	:	Urticaceae - DR 159/10
4/4, 4/5	Type	:	Urticaceae, Pipturus sp. - ref. 62-4-2
4/6	Type	:	Urticaceae, Boehmeria sp. -ref. 62-7-1
5/1, 5/2) 5/3, 5/4)	Fossil	:	?Araliaceae (CP2, syncolpate) - DR 159/484
5/5, 5/6	Fossil	:	?Araliaceae (CP3, syncolpate) - DR 159/444
6/1, 6/2) 6/3, 6/4)	Fossil	:	Unknown 5 (CP3, reticulate) ?Euphorbiaceae - DR 159/464
6/5, 7/4, 7/5	Fossil	:	Unknown 6 (CP3, microreticulate) ?Euphorbiaceae - M6/31
7/1, 7/2, 7/3	Fossil	:	Unknown 4 (C3?P3, baculate) ?Euphorbiaceae - M6/71
8/1, 8/2, 8/3	Fossil	:	Unknown 7 (CP3, clavate) ?Euphorbiaceae - M6/160
8/4, 8/5	Fossil	:	Unknown 10 (C4, scabrate) ?Scrophulariaceae, ?Euphorbiaceae - DR 159/484
9/1, 9/2, 9/3	Fossil	:	Unknown 8 (CP3, gemmate)- M1/199
9/4, 9/5	Fossil	:	Unknown 9 (C3, scabrate) ?Scrophulariaceae - DR/40B/109

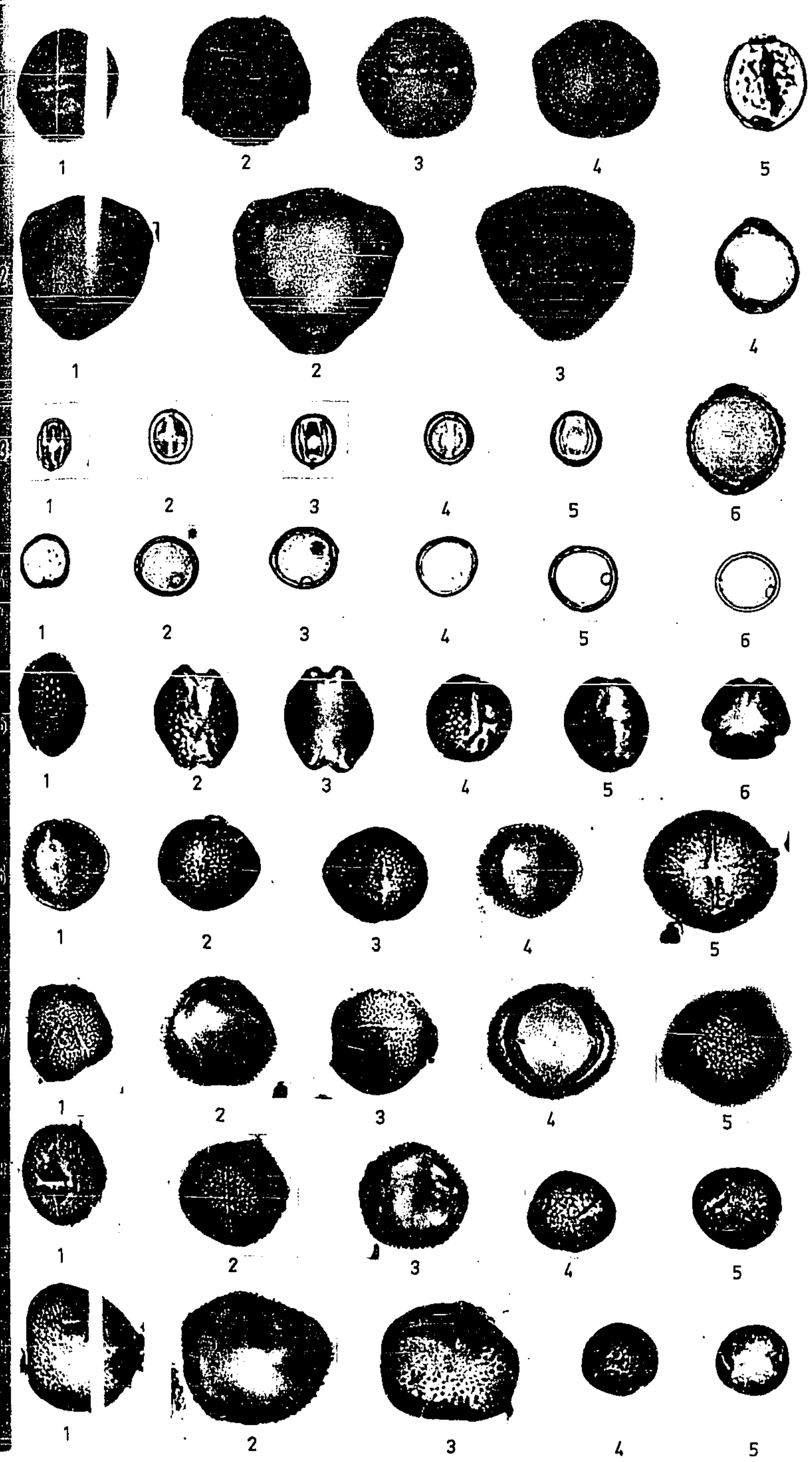


PLATE 24

1/1, 1/2 Fossil : Dodonaea sp. - WK8

1/3, 1/4 Type : Dodonaea viscosa - ref. 168-5-1c

2/1 Fossil : Casuarina sp. - WK8

2/2, 2/3 Type : Casuarina oligodon - ref. 45-1-10

1/5 Fossil : Trema sp. - KW2

2/4, 3/6 Type : Trema sp. - ref. 60-2-9

3/1, 3/2, 3/3 Fossil : ?Saurauia sp. - DR/II/29/544

3/4, 3/5 Type : Saurauia sp. - ref. 182-2-11

4/1 Fossil : Urticaceae - DR 159/464

4/2, 4/3 Fossil : Urticaceae - DR 159/10

4/4, 4/5 Type : Urticaceae, Pipturus sp. - ref. 62-4-2

4/6 Type : Urticaceae, Boehmeria sp. -ref. 62-7-1

5/1, 5/2, 5/3, 5/4 Fossil : ?Araliaceae (CP2, syncolpate) - DR 159/484

5/5, 5/6 Fossil : ?Araliaceae (CP3, syncolpate) - DR 159/444

6/1, 6/2, 6/3, 6/4 Fossil : Unknown 5 (CP3, reticulate) ?Euphorbiaceae - DR 159/464

6/5, 7/4, 7/5 Fossil : Unknown 6 (CP3, microreticulate) ?Euphorbiaceae - M6/31

7/1, 7/2, 7/3 Fossil : Unknown 4 (C3?P3, baculate) ?Euphorbiaceae - M6/71

8/1, 8/2, 8/3 Fossil : Unknown 7 (CP3, clavate) ?Euphorbiaceae - M6/160

8/4, 8/5 Fossil : Unknown 10 (C4, scabrate) ?Scrophulariaceae, ?Euphorbiaceae - DR 159/484

9/1, 9/2, 9/3 Fossil : Unknown 8 (CP3, gemmate)- M1/199

9/4, 9/5 Fossil : Unknown 9 (C3, scabrate) ?Scrophulariaceae - DR/40B/109

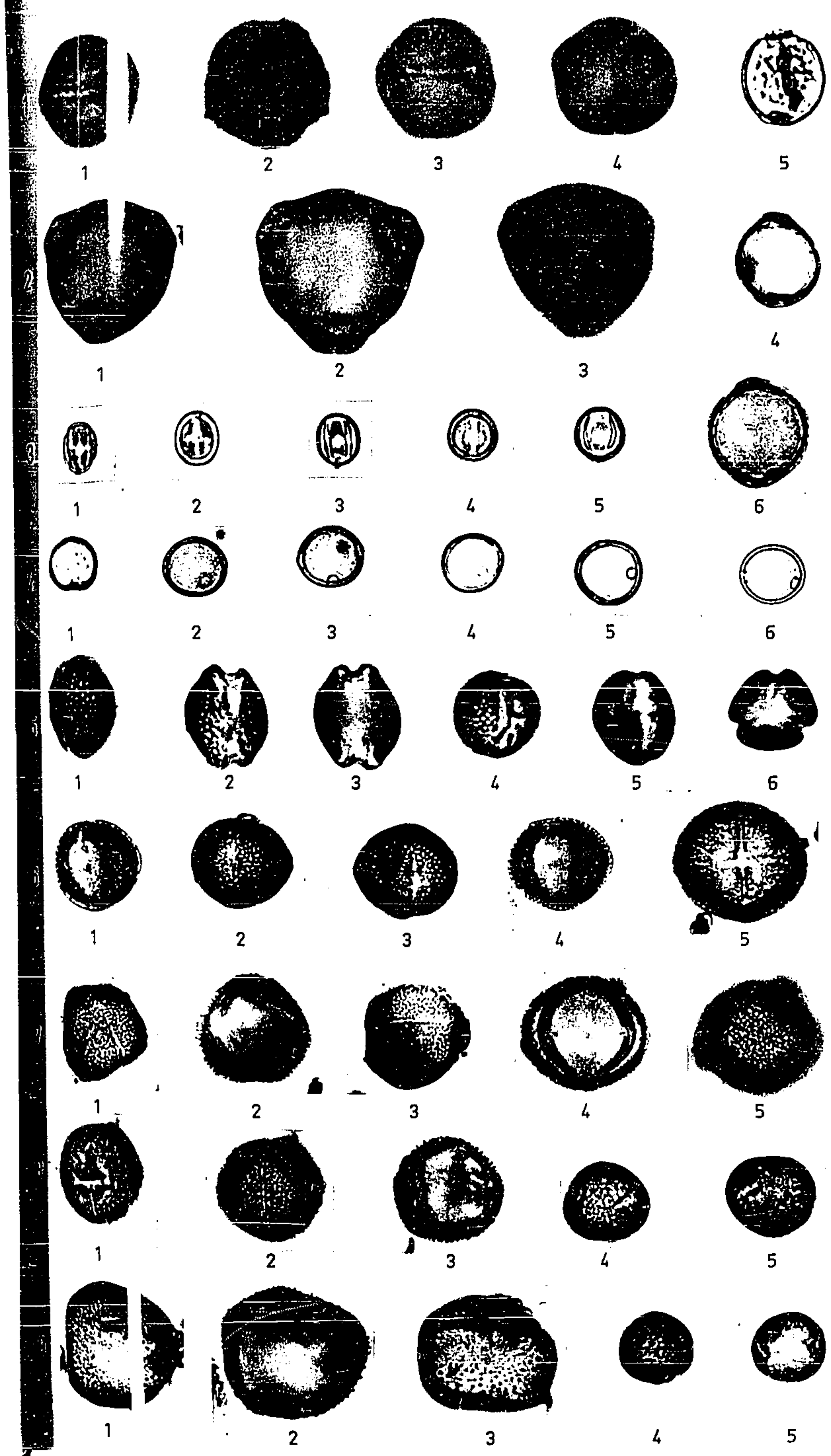


PLATE 25

1/1, 1/2, 1/3	Fossil	:	*Amaranthus* sp. - M6/61, 61A
1/4	Fossil	:	*Amaranthus* sp. - M6/81
2/1, 2/2	Type	:	*Amaranthus* sp. - ref. 77-1-5
2/3	Fossil	:	Caryophyllaceae - M1/145
2/4, 2/5	Fossil	:	Caryophyllaceae - M1/111
3/1, 3/2	Type	:	Caryophyllaceae, *Drymaria* sp. - ref. 84-10-2
3/3, 3/4	Fossil	:	Caryophyllaceae, sim. *Drymaria* sp. - DR/40A/179
4/1	Type	:	Chenopodiaceae, *Rhagodia* sp. - ref. 76-3-2
4/2, 4/3	Fossil	:	Chenopodiaceae, sim. *Rhagodia* sp. - WUR8
4/4	Fossil	:	Apiaceae, sim. *Oreomyrrhis* sp. - DR/II/29/704
4/5	Type	:	Apiaceae, *Oreomyrrhis* sp. - ref. 232-4-5
5/1	Type	:	Asteraceae, *Senecio* sp. - ref. 286-11-4
5/2, 5/3	Fossil	:	Asteraceae, sim. *Senecio* sp. - WUR3
5/4	Type	:	Asteraceae, *Ageratum* sp. - ref. 286-88-1
5/5	Fossil	:	Asteraceae, sim. *Ageratum* sp. - M1/145
6/1	Type	:	Asteraceae, *Lactuca indica* - ref. 286-17-6
6/2	Fossil	:	Asteraceae, sim. *Lactuca* sp. - DR 159/294
6/3	Fossil	:	*Haloragis* sp. - DR 159/294
6/4	Type	:	*Haloragis* sp. - ref. 228-2-9
7/1, 7/2, 7/3	Fossil	:	Commelinaceae, *Anielema* sp. - M6/101
8/1, 8/2, 8/3	Type	:	*Anielema* sp. - ref. 26-2-2

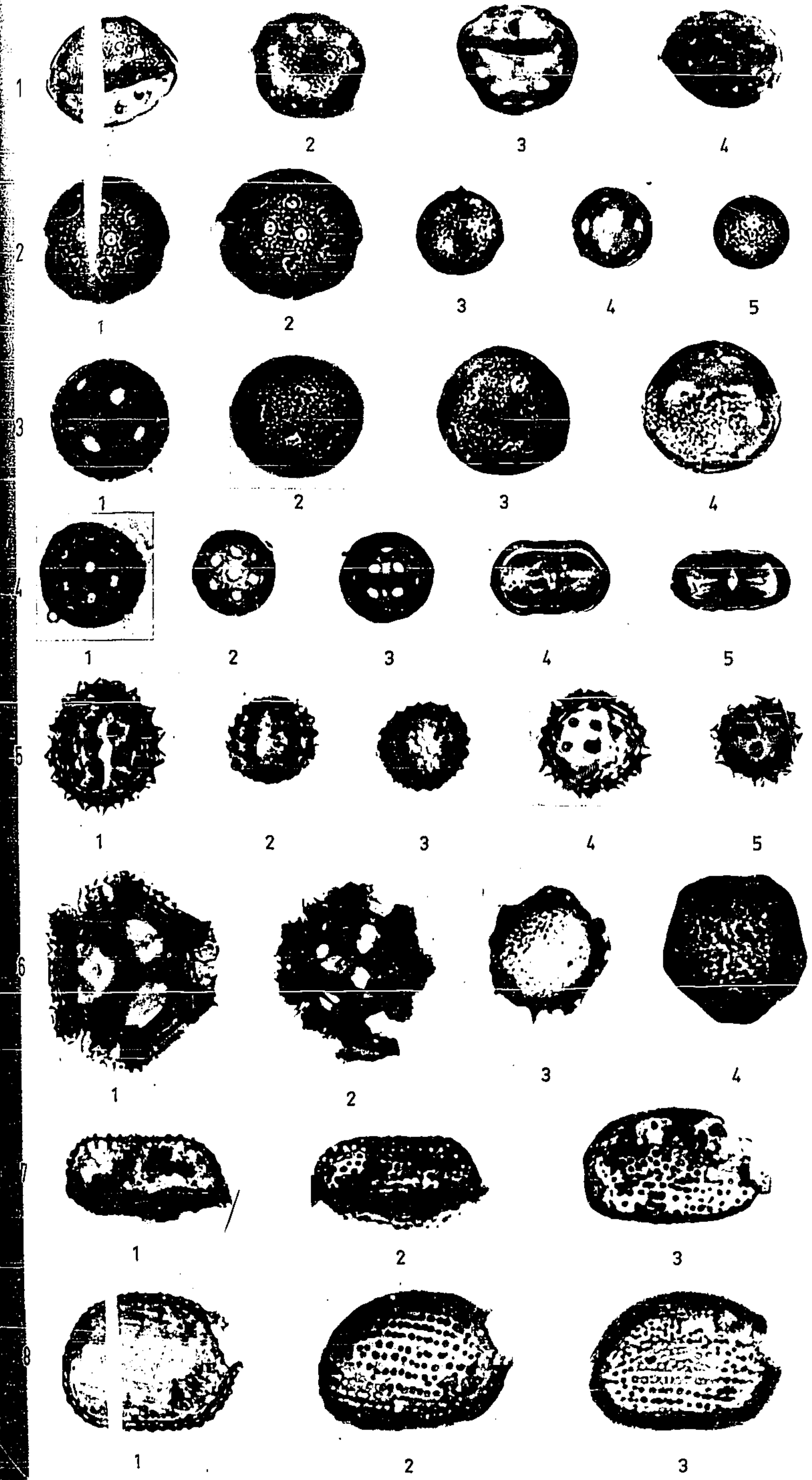


PLATE 26

1/1, 1/2 Fossil : *Wahlenbergia* sp. - DR/II/29/704

1/3, 1/4 Fossil : *Wahlenbergia* sp. - DR/II/29/664

2/1, 2/2, 2/3 Type : *Wahlenbergia* sp. - ref. 281-3-1

3/1, 3/2 Fossil : Brassicaceae, sim. *Cardamine* sp. - DR/II/29/544

3/3, 3/4 Type : *Cardamine* sp. - ref. 105-5-3

4/1, 4/2, 4/3 Fossil : Brassicaceae, sim. *Cardamine* sp. - DR/II/29/544

5/1, 5/2, 5/3 Type : *Cardamine dictyosperma* - ref. 105-5-1

4/4, 4/5 Fossil : Brassicaceae - M6/121

5/4, 6/4 Fossil : ?Brassicaceae, ?Lamiaceae - M6/31

6/1, 6/2, 6/3 Fossil : Brassicaceae, sim. *Rorippa* sp. - M1/29

7/1, 7/2, 7/3 Type : *Rorippa* sp. - ref. 105-2-2

7/4, 7/5 Fossil : Lamiaceae, sim. *Coleus* sp. - M1/29

8/1 Fossil : ?Lamiaceae - M6/43

8/2 Fossil : ?Lamiaceae - M6/121

8/3, 8/4 Type : Lamiaceae, *Coleus* sp. - ref. 259-12-2

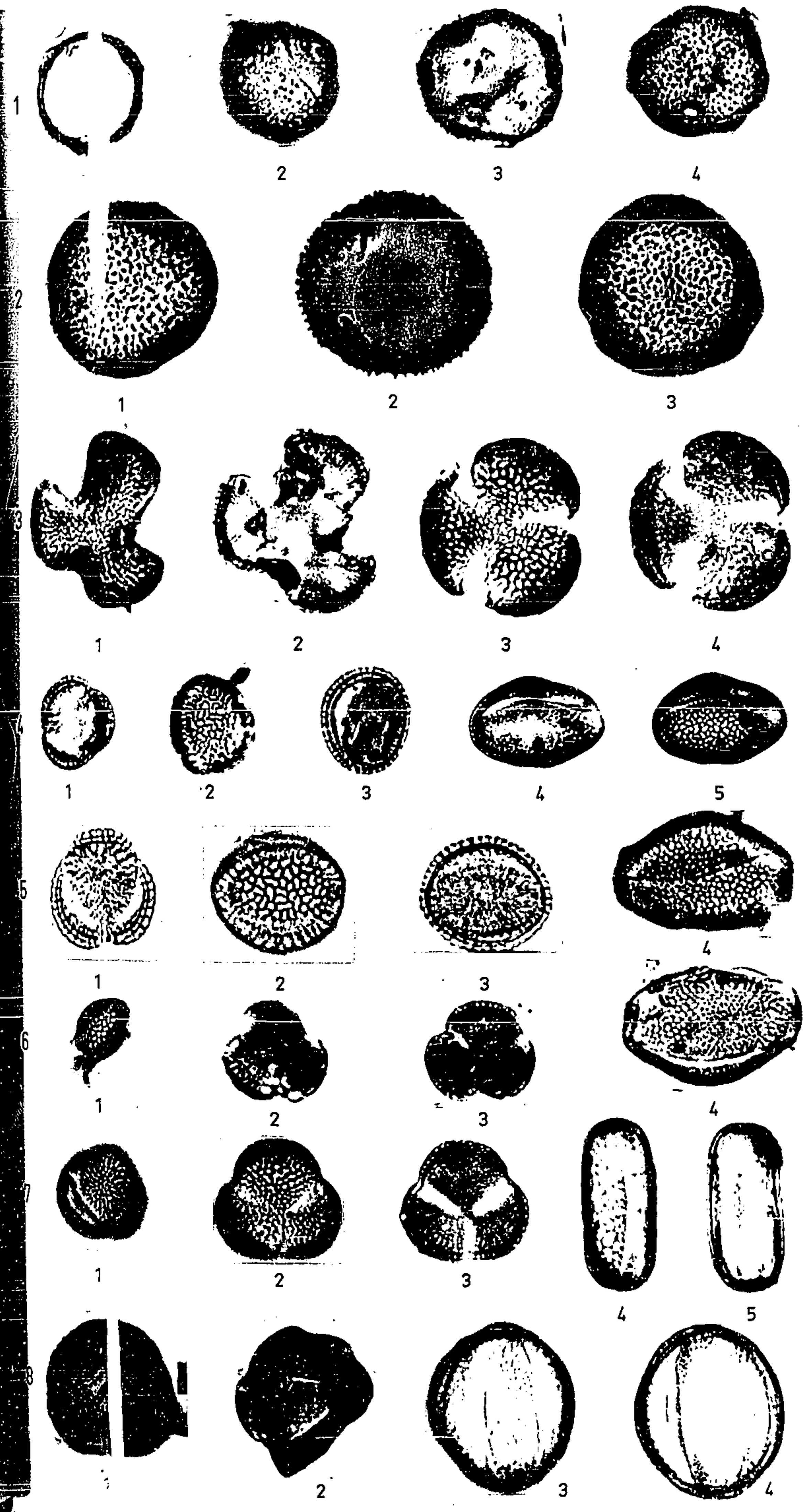


PLATE 27

1/1, 1/2	Fossil	:	*Astelia* sp. - DR/II/29/484
1/3, 1/4	Fossil	:	*Astelia* sp. - HS3
1/5, 1/6	Type	:	*Astelia alpina* - ref. 32-31-16
2/1	Fossil	:	*Fagraea* sp. - DR/II/29/664
2/2, 2/3, 2/4	Fossil	:	*Fagraea* sp. - DR 159/540
3/2, 3/3, 3/4	Type	:	*Fagraea* sp. - ref. 249-2-1
3/1	Fossil	:	*Plantago* sp. - WUR3
4/1	Fossil	:	*Plantago* sp. - M6/101
4/2	Fossil	:	*Plantago* sp. - M6/10
4/3, 4/4, 4/5	Type	:	*Plantago lanceolata* - ref. 274-1-1a
5/1	Fossil	:	*Polygonum* sp. - M6/138
5/2	Type	:	*Polygonum* sp. - ref. 75-2-9
5/3a, 5/4a	Fossil	:	*Rumex* sp. - M6/10
5/3b, 5/4b	Type	:	*Rumex acetosella* - ref. 75-1-1
6/1, 6/2	Fossil	:	*Ranunculus* sp. - HS9
6/3, 6/4	Type	:	*Ranunculus* sp. - ref. 89-1-15
7/1	Fossil	:	*Solanum* sp. - DR/II/29/544
7/2, 7/3	Fossil	:	*Solanum* sp. - DR 159/444
7/4, 7/5	Type	:	*Solanum* sp. - ref. 261-2-8

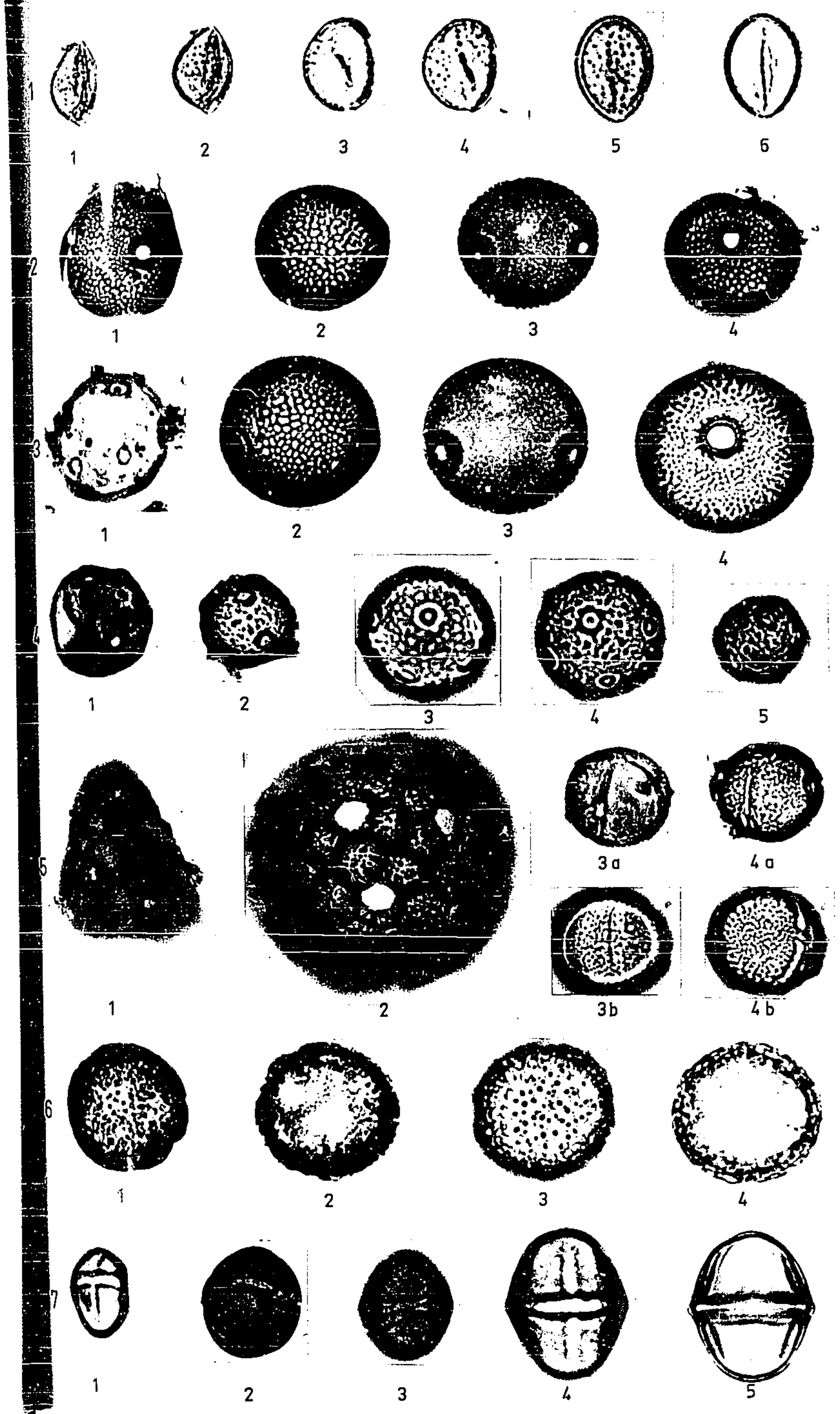


PLATE 28

2/2, 2/3 Fossil : Detzneria sp. - DR 159/70-71

2/1, 2/2, 2/3 Fossil : Detzneria sp. - DR/II/29/175

3/1, 3/2, 3/3 Type : Detzneria tubata - ref. 262-18-3

1/3, 1/4 Fossil : ?Scrophulariaceae (C3, scabrate colpi) - DR 159/70

2/4 Fossil : ?Scrophulariaceae (C5, scabrate) - M6/91

4/1, 4/2 Fossil : ?Scrophulariaceae - DR 159/70

4/3, 4/4 Fossil : Eriocaulon sp. - DR/II/29/624

4/5 Type : Eriocaulon sp. - ref. 22-1-2

5/1 Type : Xyris sp. - ref. 21-1-3

5/2 Fossil : Xyris sp. - DR 40B/174

5/3, 5/4 Fossil : Cyperus sp. - M6/160

6/1, 6/2 Fossil : Sparganium sp. - M6/10

6/3 Type : Sparganium simplex - ref. 3-1-1a

6/4, 6/5 Type : Cyperus sp. - ref. 12-6-2

7/1 Fossil : Poaceae - HS3

7/2 Fossil : Poaceae - M6/101

7/3 Fossil : Scirpus sp. - DR/II/29/704

7/4 Type : Scirpus mucronatus - ref. 12-1-3b

8/1 Fossil : Machaerina sp. - DR/40B/154

8/2 Fossil : Machaerina sp. - DR 159/540

8/3 Type : Machaerina sp. - ref. 12-4-2a

8/4 Fossil : Kyllinga sp. - M6/4

8/5 Type : Kyllinga sp. - ref. 12-13-2

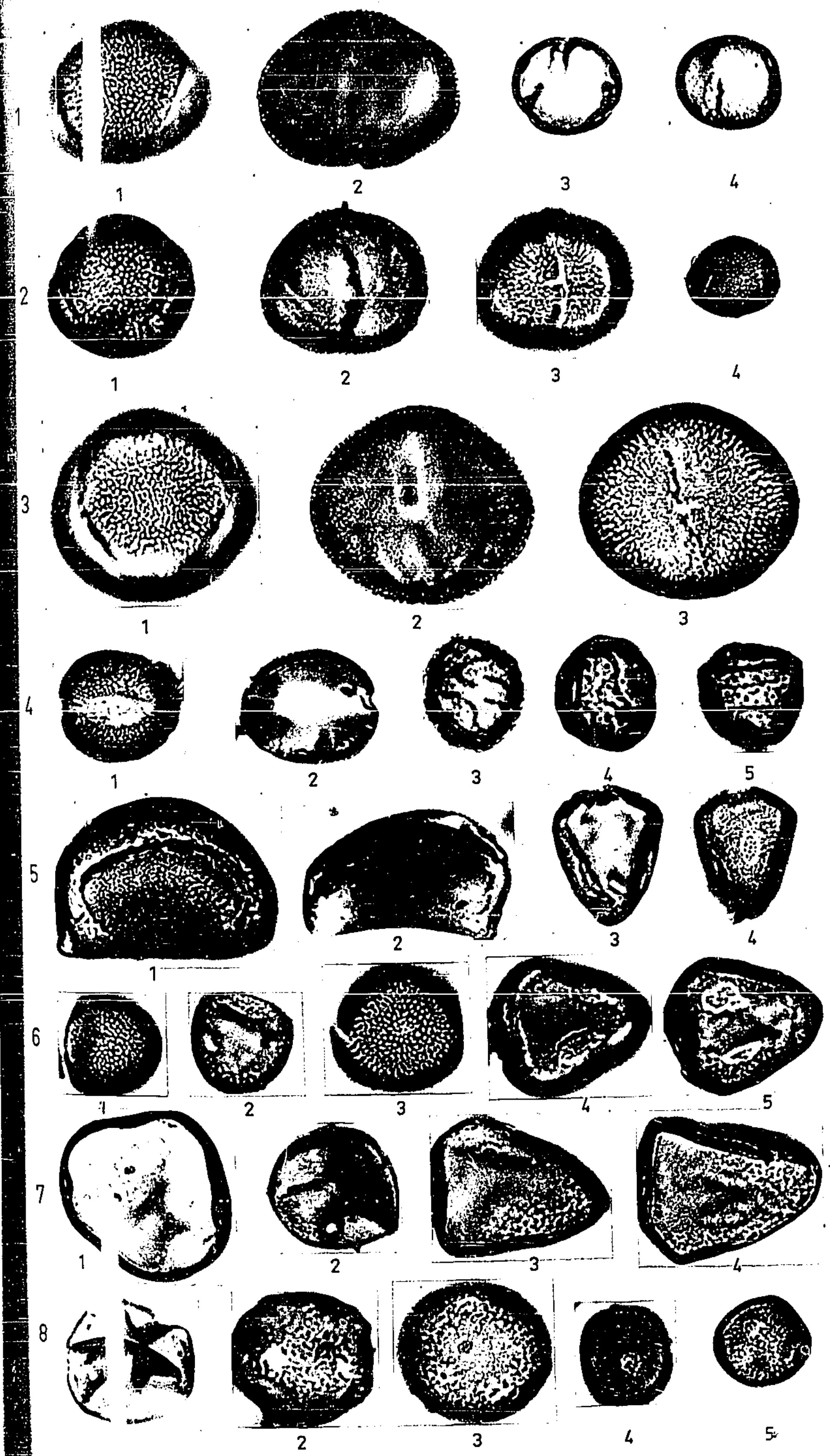


PLATE 29

1/1, 1/2	Fossil	: Unknown 1, ?Sapindaceae, P3, 20µ, reticulate, triangular, annulate pore - DR/II/29/544
1/3, 1/4	Fossil	: Unknown 2, CP4, 17µ, micro-reticulate - M1/171
1/5	Fossil	: Unknown 11, CP3, 14-15µ, scabrate, angular, ?Rhamnaceae - M6/61
1/6	Fossil	: Unknown 12, CP4, 17µ, scabrate, ?Rhamnaceae - DR 159/484
2/1	Fossil	: ?Rosaceae - DR 159/389
2/2	Fossil	: ?Asteraceae - M6/41
2/3, 2/4	Fossil	: Unknown 17, CP3, 15x12µ, prolate, psilate-scabrate - M6/37
2/5, 2/6	Fossil	: Unknown 18, CP3, 15µ, scabrate - DR/II/29/704
3/1, 3/2, 3/3	Fossil	: Unknown 19, CP3, reticulate, 18-20µ, oblate, ?Leguminosae-M1/209
3/4	Fossil	: Unknown CP3, 15µ, scabrate - DR 159/130
3/5	Fossil	: Unknown CP3, 14µ scabrate - DR 159/70
3/6	Fossil	: ?Sapindaceae, ?Proteaceae, CP3, scabrate, triangular - DR 159/444
4/1, 4/2, 4/3	Fossil	: Unknown 14, C1/P1, gemmate, 21µ - DR/40A/54
4/4, 4/5	Fossil	: Unknown 21, tetrad, 21-22µ, gemmate - DR/II/29/704
5/1, 5/2	Fossil	: Unknown 20, CP3, gemmate - DR/II/29/684
5/3, 5/4	Fossil	: (X625 magn.) Unknown 16, C3, 75µ, triangular, scabrate - M1/171
6/1	Fossil	: Unknown 15, C3, scabrate, 35µ - DR/II/SS
6/2	Fossil	: Monolete, verrucate fern - M6/71, sim. Davalliaceae, Dennstaedtiaceae, Oleandraceae.
6/3, 6/4	Type	: Oleandraceae, <u>Nephrolepis</u> sp. - ref. 407-34-2
7/1, 7/2	Fossil	: Monolete, verrucate ferns - M6/41, M6/160, sim. Dennstaedtiaceae
7/3	Type	: Dennstaedtiaceae, <u>Histiopteris</u> sp. - ref. 407-26-1
7/4	Fossil	: ?Polypodiaceae, 26µ - HS3
8/1, 8/2	Fossil	: Dennstaedtiaceae, sim. <u>Dennstaedtia</u> sp. - M6/10
9/1, 9/2	Type	: <u>Dennstaedtia</u> sp. - ref. 407-27-1
8/3	Fossil	: Monolete, psilate - M6/10
9/3	Fossil	: Monolete, psilate - M6/141.

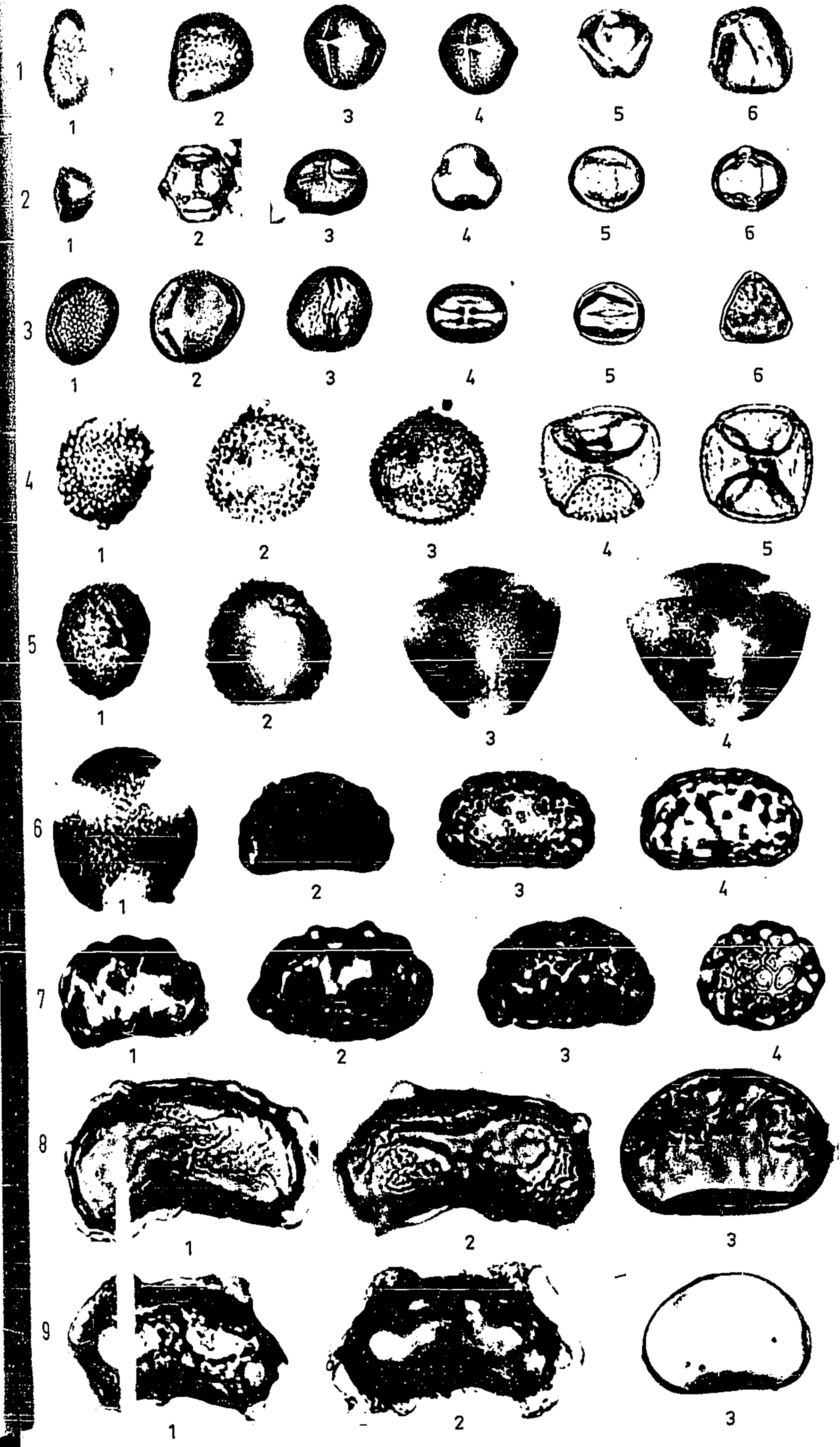
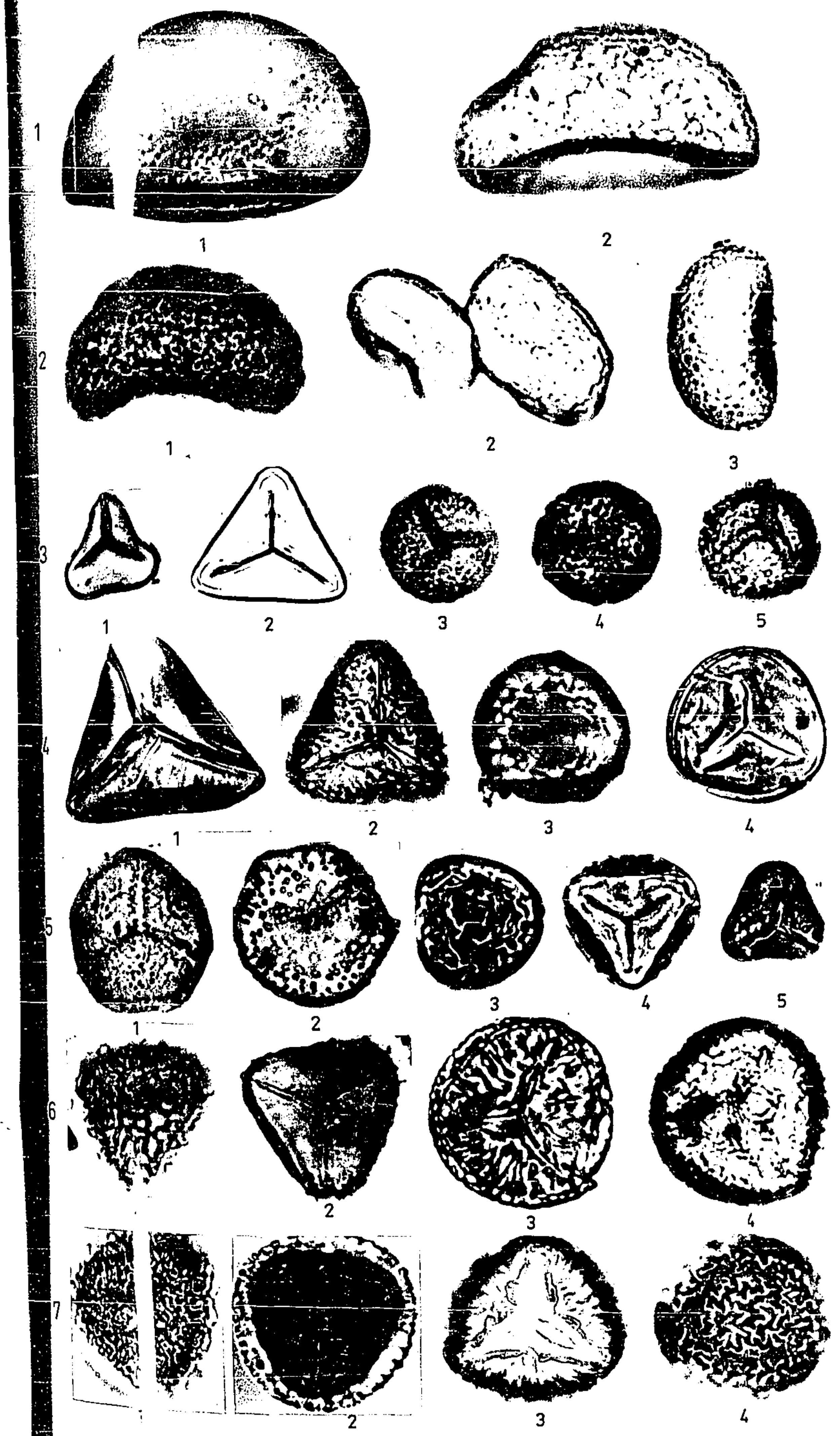


PLATE 30

1/1	Fossil	:	Monolete, 'scabrate' fern - DR 159/464
1/2	Fossil	:	Polypodiaceae, sim. Belvisia sp. - DR 159/464
2/1	Fossil	:	Polypodiaceae, sim. Loxogramme sp. - DR/II/29/484
2/2	Fossil	:	Monolete, 'scabrate' - M6/155
2/3	Fossil	:	Polypodiaceae - M6/101
3/1	Fossil	:	?Cyatheaceae - M6/160
3/2	Type	:	Cyathea sp. - ref. 407-18-1-5
3/3, 3/4	Fossil	:	Grammitidaceae - DR/II/29/524
3/5	Type	:	Grammitis stomocarpa - ref. 407-18-3
4/1	Fossil	:	?Gleicheniaceae - DR 159/444
4/2	Fossil	:	Trilete, 'striate-rugulate', - M6/160
4/3, 4/4	Fossil	:	Lycopodium sp., sim. L. cernuum - DR 159/344
5/1, 5/2	Fossil	:	Trilete, 'echinate' - M6/101
5/3, 5/4	Type	:	Lycopodium cernuum - ref. 401-1-17
5/5	Fossil	:	Lycopodium sp., 'fossulate' - M6/160
6/1, 6/2	Fossil	:	Lycopodium sp., sim. L. volubile - DR 159/10
7/1, 7/2	Type	:	Lycopodium volubile - ref. 401-1-18
6/3, 6/4	Fossil	:	Lycopodium sp., 'large rugulate', sim. 401-1-15 - DR/II/29/544
7/3, 7/4	Type	:	Lycopodium sp. - ref. 401-1-15.



crumpled and obscured grains which could not be identified readily were recorded as 'undeterminable'.

No attempt has been made in the present study to obtain absolute pollen counts. While the value of such counts is acknowledged (Davis 1967, Tsukada 1966) the methods involved in the preparation of such samples are extremely laborious and time consuming (Davis 1965, Benninghoff 1962, Jørgensen 1967) and even then are subject to various errors. The information gained by the counting of a greater number of samples than otherwise possible, is considered to offset the disadvantages of non-absolute counts in the present study. Techniques of preparation could not be kept entirely standard since different sediment types were present and a certain loss of material must always be sustained with methods involving a great number of individual steps. However, the samples counted may be considered very roughly equivalent since firstly, similar amounts of sediment were used from the start of the preparation process (1cc), material was suspended in equal aliquots of Silicon oil after processing and similar amounts of the suspension were transferred to the slides for counting.

With counting carried out by means of traverses back and forth across the slides a decision has to be made on the number of pollen grains to be counted per sample. This will depend upon the number of different pollen taxa present in the sample and the accuracy with which their separate frequencies need to be determined. Certainly with a high total number statistical errors are reduced, especially for those types that occur only rarely in the sample; on the other hand a minimum total count which gives a reliable estimate of the frequencies of the common taxa may be sufficient for the purposes of the study.

Some authors, such as Jørgensen (1963) use high total numbers (up to 2000 grains per sample) but many consider 200 to 500 grains per sample give accurate results, at least for the more common taxa (Coetzee, 1967) and that more reliable information can be gained by counting a large number of closely spaced samples, using a relatively small total count than by counting greater numbers of grains in a few, widely spaced samples (Walker, 1966b). Martin (1963), utilizing total pollen counts, considered changes in frequency of individual taxa and in numbers of species as functions of sample size. He found that, by increasing the sample size from 200 to 2000 pollen grains, the difference in individual frequency did not exceed 4% and that 10 new pollen types were added. He concluded that while a sample size of 200 grains was sufficient for estimating the frequency of abundant pollen types, it was too small to necessarily include rare items, possibly of ecological importance, or to provide a meaningful record of pollen types of low frequency (less than 2%).

In the present study a similar situation was found, namely all the common pollen types were present in a count of 200 grains and an increase in sample number from 200 to 800 grains did not increase greatly the number of taxa recorded, or change the frequencies of individual taxa present. Hence it was considered that the time available for sample counting in the present study would be used to the best advantage by examining as many samples as possible using a small total pollen count rather than counting large numbers of grains in a few samples. Also, accepting the difficulties of pollen identification in a new geographical area, as well as problems of interpretation based on scanty vegetation data, it was considered that only broad vegetation changes could be indicated in the diagrams and that it was changes in frequencies of the common taxa which would be used in interpretation of the data, with little significance being attached to the single occurrence of a new pollen taxa, or to isolated changes in frequency of a single type.

Initially the only restrictions placed on counting were that at least 200 grains were counted per sample and that complete traverses were made across the slides. Later, when it was found that counts of pollen types belonging to herbaceous plants outweighed greatly those belonging to woody plants a third condition was imposed, namely, that at least 150 tree and shrub pollen be counted. An attempt was made to fulfil this requirement by counting further slides but lack of time did not allow completion of the task. All pollen counts are given in Appendix 2.

Calculation of the modern pollen rain and fossil sample results

Counts of individual pollen taxa comprising the pollen spectrum of each sample level of a fossil core or of each modern pollen rain sample are normally expressed as percentages, calculated on the basis of a 'pollen sum'. The choice of a 'pollen sum' is largely arbitrary but should relate as closely as possible to the problems to be solved. (Faegri and Iversen 1964, Faegri 1966). Thus, if changes in forest composition are under study then the total tree pollen is the most appropriate pollen sum, while if relative changes between forest and non-forest vegetation are of interest, total pollen should be used instead. Generally, certain taxa, such as local swamp plants are excluded from the pollen sum and their frequencies calculated outside it. The establishment of a pollen sum which includes only some of the pollen taxa present in the spectrum implies knowledge of the ecological tolerance of the parent plants involved. While in many cases these are known and readily defined (for example, European forest tree taxa) in others lack of knowledge (for example, of the wide-ranging tolerance of Cyperaceae and Poaceae in American diagrams) may lead to a pre-judging of interpretation (Wright and Patten, 1963).

In the present study differences (as expressed in the modern rain samples) and changes (as possibly expressed in the fossil record) in forest composition, in the relative proportions of forest and non-forest trees and shrubs and of forest and non-forest vegetation as a whole are of interest. The pollen sums used are total pollen (excluding aquatics) and total of tree and shrub pollen.

To gain these totals pollen taxa are organized according to the growth form of the parent plant. The categories distinguished are large trees, shrubs and small trees, forbs, lianes and climbers, grasses, sedges, ferns and lycopods. Most taxa are readily placed into a single category but Urticaceae, identified to family level only in the pollen, poses a problem as it contains both shrubs and herbs. It has been included in the shrub category initially for convenience and will be discussed further below.

Allocation of taxa to ecological groups for use in summary diagrams is made on the basis of local representation in modern pollen rain spectra and in vegetation; where taxa are wide-ranging in ecological tolerances, such as Poaceae, Cyperaceae, Pteridae and Lycopodiaceae, they are kept as separate categories in the pollen diagram. Other categories recognised include mixed forest, beech and oak forest, and regrowth vegetation.

<u>Comparison of modern pollen rain spectra and vegetation data</u>

Since the pollen taxa are identified taxonomically at generic and family rather than specific level, the vegetation data were rearranged into equivalent taxonomic groups to permit direct comparison of the composition of the two. The forest vegetation data were then expressed as the relative percentage density (per hectare) of individual tree, small tree and shrub taxa using as bases:

(a) total number of large trees (defined as those above 24 cm diameter breast height and including the canopy and uppermost levels of the forest) per hectare,

(b) total number of small trees and shrubs per hectare (representing the middle levels of the forest), and

(c) total number of large and small trees and shrubs per hectare (i.e. a + b).

The resulting values were compared with the pollen percentages of total tree and shrub pollen. In addition the relative percentage densities of individual taxa of divaricating shrubs, lianes and climbers, forbs, ferns and grasses were calculated using the total number of individuals per hectare as the base, and these values were compared with pollen percentages calculated on a total pollen base.

The non-forest vegetation data were also rearranged according to taxa equivalent to those found in the pollen and then, for each taxon, the range of cover-density values present, the mean cover density value and the relative per cent value of the mean was compared directly with the relative pollen percentages, calculated on the base : total pollen.

The results are considered in the next chapter.

CHAPTER 7

THE MODERN POLLEN RAIN

Figures 7.1 and 7.2 show the species composition of modern pollen rain samples from the Mt Hagen region using total pollen (excluding aquatics) as the pollen sum, while Figures 7.3 and 7.4 show the relative abundance of the various woody taxa in the same samples, calculated on the pollem sum: total of tree and shrub pollen.

The same data are incorporated in Tables 7.1 to 7.5 so that the pollen data may be compared directly with that of the vegetation to give some idea of pollen representation and source areas.

REPRESENTATION IN FORESTS

Table 7.1 compares the relative density of plants in the forests surveyed with the percentages of their pollen found in samples collected nearby. Correlations between vegetation and pollen in this table appear closest when the vegetation data are calculated on base (a) for the large tree taxa and on bases (b) and (c) for the small trees and shrubs. The differing best correlation base for large trees and for small trees and shrubs is acceptable since the large (assumed mature) trees in base (a) are the main pollen producers. In all that follows the term 'over-represented' means that pollen values exceed the vegetation measure of the taxon or taxa being discussed; 'under-represented' implies the opposite.

Considering first the mixed forests, a close correlation between percentage density of plants and percentage pollen is seen for the trees <u>Ilex</u>, <u>Podocarpus</u>, <u>Saurauia</u>, <u>Prunus</u>, <u>Pandanus</u>, <u>Quintinia</u>, <u>Drimys</u> and Myrtaceae. Others such as Myrsinaceae, Elaeocarpaceae, Ericaceae, Cunoniaceae, Lauraceae and <u>Symplocos</u> are underrepresented.. Among the small tree and shrub species <u>Evodia</u>, <u>Sphenostemon</u>, <u>Claoxylon</u>, and Proteaceae are equally represented in the vegetation and the pollen rain, while <u>Schefflera</u> and Epacridaceae are over-represented, Moraceae and <u>Omalanthus</u> underrepresented. Among the hercaceous taxa, the ferns show overrepresentation and others underrepresentation.

Within the beech forests the only equivalent representation in vegetation and pollen is shown by Nothofagus among the large trees, by Schefflera, Sphenostemon and Sapindaceae among the small trees and shrubs. Elaeocarpaceae, Cunoniaceae and Moraceae are underrepresented and Lauraceae and Drimys overrepresented. Among the lower growth forms, Urticaceae and Poaceae are underrepresented, while Pteridae are equally represented in the pollen spectra and vegetation. Pollen taxa represented in the pollen rain of the mixed forests and present in the vegetation of the beech forests but not in the pollen spectra there include Myrsinaceae, Prunus, Pandanus, Quintinia, Myrtaceae, Saurauia, Evodia and Proteaceae.

In the degraded beech forests, Nothofagus is greatly overrepresented, Lauraceae also overrepresented and Elaeocarpaceae underrepresented. Macaranga considered to be a light-demanding species, is slightly overrepresented. Among the lower growth forms the Poaceae are underrepresented, the Pteridae equally represented and Urticaceae overrepresented. Taxa represented in other modern pollen rain samples (mixed and beech forest) but found here only in the vegetation include Ilex, Myrtaceae, Quintinia, Cunoniaceae, Evodia and Moraceae.

The mixed oak-beech forests show more or less equal representation of Castanopsis, Myrtaceae and Podocarpus in the vegetation and pollen rain but Nothofagus is greatly overrepresented, Elaeocarpaceae slightly overrepresented and Cunoniaceae underrepresented. Among the shrubs and small trees, Pandanus, Evodia and Proteaceae show nearly equal representation in the vegetation and in the pollen rain, Macaranga is slightly overrepresented, Sphenostemon underrepresented. Pollen of Lauraceae, recorded in modern pollen rain spectra from the mixed and beech forests is absent here despite its relatively high density in the vegetation. Prunus and Sapindaceae are unrecorded also from the pollen samples.

In the degraded forests of this type the pattern is essentially similar except that Myrtaceae are overrepresented and Moraceae underrepresented. Acalypha and Trema are recorded from these samples and indicate disturbance of the forests.

Table 7.1 Comparative representation of plant and pollen taxa in vegetation plots and modern pollen rain samples from forest areas.

Plant and Pollen Taxa	Mt Hagen Mixed Forests: Vegetation % Relative Density (a) Base total Large trees	(b) Base total Small trees	(c) Base total All trees & shr.	% Pollen Base total All trees & shr.	Mt Hagen Nothofagus Forest: Vegetation % Relative Density (a) Base total Large trees	(b) Base total Small trees	(c) Base total All trees & shr.	% Pollen Base total All trees & shr.	Mt Hagen Degraded Nothofagus Forest: Vegetation % Relative Density (a) Base total Large trees	(b) Base total Small trees	(c) Base total All trees & shr.	% Pollen Base total All trees & shr.
Castanopsis												
Cunoniaceae	9-17	2-4	3-8	0-6	3-11	1-2	2-3	1	5-30	1-11	2-12	
Drimys	0-3	5-14	1-12	0-4	0-2	1-4	0-3	5-38		0-1	<1	
Elaeocarpaceae	13-23	8-13	9-14	10-12	5-26	17-32	18-26	2-3	0-15	2-10	3-9	1
Ericaceae	7-12	1-4	2-5	0-2			0-5	<1			2-4	0-1
Ilex	0-5	0-5	0-5	0-5					0-5	0-4	0-4	0-1
Lauraceae	7-8	4-6	5-7	1-3	3-5	3-6	4-5	1-15		2-4	2-4	0-11
Myrsinaceae	0-5	0-18	0-16	0-1	1-2	7-10	6-9			1-8	1-7	
Myrtaceae	2-14	1-2	1-3	1-13	0-9	5-6	5-6		0-10	0-1	0-2	
Nothofagus					32-66	4-8	11-18	39-50	15-40	0-4	5-8	46-74
Pandanus	0-2	0-1	0-1	0-1	5-11	4-8	4-8					
Podocarpus	0-5	0-1	0-1	0-7						0-1	0-1	0-1
Prunus	1-2	0-1	0-1	0-2	2-10	1-5	2-4			0-1	0-1	
Quintinia	12-25	3-5	5-8	12-23	1-2	0-1	0-1		0-10		0-1	
Saurauia	0-1	0-4	0-3	0-1	0-2	0-1	0-1			2-10	2-10	0-1
Symplocos	2-16	2-11	2-12	0-1						0-2	0-2	0-1
Acalypha												
Ascarina		+	+	0-1							+	0<1
Claoxylon		0-2	0-2	0-2								
Coprosma			4	2								
Epacridaceae			+	0-4								
Evodia		1-5	1-3	0-4		1-9	1-7		0-5	0-3	0-3	
Macaranga									0-15	0-13	0-13	2-22
Moraceae		3-6	3-4	0-2		3-5	3-4	0-1	0-15	0-2	0-2	
Omalanthus	0-2	0-2	0-2			0-2	0-1			2-30	2-26	0<1
Proteaceae		0-1	0-1	0-1		0-3	0-2					
Sapindaceae						0-1	0-1	<1		0-2	0-2	
Schefflera		0-5	0-4	0-8		0-1	0-1	0<1		0-3	0-2	0-1
Sphenostemon		0-4	0-3	1-4		0-1	0-1	1				
Trema												

Plant and Pollen Taxa	Mixed Forests: Vegetation Base:total plants/ha	Mixed Forests: % Pollen Base:total pollen	Nothofagus Forest: Vegetation Base:total plants/ha	Nothofagus Forest: % Pollen Base:total pollen	Degraded Nothofagus Forest: Vegetation Base:total plants/ha	Degraded Nothofagus Forest: % Pollen Base:total pollen
Asteraceae						
Urticaceae	9-31	2-8	14-20	1-8	1-5	5-13
Poaceae	4-7	2-4	10-12	2	5-12	2-4
Cyperaceae	+	0-1		0<1	++	1
Pteridae	13-20	20-47	9-12	9-10	12-25	6-21
Lycopodiaceae	1-6	0-1			++	0<1

Table 7.1 continued

Plant and Pollen Taxa	Wurup – Mt Oga Castanopsis Nothofagus Forest: Vegetation % Relative Density (a) Base total Large trees	(b) Base total Small trees	(c) Base total All trees & shr.	% Pollen Base total All trees & shr.	Wurup – Mt Oga Degraded Castanopsis-Nothofagus Forest: Vegetation % Relative Density (a) Base total Large trees	(b) Base total Small trees	(c) Base total All trees & shr.	% Pollen Base total All trees & shr.
Castanopsis	53-72	16-41	24-52	24-70	0-27	0-2	0-7	9-25
Cunoniaceae	10-21	14-17	15-16	0-1	0-13	0-7	0-8	1-4
Drimys								
Elaeocarpaceae		0-2	0-1	0-3			+	2-7
Ericaceae			+					
Ilex								
Lauraceae	5-7	4-7	5-7		0-3	0-13	0-11	
Myrsinaceae		1-2	1				+	
Myrtaceae	0-5	2-3	1-3	0-5	0-3		0-1	1-14
Nothofagus	5-7	4	5	8-58	0-10		0-2	13-53
Pandanus		0-1	0-1	0<1			+	
Podocarpus		0-2	0-1	0-1			+	
Prunus	0-3	1-4	1-3					
Quintinia				0<1				
Saurauia		0-3	2					
Symplocos		1-2	0-1					
Acalypha							++	3-5
Ascarina							+	
Cleoxylon								
Coprosma								
Epacridaceae								
Evodia		0-2	0-1	0-1			+	1
Macaranga		0-1	0-1	1-2		0-3	0-3	2-3
Moraceae			+	0-1	0-3	0-7	0-6	0-1
Omalanthus				0-1		0-1	0-1	0-1
Proteaceae		0-1.	0-1	0-1				
Sapindaceae			+	<1		0-3	0-3	
Schefflera			+	0-2			+	0-2
Sphenostemon	0-5	0-7	0-7	0<1				
Trema							++	2-35
			Vegetation Base: total plants/ha	% Pollen Base: total pollen			Vegetation Base: total plants/ha	% Pollen Base: total pollen
Asteraceae							+	0<1
Urticaceae			++	3-9			++	3-8
Poaceae			++	3-5			++	3-10
Cyperaceae				0-1			+	0-2
Pteridae			+++	4-12			++	11-16
Lycopodiaceae							+	<1

Generalizing about the forests as a whole, Nothofagus and Castanopsis are usually overrepresented, while Quintinia, Podocarpus, Ilex, Prunus, Pandanus, and Sapindaceae among the trees and Saurauia, Claoxylon, Ascarina, Sphenostemon, Moraceae and Proteaceae among the small trees and shrubs are either equally represented or underrepresented; Cunoniaceae, Ericaceae, Myrsinaceae and Omalanthus are consistently underrepresented. Other taxa such as Drimys, Evodia, Elaeocarpaceae, Lauraceae, Myrtaceae and Schefflera show variable representation.

REPRESENTATION IN NON-FOREST AREAS

Table 7.2 compares plant taxa present in non-forest vegetation types, such as swampland, grasslands, gardens, garden fallow and regrowth, with pollen found in related modern pollen rain samples. Correlations are not close, perhaps due in part to the level of pollen identification possible for the main plants (Poaceae, Cyperaceae, Pteridae and Lycopodiaceae) and to the lack of an appropriate basis for calculation of the vegetation data, but most likely to the great variety of pollen sources available to an 'open' area.

In the swampland and grassland at Draepi, sedges and forbs are underrepresented, grasses are equally - or underrepresented and ferns and lycopods are overrepresented. A similar situation applies on the Manton swampland, except that here sedges as well as ferns and lycopods are overrepresented and two shrub taxa present are underrepresented. Within the gardened areas surveyed, direct comparisons can be made between vegetation plots and pollen rain of young (0-2 years old) and older fallow (more than 2 years old and up to 10 years old), sweet potato gardens and mixed crop gardens. In the young sweet potato garden areas, representation of grasses is slightly greater in the pollen rain than in the vegetation, that of sedges and forbs less than equal, while ferns and lycopods are overrepresented. In the older fallow area grasses are underrepresented but other relations are as above.

In the mixed crop gardens, on the other hand, grasses are overrepresented, sedges show equivalent representation in vegetation and pollen rain, forbs are

Table 7.2 Comparative representation of plant and pollen taxa in vegetation plots and in modern pollen rain samples from non-forest areas.

Plant and Pollen Taxa	Vegetation Data: Weylk Young SP Garden — Range of Values	Mean	Rel.% Means	Vegetation Data: Weylk SP Garden Fallow — Range of Values	Mean	Rel.% Means	Vegetation Data: Weylk Combined SP Garden and Fallow — Range of Values	Mean	Rel.% Means	Pollen Data[1] Weylk and Wurup: Young SP Garden WK 6, WUR 3 — Range % Values	Mean Rel.%	Pollen Data[1]: Old SP Garden WK 7 — Range %	Mean Rel.%	Pollen Data[1]: Combined Gardens WK 6, WUR 3, WK7 — Range % Values	Mean Rel.%	Vegetation Weylk Mixed Garden — Range of Values	Mean	Rel.% Mean	Pollen Weylk and Wurup Mixed Gardens WK 4, WUR 4, WK 8 — Range % Values	Mean Rel.%
Acalpha										0-3	1.4	1	1	0-3	1.4	0-4	1.5		1-4	2.5
Casuarina										2-8	4.8	1	1	1-8	3.5	0-7	1.2		2-17	7.0
Dodonaea										<1	0.3			<1	0.2	0-8	4.1		0-6	2.4
Glochidion																0-6	0.6			
Ilex																				
Macaranga										0-2	1	1	1	0-2	0.7	0-4	1.4		0-22	7.6
Melastomataceae																				
Moraceae										0-1	0.5			0-1	0.3	0-7	2.2		0-1	0.3
Omalanthus																0-3	0.6		0-1	0.5
Saurauia																0-4	0.5			
Urticaceae										3-4	3.6	5	5	3-5	5.3	0-6	2.1	(20.7)	5-9	6.3
Asteraceae	6-14	9	(42.4)[2]	4-21	12	(37.3)	4-21	10.8	(38.8)	0-1	0.5			0-1	0.3	0-8	8.4	(43.4)	0-1	0.8
Caryophyllaceae	0-4	1		0-5	0.6		0-5	0.8								0-5	2.9		0-1	0.3
Haloragis										<1	0.3			0<1	0.2				0-1	0.4
Lamiaceae				0-5	1.2		0-5	0.6		0<1	0.2			0<1	0.1	0-2	0.1			
Oenanthe																0-5	1.1		0<1	0.1
? *Utricularia*																				
Wahlenbergia	0-2	0.2		0-2	0.2		0-2	0.2								0-2	0.2			
Poaceae	8-30	21	46.7	21-50	35	44.9	8-50	28.4	45.5	45-59	52	55	55	45-59	53.0	4-32	17.4	26.6	11.52	35.3
Cyperaceae	0-11	5	11.2	5-25	12	15.4	0-25	8.8	14.1	1-9	5	1	1	1-9	3.7	0-9	4.5	4.0	2-7	4.0
Pteridae				0-23	1.6	2.1	0-23	0.9	1.4	15-20	18	21	21	15-21	18.7	0-13	4.9	4.3	15-23	19.1
Lycopodiaceae				0-1	0.2	0.3	0-1	0.1	0.2	2-4	3	3	3	2-4	3.0				0-1	0.5

*1 Pollen sum = Total pollen

*2 Figures in brackets : Rel. % means - totals for forbs and shrubs within vegetation data (see Table 7.4).

Table 7.2 continued.

Plant and Pollen Taxa	Vegetation Data: Grassland Range of Values	Grassland Mean	Grassland Rel.% Means	Vegetation Data: Manton-Wurup Regrowth Range of Values	Manton-Wurup Regrowth Mean	Manton-Wurup Regrowth Rel.% Means	Vegetation Data: Combined Grassland and Regrowth Range of Values	Combined Grassland and Regrowth Mean	Combined Grassland and Regrowth Rel.% Means	Pollen: Grassland and Regrowth KW1, KW4 Range % Values	Grassland and Regrowth KW1, KW4 Mean Rel.%	Vegetation Data: Draepi Wet Swamp Range of Values	Draepi Wet Swamp Mean	Draepi Wet Swamp Rel.% Means	Vegetation Data: Draepi Grassland Range of Values	Draepi Grassland Mean	Draepi Grassland Rel.% Means	Vegetation Data: Draepi Combined Swamp and Grassland Range of Values	Draepi Combined Swamp and Grassland Mean	Draepi Combined Swamp and Grassland Rel.% Means	Pollen: Draepi Wet Swamp DR 12, 13 Range % Values	Draepi Wet Swamp DR 12, 13 Mean Rel.%	Pollen: Draepi-Weyik Swamp and Grassland DR/SW II, WK 3 Range % Values	Draepi-Weyik Swamp and Grassland DR/SW II, WK 3 Mean Rel.%
Acalypha										2-11	6.3										2-3	2.6	1-2	1.3
Casuarina										3-5	4.1										1-5	3.0	1-2	1.5
Dodonaea				0-6	2.6		0-6	1.6		<1	0.4										0-1	0.6	0-1	0.9
Glochidion				0-2	0.6		0-2	0.4																
Ilex				0-1	0.1		0-1	0.1		0<1	0.2													
Macaranga				0-7	3.1		0-7	1.9		1-2	1.5										1-2	1.6	0<1	0.2
Melastomataceae				0-4	1.0		0-4	0.8															0-1	0.4
Moraceae				0-6	1.2		0-6	0.8		0-1	0.4												0<1	0.2
Omalanthus				0-2	0.5		0-2	0.3																
Saurauia				0-6	0.5		0-6	0.3																
Urticaceae				0-8	1.6	(24.5)	0-8	1.1	(19.2)	3-14	8.2										5	4.8	3-4	3.5
Asteraceae	4-6	5	(17.7)	3-13	8	(26.2)	3-13	6.7	(23.5)	0<1	0.2	0-5	1.5	(25.0)	0-15	5	(24.0)	0-15	3	(24.5)				
Caryophyllaceae																								
Haloragis															0-3	0.2		0-3	0.1		0<1	0.2	1-2	1.5
Lamiaceae				0-5	1.5		0-5	0.9				0-4	2.0		0-1	0.1		0-4	1.0				0-1	0.6
Oenanthe												0-3	1.0					0-3	0.5					
? Utricularia												0-4	0.7		0-1	0.1		0-4	0.4		0-1	0.7		
Wahlenbergia																					0<1	0.2		
Poaceae	31-45	35	60.8	21-32	27	30.9	21-45	30	39.6	10	9.7	15-30	22	34.5	17-36	29	47.3	15-36	25.7	41.6	13-24	20.8	37-67	52
Cyperaceae	3-11	8	13.9	0-11	5.8	6.6	0-11	6.5	8.6	1-2	1.5	19-33	25	39.2	0-13	9	14.7	0-33	16.2	26.3	10-19	16.2	3-7	5.2
Pteridae				5-13	8	9.2	0-13	5	6.6	16-32	24.1				0-22	7	11.4	0-22	3.7	6	13-16	16.2	11-22	16.4
Lycopodiaceae	0-2	0.6	1.0	0-4	1.4	1.6	0-4	1.2	1.6	0-1	0.4	0-2	0.3	0.5	0-6	1.5	2.4	0-6	0.9	1.5	7-13	11.2	1-6	3.8

Pollen sum = Total pollen.

Figures in brackets : Rel.% means - totals for forbs and shrubs within vegetation data (see Table 7.4)

Table 7.2 continued

Plant and Pollen Taxa	Undrained Swamp			Vegetation Mantons Drained Swamp			Combined Swamp			Undrained Swamp VUR 8		Pollen Mantons Drained Swamp VUR 2, 6, 7		Combined Swamp VUR 2, 6, 7, 8	
	Range of Values	Mean	Rel.% Means	Range of Values	Mean	Rel.% Means	Range of Values	Mean	Rel.% Means	Range % Values	Mean Rel.%	Range % Values	Mean Rel.%	Range % Values	Mean Rel.%
Acalypha										1	0.5	1-2	1.1	1-2	1.0
Casuarina										1	0.5	0-3	1.1	1-3	1.1
Dodonaea												0-1	0.5	0-1	0.4
Glochidion				0-6	4.0		0-6	1.9				0-1	0.3	0-1	0.2
Ilex															
Macaranga												1	0.9	0-1	0.7
Melastomataceae				0-9	5.0		0-9	3.4				0<1	0.1	0<1	0.1
Moraceae												0.1	0.2	0-1	0.1
Omalanthus															
Saurauia															
Urticaceae	0-8	2.7	(4.9)	2-9	6.0	(27.1)	0-9	4.9	(19.8)	13	12.5	2-5	3.6	2-13	5.8
Asteraceae	0-8	2.7	(28.2)	0-8	4.0	(27.5)	0-8	3.4	(27.8)			0-1	0.3	0-1	0.3
Caryophyllaceae										1	0.5			0-1	0.1
Haloragis															
Lamiaceae	0-5	2.2		0-6	2.8		0-6	2.6							
Oenanthe	1-7	4.0		2-7	5.0		1-7	4.5		1	1.0			0-1	0.3
?Utricularia												0-1	0.3	0-1	0.2
Wahlenbergia															
Poaceae	20-37	29	49.7	17-36	23	40.1	17-37	25.1	46.5	17	16.5	30-53	40.3	17-53	34.3
Cyperaceae	0-6	1.5	2.6	0-4	0.6	1.0	0-6	0.9	1.7	9	9.0	5-9	6.5	5-9	7.1
Pteridae	0-3	7.4	12.8	0-5	1.9	3.3	0-5	1.5	2.8	50	50.0	15-36	25.0	15-50	31.3
Lycopodiaceae	0-3	1.1	1.9	0-3	0.6	1.0	0-3	0.8	1.5			2-6	3.6	0.6	2.7

underrepresented, ferns and shrubs overrepresented. Comparison of vegetation and pollen data from grassland and shrub regrowth areas suggests underrepresentation of grasses, sedges, forbs and lycopods, equal representation of shrubs and overrepresentation of ferns. While the overall shrub representation is equivalent in the vegetation and the pollen rain, only five taxa are found in common; Urticaceae are overrepresented, Ilex equivalent, while Macaranga, Dodonaea and Moraceae are underrepresented.

Considering all the non-forest samples together suggests that ferns are always overrepresented in the pollen rain, grasses, sedges and shrubs are usually equally - or underrepresented and forbs are consistently underrepresented.

In addition to the taxa found in both the vegetation and the modern pollen rain samples there are a number which are restricted to either the vegetation data or the modern pollen rain counts. Table 7.3 lists the plants recorded from the forest plots but not in the modern pollen rain samples; these include such trees as Eurya, Polyosma, Schuurmansia, Timonius, Turpinia and Flaucourtiaceae, together with many small trees and shrubs and most of the lianes, climbers and forbs. They vary greatly in density within the forests but some, such as Polyosma, Timonius, Schuurmansia, Phyllanthus and families Monimiaceae, Rubiaceae, Anarcardiaceae, Piperaceae, Rosaceae and Zingiberaceae are well represented and could be expected to be recorded in the modern pollen rain spectra. Their absence from the latter may be due to one or more of the following causes:

(a) they are poor pollen producers, or their pollen is not readily transferred and hence is unlikely to be present in a moss polster sample,

(b) their pollen is destroyed in the deposit after sedimentation,

(c) their pollen is present in the sample but is represented in such low numbers as to be unrecorded in a total count of 200 - 300 grains, or of 3050 grains, for all forest samples counted.

(d) their pollen is recorded but unrecognized.

Table 7.3 Relative density of plants recorded from forest plots : pollen not represented in modern pollen rain samples.

Plant Taxa	Mt Hagen Mixed Forest % Relative Density Bases (a)	(b)	(c)	Mt Hagen Nothofagus Forest % Relative Density Bases (a)	(b)	(c)	Wurup - Mt Ogn Nothofagus - Castanopsis Forest % Relative Density Bases (a)	(b)	(c)	Mt Hagen Degraded Nothofagus Forest % Relative Density Bases (a)	(b)	(c)	Wurup - Mt Ogn Degraded Nothofagus - Castanopsis Forest % Relative Density Bases (a)	(b)	(c)
Acronychia	0-2	2-5	1-4		2-5	2-4		0-2	0-1					0-3	0-2
Anacardiaceae													0-40	0-38	0-38
Eurya	0-2	1-8	1-7		1-2	0-1		0-5	0-3	0-5	1-4	0-4		0-2	0-1
Melastomataceae	0-2	5-6	4-5		2	2		0-1	0-1		0-2	0-2			+
Monimiaceae	0-1	1-8	1-6		5-11	4-10				0-5	0-2	0-3			
Pittosporaceae	0-1	0-1	0-1								0-2	0-2			
Polyosma	2-12	8-30	6-28		4-5	0-4		1-2	0-1		0-1	0-1			
Schuurmansia	7-9	6-13	6-11	0-5	0-1	0-2		0-2	0-1		0-1	<1		0-2	0-1
Timonius	1-21	0-3	0-6		2-3	2-3	0-5	3-4	2-3	0-5	1-11	1-11			
Turpinia	0-2	0-4	0-4		0-2	0-2									
Alphitonia								0-4	0-3		0-3	1-3		0-1	0-1
Amaracarpus			9-17			8-9			+			3-5			+
Apocynaceae												+		0-1	0-1
Cordyline									+		0-1	0-1			+
Dryadodaphne										5-10	0-4	0-5			
Euphorbiaceae								0-2	0-1		1	1		0-2	0-1
Evodiella								0-2	0-1			+			
Flacourtiaceae			+		1-3	1-2		0-3	0-2						
Garcinia								0-3	0-2	0-5	0-1	0-1			
Gardenia										+					+
Geniostoma								0-1	0-1		2	2			
Glochidion								0-2	0-1		0-3	0-3		0-7	0-5
Goodeniaceae									+						
Himantandraceae									+			+			
Palmae								0-3	0-2						
Phyllanthus		0-19	0-16					2-4	1-2		6-7	5-6			
Piperaceae			2-9			2-4			+			2-5			+
Planchonella								0-1	0-1			+			
Polyscias								0-2	0-1		0-1	0-1		0-2	0-1
Rhizophoraceae								0-7	0-6					0-2	0-1
Trimeniaceae									+		0-3	0-2			+
Wendlandia														0-7	0-5
Acanthaceae															+
Asteraceae			+									0-2			
Cucurbitaceae												1-4			
Fabaceae															+
Freycinetia			4			4-8			+			5-11			+
Gesneriaceae			1			0-2			+			0-1			
Gunnera			+												
Lamiaceae						0-1						1-2			+
Loranthaceae			+												
Orchidaceae									+			1			
Palmeria			4-5			6-7			+			2-7			+
Potentilla			0-2									+			
Rubiaceae						1-2									
Rubus			3-7			2-4			+			2-4			+
Solanum			2												
Scrophulariaceae			0-5												
Thymelaeaceae			+						+						
Vitaceae						3			+			0-3			+
Zingiberaceae			12-15			15-17			+			15-19			+

Table 7.4 Relative density of plants recorded from non-forest plots : pollen not represented in modern pollen rain samples.

Plant Taxa	Weylik: Young S.P. Garden – Range of Values	Weylik: Young S.P. Garden – Mean Value	Weylik: S.P. Garden Fallow – Range of Values	Weylik: S.P. Garden Fallow – Mean Value	Weylik: Combined S.P. Garden & Fallow – Range of Values	Weylik: Combined S.P. Garden & Fallow – Mean Value	Weylik: Mixed Garden – Range of Values	Weylik: Mixed Garden – Mean Value	Nanton-Wurup-Oga: Grassland – Range of Values	Nanton-Wurup-Oga: Grassland – Mean Value	Nanton-Wurup-Oga: Regrowth – Range of Values	Nanton-Wurup-Oga: Regrowth – Mean Value	Nanton-Wurup-Oga: Grassland & Regrowth – Range of Values	Nanton-Wurup-Oga: Grassland & Regrowth – Mean Value
Alphitonia							0-5	0.5						
Cordyline							0-6	0.9						
Eurya							0-7	1.1			0-7	0.5	0-7	0.3
Malvaceae									0-4	0.8	0-2	0.3	0-4	0.5
Musa							0-11	4.5						
Ochnaceae											0-7	3.6	0-7	2.2
Piperaceae							0-2	0.1						
Ricinus							0-6	3.1						
Sterculiaceae											0-2	0.2	0-2	0.2
Wendlandia									1-3	2.0	3-8	5.0	1-8	4.1
Acanthaceae							0-4	1.0						
Amaranthus							0-3	0.9						
Apocynaceae									0-5	1.0			0-5	0.3
Begoniaceae											0-4	0.3	0-4	0.2
Boraginaceae			0-4	0.7	0-4	0.4	0-4	1.2						
Centella	0-2	0.2	0-5	1.7	0-5	0.9	0-5	1.8	2-5	4.0	0-5	3.4	0-5	3.6
Colocasia							0-20	11.2						
Commelinaceae	0-6	3.0	0-5	3.0	0-6	2.9	0-6	2.9						
Convolvulaceae											0-2	0.4	0-2	0.2
Cucurbitaceae											0-7	1.6	0-7	1.0
Dioscorea							0-4	0.7						
Euphorbiaceae			0-3	0.4	0-3	0.2								
Fabaceae			0-3	0.3	0-3	0.2	0-6	3.2			0-6	2.3	0-6	1.4
Flueggia											0-4	0.3	0-4	0.2
Hydrocotyle							0-3	0.4						
Loranthaceae											0-5	0.4	0-5	0.2
Melastomataceae			0-1	0.2	0-1	0.1			0-2	0.5				
Menispermaceae											0-4	0.5	0-4	0.3
Oxalis	0-4	0.5	0-2	0.6	0-4	0.5	0-3	1.2						
Philesciaceae											0-4	0.6	0-4	0.4
Polygalaceae			0-4	0.5	0-4	0.3	0-6	1.5	0-2	0.3	0-1	0.2	0-2	0.2
Polygonaceae	0-6	4.0	0-6	3.0	0-6	3.1	0-8	2.9						
Primulaceae							0-4	0.6						
Rubus	0-2	0.5	0-5	1.3	0-5	0.9	0-5	1.7			0-5	1.2	0-5	0.7
Solanaceae			0-1	0.1	0-1	0.1	0-4	1.8						
Violaceae	0-2	0.8	1-3	3.0	0-5	2.0	0-5	2.2			0-4	1.8	0-4	1.1
Poaceae - *Saccharum*							0-8	8.2						
- *Setaria*							0-7	0.4						
Orchidaceae			0-3	0.3	0-3	0.2			0-1	0.4	0-4	0.5	0-4	0.5

Table 7.4 continued

Plant Taxa	Draepi Swampland Range of Values	Draepi Swampland Mean Value	Draepi Grassland Range of Values	Draepi Grassland Mean Value	Draepi Swamp ∩ Grassland Range of Values	Draepi Swamp ∩ Grassland Mean Value	Undrained Swamp Range of Values	Undrained Swamp Mean Value	Manton-Wurup-Oga Drained Swamp Range of Values	Manton-Wurup-Oga Drained Swamp Mean Value	Combined Swampland Range of Values	Combined Swampland Mean Value
Malvacene							0-2	0.1			0-2	0.1
Ochnaceae			0-1	0.1	0-1	<1						
Amaranthus							0-2	0.8	0-2	0.4	0-2	0.6
Boraginaceae			0-3	0.2	0-3	0.1						
Caldesia	0-6	1.7			0-6	0.8						
Centella			0-5	2.3	0-5	1.2						
Eriocaulon	1-6	2.0	0-3	0.2	0-6	1.2						
Fabaceae			0-2	0.2	0-2	0.1	0-6	0.6	0-4	0.3	0-6	0.4
Hypericum	0-3	1.3	0-1	0.2	0-3	0.7						
Melastomataceae			0-4	1.6	0-4	0.8						
Nepenthes							0-3	2.7	0-2	0.4	0-3	0.4
Philesciaceae									0-4	0.6	0-4	0.4
Polygalaceae			0-4	1.7	0-4	1.0						
Polygonaceae							0-5	1.8	0-5	2.3	0-5	2.1
Scrophulariaceae	0-4	4.0			0-4	1.6						
Violaceae	0-4	1.3	0-9	2.6	0-9	2.0	0-5	1.5	0-3	0.6	0-5	1.0
Xyris	0-1	0.3	0-1	0.1	0-1	0.2						
Orchidaceae	0-5	0.6	0-1	0.2	0-5	0.4						

Table 7.5 Taxa present in modern pollen rain samples : not recorded in correlated vegetation plots.

Pollen Taxa	Mt. Hagen Mixed Forest		Mt. Hagen Nothofagus Forest		Wurup-Oga Nothofagus -Castanopsis Forest		Mt. Hagen Degraded Nothofagus Forest		Wurup-Oga Degraded Nothofagus -Castanopsis Forest		Weyik - Wurup Young SP. Garden WK 6, WUR 3		Weyik - Wurup SP. Garden Fallow WK 7		Weyik - Wurup Combined SP. Garden & Fallow WK 6, WUR 3, WK 7	
	Rel. % Trees & Shrubs	Rel. % Total Pollen	Rel. % Trees & Shrubs	Rel. % Total Pollen	Rel. % Trees & Shrubs	Rel. % Total Pollen	Rel. % Trees & Shrubs	Rel. % Total Pollen	Rel. % Trees & Shrubs	Rel. % Total Pollen	Rel. % Trees & Shrubs	Rel. % Total Pollen	Rel. % Trees & Shrubs	Rel. % Total Pollen	Rel. % Trees & Shrubs	Rel. % Total Pollen
Ascarina			0-1	0-1	0<1	0<1							3	1	0-3	0-1
Castanopsis	2-6	1-5	1	<1			1-3	1-2			10-22	3-4	13	2	10-22	2-4
?Celastraceae	0-4	0-3														
?Euphorbiaceae	0-10	0-6			0-1	0<1										
Fagraea	0-3	0-2							0-1	0<1						
Ilex									0-1	0<1						
Nothofagus	11-16	6-9									17-20	3-5	24	4	17-24	3-5
Pandanus											0-3	0<1	3	1	0-3	0-1
Phyllocladus		0-1				<1										
Podocarpus (2-vesiculate)							0-1	<1			3	0-1			0-3	0-1
Quintinia					<1	<1										
Sapindaceae	0-1	0-1														
Acalypha	0-2	1-2	0-2	0-2	1-2	0-1	1	0-1								
Casuarina	0-3	0-2	0-1	0-1	0-1	0-1	1-2	0-1	0-4	0-3						
Dodonaea	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	1	<1						
Macaranga	2-4	1-3	5-9	4-8	0-3	0-2										
Trema	1-5	0-3	4	3-4	2-3	1-3	2	1-2			5-14	1-2	16	3	5-16	1-3
Amaranthus							0-1	0<1								
Asteraceae (fenestrate)	0-1	0<1														
Caryophyllaceae							0-12	0-8								
Cruciferae	0-1	0<1									0-3	0-1	3	1	0-3	0-1
Haloragis			0<1	0<1	0<1	0<1	0-2	0-3								
Liliaceae (C3)							0-1	0<1								
Plantago											0-1	0<1			0-1	0<1
Wahlenbergia	0-1	0<1														
Cyperaceae			0<1	0<1	0-1	0-1										
Lycopodiaceae					0<1	0<2										

Table 7.5 continued

Pollen Taxa	Weyik - Wurup Mixed Garden: Rel. % Trees & Shrubs	Weyik - Wurup Mixed Garden: Rel. % Total Pollen	Manton - Wurup Grassland & Regrowth: Rel. % Trees & Shrubs	Manton - Wurup Grassland & Regrowth: Rel. % Total Pollen	Draepi Wet Swamp DR12, DR13: Rel. % Trees & Shrubs	Draepi Wet Swamp DR12, DR13: Rel. % Total Pollen	Draepi Grassland & Swamp WK 3, DR/SW II: Rel. % Trees & Shrubs	Draepi Grassland & Swamp WK 3, DR/SW II: Rel. % Total Pollen	Mantons Undrained Swamp WUR 8: Rel. % Trees & Shrubs	Mantons Undrained Swamp WUR 8: Rel. % Total Pollen	Mantons Drained Swamp WUR 2, 6, 7: Rel. % Trees & Shrubs	Mantons Drained Swamp WUR 2, 6, 7: Rel. % Total Pollen	Mantons Combined Swampland WUR 2, 6, 7, 8: Rel. % Trees & Shrubs	Mantons Combined Swampland WUR 2, 6, 7, 8: Rel. % Total Pollen	Mt. Hagen Subalpine Grassland HS 3, HS 5, HS 9: Rel. % Trees & Shrubs	Mt. Hagen Subalpine Grassland HS 3, HS 5, HS 9: Rel. % Total Pollen
Ascarina	0-2	0<1														
Castanopsis	8-14	2-6	9-25	5-17	9-13	4-5	20-25	3-5	9	2	8-14	2-8	8-14	2-8		
Cunoniaceae	0-7	0-2	1-16	0-9	0-1	0<1	0-3	0-1			0-6	0-1	0-6	0-1		
Dacrydium	0-2	0<1									0-2	0-1	0-2	0-1		
Elaeocarpaceae			1-2	0-1	1	<1	0-4	0-1			0-5	0-1	0-5	0-1		
Evodia			1	<1					2	1			0-2	0-1		
Lauraceae							0-3	0-1								
Myrtaceae	0-1	0-1	1	<1	1-4	0<1			4	1	0-2	0-1	0-4	0-1	0-2	0-1
Nothofagus	6-28	4-6	6-53	4-37	24-46	8-23	11-17	2-4	15	4	12-40	2-13	12-40	2-13	22-40	8-19
Pandanus	0-4	0-1			0-2	0-1	0-2	0<1	2	1	0-6	0-2	0-6	0-2		
Phyllocladus	0-2	0<1	0-1	0<1					2	1	0-5	0-1	0-5	0-1		
Podocarpus (2-vesiculate)	1-2	0<1			0-1	0<1	0-3	0-1	4	1	0-6	0-1	0-6	0-1		
Schefflera			0-2	0-1							0-2	0-1	0-2	0-1		
Trema	2-7	0-2	2-9	2-5	9-24	5-8	8-23	2-4			2-6	0-1	0-6	0-1		
Amaranthus	0-9	0-2														
Cruciferae					0-2	0-1					0-2	0<1	0-2	0<1		
Plantago					0-1	0<1										

Table 7.4 lists plant taxa recorded from non-forest vegetation plots which do not occur in the modern pollen rain samples. These comprise predominantly forbs but include also many of the crop plants. Pollen production and, or transfer must be very low in these forms.

POLLEN SOURCES AND TRANSFER MECHANISMS

Almost all of the pollen taxa represented in the modern pollen rain samples are recorded in one vegetation type or another. Those which show equivalent representation in modern pollen rain and vegetation, or are underrepresented or overrepresented in the pollen (Tables 7.1 - 7.4) are derived from purely local sources (at or very close to the sample site) or from a mixture of local and extralocal sources. Taxa which are recorded only in the modern pollen rain samples must be derived from extralocal and regional sources. Most of these are recorded extralocally (within a few km of the site of sample collection) but others, such as Fagraea, Dacrydium and Phyllocladus are unrecorded to date in the vegetation surveyed and their pollen might belong to a more regional component.

No direct data are available to elucidate methods of pollen transfer or to indicate distances traversed by pollen in the Mt Hagen region. However, if the ranges of values for local and extralocal representation of various pollen taxa (as given in Tables 7.1, 7.2 and 7.5) are compared, wide variations are found between individual taxa and even within a taxon which is represented extralocally over a wide range of vegetation types. This suggests that a number of factors may be involved in any transfer of pollen from source area to sedimentation area. While differences in pollen production and dispersal capacity may resolve some of the discrepancies, the data might also be explained in terms of different modes of pollen transfer, of varying distances of transfer from the source area and of differential filtration by vegetation.

General features of the climate of the Mt Hagen region have been described in Chapter 2. Regional winds are variable and seldom strong, except during the 'dry' season when the southeasterlies may dominate the circulation. Local winds develop near the mountains and create a daily pattern of morning updrafts and afternoon downdrafts. The forests are so dense as to be virtually windless.

In these circumstances pollen liberated from forest canopy plants may fall vertically or drift over short distances within the forest, may be carried to higher or lower elevations by local winds, or be distributed more widely by regional winds. Pollen liberated from subcanopy and lower structual levels of the forest is unlikely to travel far. Local and regional winds are also likely to be important in the transfer of pollen from non-forest vegetation types. Annual precipitation is high in the Mt Hagen region (2600 mm) and there are few days when rain does not fall. Usually rain clouds build up around the mountains in the late morning, move across the valleys and bring widespread rain in the afternoon and evening. The pollen rainout component must therefore be a large and important one and is probably mainly regional.

On this basis then, it can be suggested that taxa which show local representation only, such as Drimys, Proteaceae, Claoxylon, Saurauia, Glochidion and Epacridaceae are transferred by vertical downfall or by drift over short distances only from parent plant to sedimentation point.

Those which show predominantly local representation but also some restricted extralocal representation, usually in neighbouring vegetation types, may be transferred mainly by local (microenvironmental) winds and drift, either within the forest or above the canopy. In some cases, such as Quintinia, Sphenostemon, Sapindaceae and Podocarpus sim. compactus this transfer appears to be predominantly upwind, in others such as Ilex, Symplocos, Lauraceae, Schefflera and Omalanthus it is variable.

Other taxa which show widespread extralocal distribution and consistent values of extralocal representation over a broad range of both forest and non-forest vegetation types may be transferred by regional winds, or more likely, represent the rainout component. Such a pattern is shown by Dodonaea, Cunoniaceae, Podocarpus sim. imbricatus, Ascarina, Myrtaceae and Elaeocarpaceae. Relatively similar values for those taxa not recorded from the vegetation plots, namely, Phyllocladus, Dacrydium and Fagraea may also be explained in these terms.

It is almost impossible to distinguish a rainout component from wind transfer without control data but varying values of extralocal representation in particular pollen taxa over a range of high and low altitude, open and closed vegetation types, may suggest the greater importance of one mode of transfer over the other and may also suggest the importance of source distances and filtering by vegetation. Taxa which show such varying patterns of extralocal representation include Nothofagus, Castanopsis, Acalypha, Casuarina, Macaranga and Trema.

Filtering by forest vegetation is indicated where values for open vegetation types at both high altitudes (the Hagen summit samples) and lower altitudes (the Manton swamp and Draepi swamp samples) are greater than those for closed vegetation types, such as forest and forest remnants. Examples include Nothofagus, Trema and Casuarina.

Regional rainout plus some downwind transfer may be the factors responsible for the pattern shown by Castanopsis, namely increasing values of extralocal representation correlated with decreasing altitude, while rainout plus upwind transfer may explain the higher values for Acalypha and Moraceae in the Mt Hagen summit samples than in any others and the tendency towards higher values for Macaranga with increasing altitude.

POLLEN TAXA AS INDICATORS OF VEGETATION TYPES

It has been suggested on the basis of the vegetation data (Chapters 4 and 5) that certain species or groups of species could be used as indicators of certain types of vegetation. Are the vegetation data supported by the pollen rain data? Examination of Tables 7.1 and 7.2 suggest that they are and that individual pollen taxa and groups of taxa may be used for classification of pollen spectra which correlate well with the classification of the vegetation. Individual taxa which show local representation in pollen rain correlated with a single set of vegetation plots (or at most with two closely related sets) or which are found in far greater quantities in one set than in all other sets, may be considered as indicators of that particular vegetation type. Small groups of taxa fulfilling essentially similar conditions may also be used, but with caution, while large groups of taxa and the relative proportions of these in the whole spectrum may indicate more general levels of the vegetation classification.

Forests

Table 7.1 lists some possible indicators of particular forest types and all except Macaranga, Omalanthus, Schefflera, Saurauia, Acalypha and Trema can be considered as indicators of forest in general. Pollen taxa which may indicate the presence of mixed forests are Quintinia, Claoxylon and Ilex, if present in quantities greater than two per cent, and Elaeocarpaceae if present in quantities greater than seven per cent, calculated on a pollen sum of total trees and shrubs.

Beech forests may be indicated by the pollen of Nothofagus, Lauraceae and Drimys and usually show a low representation or absence of Castanopsis. Mixed beech-oak forest may be indicated by high values of Castanopsis together with lower or equal values for Nothofagus; Lauraceae and Drimys are absent.

Degraded and disturbed forests may be indicated by high values of Macaranga, by Trema and Acalypha, as well as the usual forest components.

Other pollen taxa, such as Myrtaceae, Cunoniaceae, Proteaceae and Ascarina are represented throughout the forest types and together with others, widespread and, or, of unknown ecological tolerances, cannot be used as indicators.

Non-forest vegetation types

Indicator species for vegetation types within the non-forest areas are more difficult to find. In general, non-forest vegetation may be indicated by the presence of Poaceae, Cyperaceae, aquatics, certain forbs and light-demanding trees and shrubs.

The presence of subalpine grassland may be suggested by pollen of Coprosma, Astelia, Ranunculus and Plantago aundensis and by Epacridaceae and Ericaceae if present in quantities greater than two per cent (base : total pollen).

Lower altitude grasslands cannot be distinguished by particular pollen taxa; Haloragis and Lamiaceae show local representation only in grasslands and sweet potato gardens but other than these, the overall complement of the grassland pollen samples is similar to that of samples from gardens, swamps and regrowth areas.

On the basis of the vegetation data, taxa such as Eriocaulon, Xyris, Dysophylla, Utricularia and Machaerina were suggested as possible indicators of wet swamp conditions such as found at Draepi. Machaerina and Utricularia are the only taxa of this group represented in the modern pollen rain but the others are found in the fossil samples and belong to plants which grow only in wet swamps.

Grass swamps, such as Manton's, show local representation of Melastomataceae and Urticaceae pollen. Urticaceae is present also as a local representative in mixed gardens and in regrowth vegetation and hence must be used with caution in interpretation of fossil pollen diagrams. Oenanthe is found in both swamps and mixed gardens and again its position must be assessed with caution.

On the basis of the vegetation data, gardens could be indicated by the presence of crop pollen taxa such as Ipomoea batatas, Colocasia esculenta, Dioscorea spp., Rungia sp., among others. However, none of these have been found in the pollen rain samples and the taxa which do show local representation in garden areas, namely, Lamiaceae, Drymaria, and Oenanthe among the forbs and Casuarina, Macaranga, Acalypha, Urticaceae, Dodonaea and Omalanthus among the small trees and shrubs are equally indicative of regrowth areas within grassland.

THE MODERN POLLEN RAIN SPECTRA

As well as certain individuals or small groups of taxa, the relative proportions of the major groups of taxa within the whole pollen spectrum may be of value in interpretation of fossil spectra. To investigate this possibility the individual pollen taxa were assigned to vegetation groups on the basis of their local representation. Table 7.6 lists the pollen taxa allocated to these groups and Figures 7.1 and 7.2 present

Table 7.6 Pollen taxa listed according to vegetation types

Mixed forest

Quintinia
Ericaceae
Epacridaceae
Acronychia
Podocarpus
Phyllocladus
Dacrydium
Ilex
Sphenostemon
Evodia
Prunus
Rapanea
Claoxylon
Fagraea
?Celastraceae

Beech and beech-oak forests

Nothofagus
Castanopsis
Lauraceae
Drimys

All forests

Elaeocarpaceae
Myrtaceae
Cunoniaceae
Symplocos
Ascarina
Sapindaceae
Proteaceae
Pandanus

Subalpine vegetation

Coprosma
Astelia
Ranunculus
?Potentilla
Plantago ?aundensis

Light-demanding regrowth vegetation

Urticaceae
Casuarina
Macaranga
Trema
Acalypha
Schefflera
Dodonaea
Saurauia
Omalanthus
Glochidion
Moraceae

Non-forest vegetation

Grasses	-	Poaceae
Sedges	-	Cyperaceae
Aquatics	-	Myriophyllum
		Potamogeton
	-	Utricularia
		Xyris
Forbs	-	Caryophyllaceae
		Apiaceae
		Brassicaceae
		Asteraceae
		Haloragis
		Plantago lanceolata
		Amaranthus
		Lamiaceae
		Wahlenbergia
		Liliaceae

Figure 7.1 Pollen analysis of surface samples. Pollen sum: total pollen (excluding aquatics).

Samples:

HS 3	Hagen summit tussock grassland, W aspect, 3640m.
HS 4	Hagen summit tussock grassland, E aspect, 3700m.
HS 9	Hagen summit tussock grassland, crest immediately above treeline, 3395m altitude.
HS 12	High altitude mixed forest, Mt Hagen, 3330m.
HF 2	Mixed forest on Mt Hagen, 3190m altitude.
HF 15	Mixed forest on Mt Hagen, 2740m altitude.
HF 3	Grass-slip area at 3055m, surrounded by mixed forest.
HF 5	Beech forest at 2740m altitude, Mt Hagen.
HF 7	Beech forest at 2585m, Mt Hagen.
HF 6	Degraded and regrowth beech forest, 2400m, Mt Hagen.
HF 10	Regrowth beech forest, 2280m, Mt Hagen.
KW 203	Oak forest on the Wurup ridgetop, 2220m.
MOF 1	Oak forest on Mt Oga, 2190m altitude.
MOF 2	Oak forest on Mt Oga, 1980m altitude.
KW 2	Regrowth forest on Wurup slopes, 1885m altitude.
KW 4	Forest edge, Wurup slopes, 1675m altitude.
WK 9	Oak patch, forest remnant at Weylk, 1885m.

Summary diagram key:

1. Mixed forest components.
2. Beech forest components.
3. Others (widespread forest taxa).
4. Light-demanding taxa.
5. Forbs.
5a. Subalpine forbs.
6. Grasses.
7. Sedges.
8. Ferns and Lycopods.
9. Unrecognized grains.

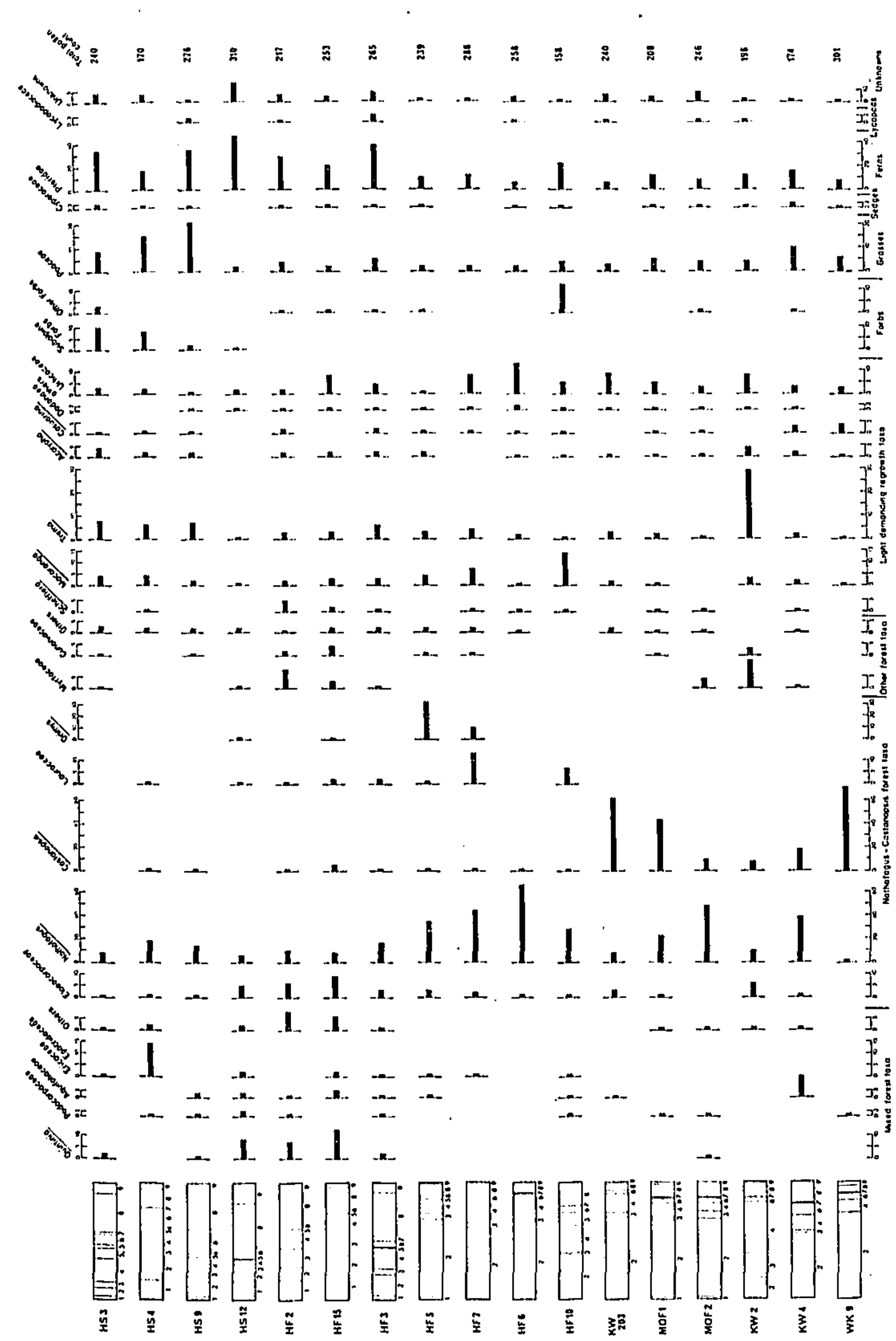


Figure 7.2 Pollen analysis of surface samples. Pollen sum: total pollen (excluding aquatics).

Samples:

KW 1	Garden area at 1825m, Wurup slopes.
WK 8	Mixed garden regrowth, Weylk settlement area, 1885m.
WK 3	Miscanthus grassland, Weylk settlement area.
WK 7	Mixed grassland fallow of sweet potato gardens, Weylk.
WK 4	Mixed garden topsoil (current garden), Weylk.
WK 6	Sweet potato garden topsoil, Weylk.
WUR 3	Sweet potato garden topsoil, Wurup slopes.
WUR 4	Mixed garden topsoil, Wurup slopes.
WUR 5	Taro garden ditch, Wurup.
WUR 2	Mixed grass swamp, near Kuna River.
WUR 6	Mixed grass swamp, adjoining Manton's plantation.
WUR 7	Mixed grass swamp, Manton site.
WUR 8	Phragmites swamp, adjoining Manton's plantation.
DR 12	Floating sedge mat, Draepi swamp.
DR 13	Grass-sedge swamp, Draepi.
DR/SW II	Minjigina grass-sedge swamp.

Summary diagram key:

1. Mixed forest components.
2. Beech forest components.
3. Others (widespread forest taxa).
4. Light-demanding taxa.
5. Forbs.
6. Grasses.
7. Sedges.
8. Ferns and Lycopods.
9. Unrecognized grains.

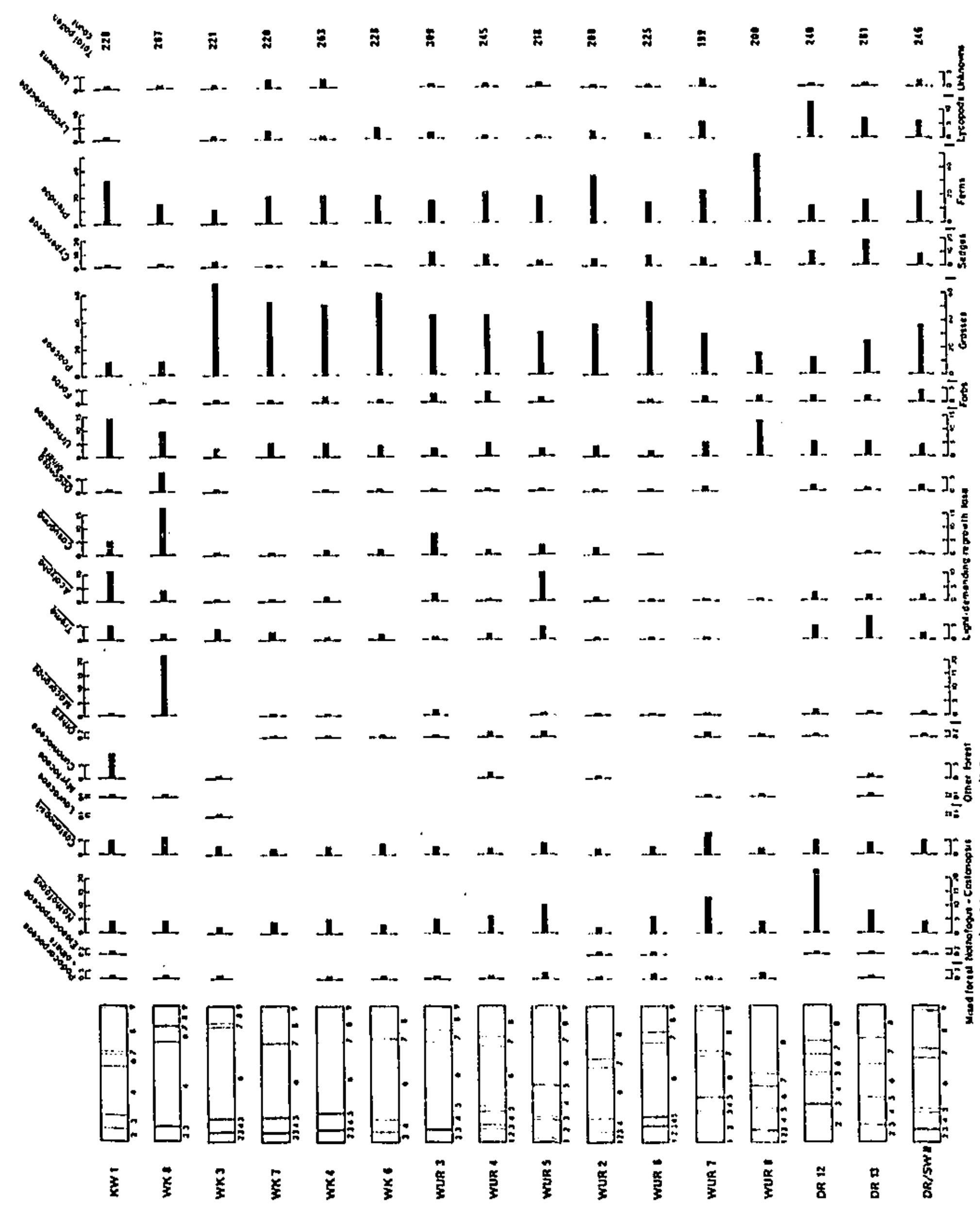


Figure 7.3 Pollen analysis of surface samples. Pollen sum: total of tree and shrub pollen.

Sample numbers as in Figures 7.1 and 7.2.

Summary diagram key:

1. Mixed forest components.
2. Beech forest components.
3. Others (widespread forest taxa).
4. Light-demanding species.

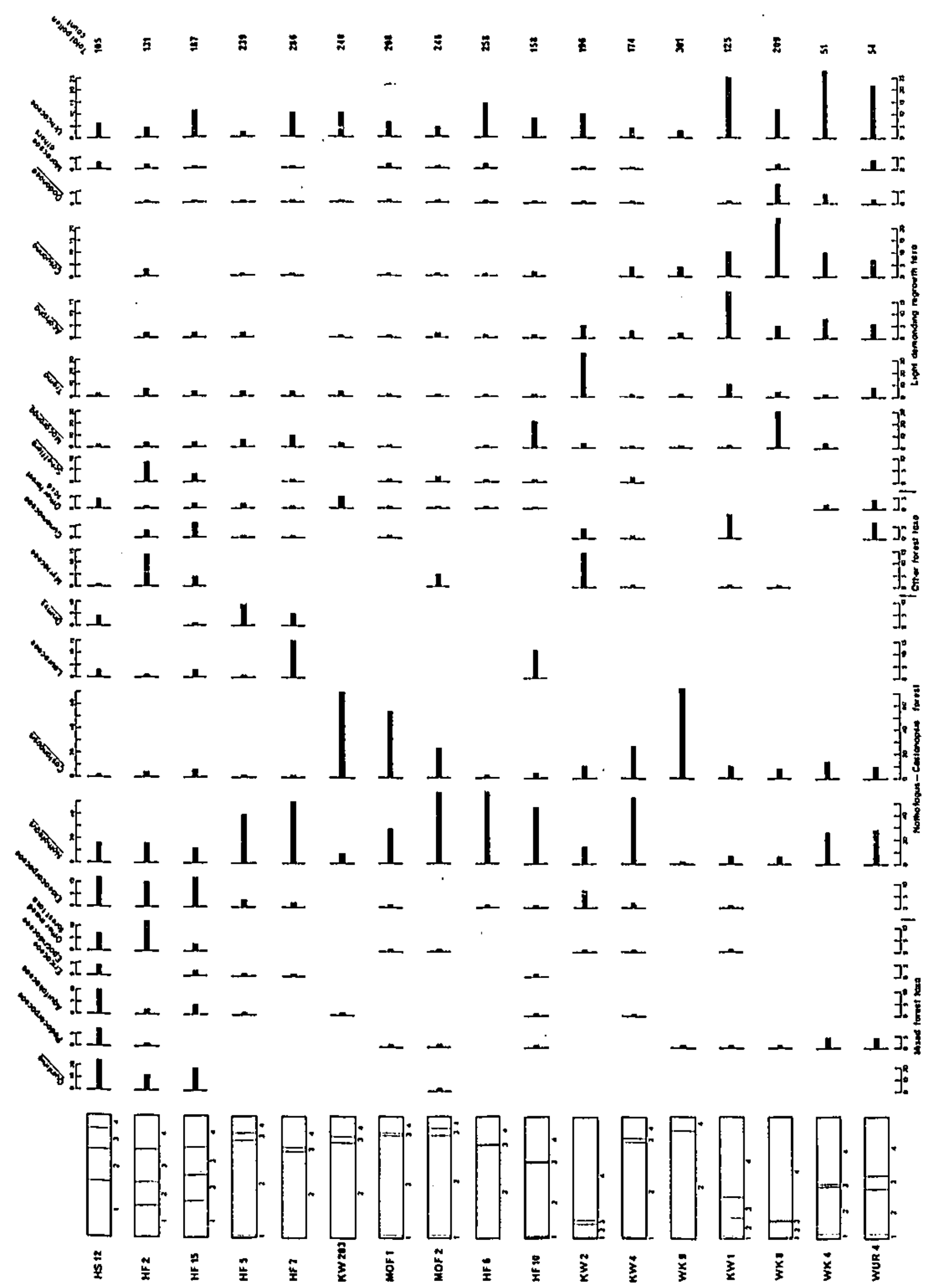
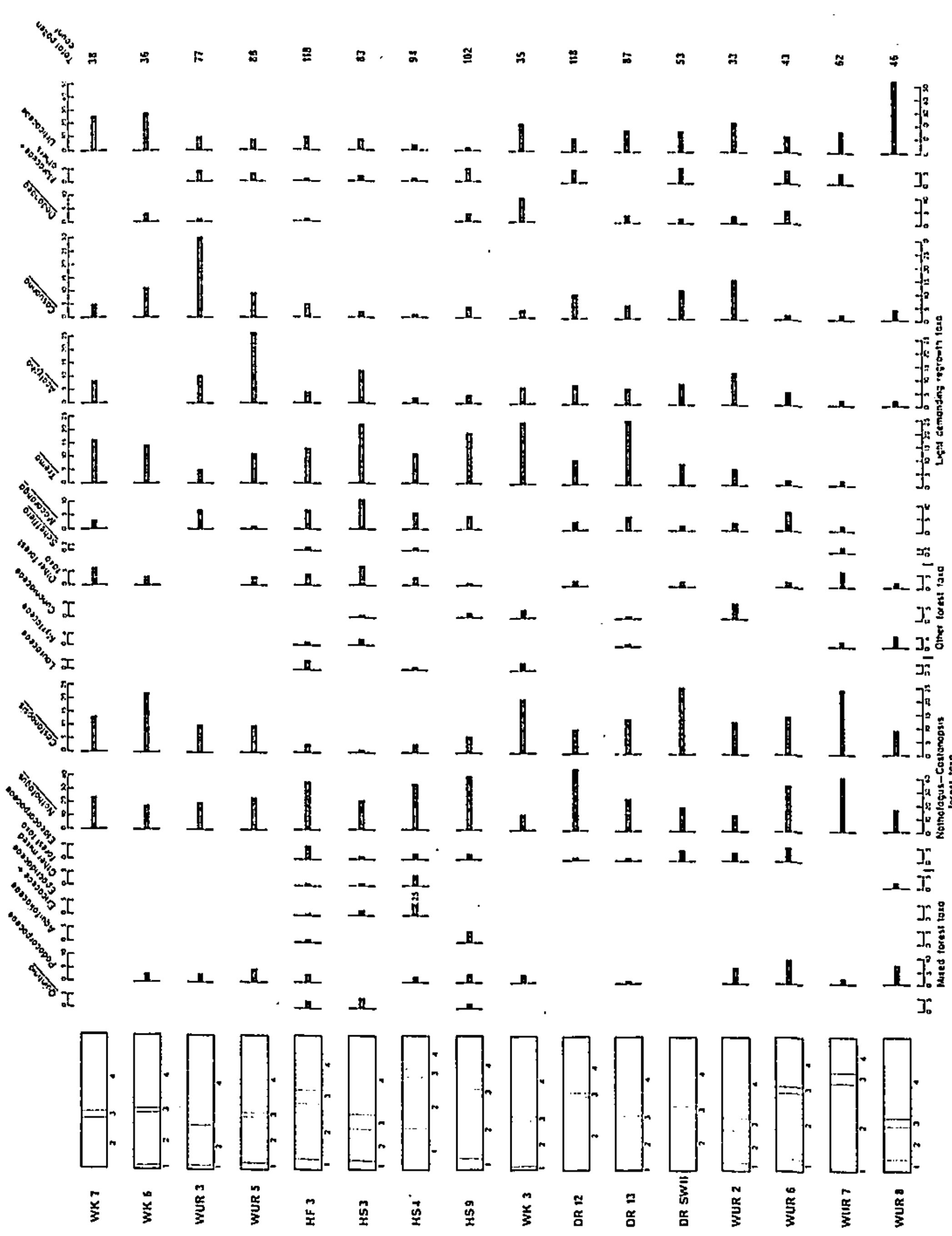


Figure 7.4 Pollen analysis of surface samples. Pollen sum: total of tree and shrub pollen.

Sample numbers as in Figures 7.1 and 7.2.

Summary diagram key:

1. Mixed forest components.
2. Beech forest components.
3. Others (widespread forest taxa).
4. Light-demanding species.



the results in graphical form, using the total pollen as the pollen sum.

The presence of forest rather than non-forest is indicated by:

(a) high values of forest tree taxa (> 60%)
(b) low values of grasses (< 10%)
(c) low values of sedges (< 2%)
(d) absence of aquatics

The highest values of forest tree taxa recorded in non-forest areas are from the subalpine grassland surface samples and from the advanced grassland regrowth surface samples, taken from near the forest margin. The subalpine grassland can be distinguished readily from forest by the presence of subalpine forb taxa and by higher values of grasses; the regrowth vegetation is not so readily differentiated but may be expected to show higher values of light-demanding shrubs and of grasses.

Degraded forest areas show similar pollen spectra to forest but usually have higher values of light-demanding shrubs and grasses. They cannot be distinguished from advanced regrowth vegetation on the basis of the present data.

Grassland and garden areas cannot be distinguished from each other on the basis of the present data; they may be differentiated from regrowth vegetation by higher values of sedges and grasses, and by lower values of forest trees.

Swamplands show similar values of grasses to the garden and grassland areas but are distinguished from them by higher values of sedges and by the presence of aquatics.

If the tree and shrub components alone are considered, the various forest types are identifiable and readily distinguished from the non-forest spectra. Figures 7.3 and 7.4 present the results of the modern pollen rain data using total trees and shrubs as the pollen sum.

Distinctions between forest, degraded forest and non-forest can be made on the basis of relative proportions of forest trees to light-demanding trees and shrubs. Forest is characterized by high values of forest trees (two to three times as great as the light-demanding component) low values of regrowth trees and shrubs, while degraded forest shows slightly lower values of forest trees, higher values of regrowth trees and shrubs, and non-forest areas show low values of forest trees together with high values of regrowth forms.

Among the forest types, mixed forest shows a high proportion of 'mixed forest' taxa and of 'others', low proportions of the 'beech' and 'beech-oak' forest components. Beech forests and the mixed beech-oak forests are pollen analytically similar, with low 'mixed forest' component, low 'others' and high 'beech' plus 'beech-oak'.

Pollen samples from non-forest areas show similar relative proportions of low 'mixed forest' and higher 'beech + beech-oak' component; only the subalpine grasslands can be distinguished by a higher proportion of the 'mixed forest' component. Considering individual pollen taxa and small groups of regrowth taxa it can be suggested that early regrowth stages would be shown by high values of Urticaceae, Dodonaea, Casuarina, Acalypha and possibly Macaranga, later regrowth stages by increases in Macaranga and by Trema, Omalanthus, Saurauia and a number of other light-demanding plants.

CONCLUSIONS

1. Representation of forest taxa in pollen rain and vegetation can be correlated on the basis of density data, in the non-forest areas on the basis of cover density data.

2. The composition of all the pollen rain samples studied can be explained in terms of local and extralocal pollen transfer, the larger part being local; a more regional component may be required to explain the presence of Phyllocladus, Dacrydium and Fagraea pollen in some samples but equally well these species may be present but rare in the vicinity of the sample site.

3. The variation in values for extralocal pollen representation within and between taxa suggests that a number of factors are involved in pollen transfer from source to sedimentation area. Some of these are suggested but control data are required before any conclusions can be drawn.

4. The specificity of local pollen representation allows the selection of particular 'indicator' pollen taxa and of groups of pollen taxa correlated with certain vegetation types which will aid interpretation of fossil assemblages.

5. The following general principles can be suggested for the interpretation of fossil diagrams; they must only be used as guides since much of the data on which they are based is fragmentary:

	Pollen spectrum	Vegetation indicated
A.	Basic sum is total pollen	
	Cyperaceae > 2% Poaceae >10%	Non-forest nearby
	Cyperaceae < 2% Poaceae <10% Forest taxa high	Forest nearby
	Machaerina, Eriocaulon, Xyris, Utricularia present	Open water or very wet swamp nearby
	Astelia, Ranunculus, Coprosma present	Subalpine grassland in the region
	Caryophyllaceae, Lamiaceae, Commelinaceae, Asteraceae Amaranthaceae present	Gardens and grassland nearby
B.	Pollen sum : total of trees and shrubs	
	Quintinia, Ilex, Podocarpus Epacridaceae present	Mixed forests in the region
	Nothofagus values > any other forest taxon, Drimys, Lauraceae present	Beech forests
	Castanopsis values = Nothofagus values; Drimys, Lauraceae absent	Mixed beech-oak forests
	Forest taxa 2.5-3 x > regrowth taxa	Relatively undisturbed forest

Forest taxa = or 1.5-2 x > regrowth taxa	Disturbed and degraded forests
Regrowth taxa > forest taxa	Non-forest vegetation
High values Urticaceae, *Dodonaea*, *Casuarina*, *Acalypha*	Gardens and early regrowth
Macaranga, *Trema* *Omalanthus*	Later regrowth

The relationships of vegetation to environment at the present day have already been tentatively established. Using that information and the relationship between pollen rain and vegetation already discussed it should be possible to identify environmental changes of the past from indications in the pollen diagrams.

Thus a climatic change to colder conditions, involving replacement of oak, beech-oak, or beech forests by mixed forests would be indicated pollen-analytically by an increase in *Quintinia*, *Ilex* and Podocarpaceae, by the appearance of Epacridaceae and by high values of Elaeocarpaceae and Myrtaceae. An even greater change in temperature, causing the replacement of forest by non-forest subalpine vegetation would be indicated in the pollen spectra by a reduction of forest taxa, together with an increase in grassland components and the appearance of subalpine taxa.

Increasing water-depth in swamps, correlated with changing species dominance in the vegetation may be indicated by a replacement of Poaceae by Cyperaceae in the pollen diagram and by the appearance of aquatics. A catastrophic clearance of forest due to natural causes should be distinguishable in the pollen diagrams from that of anthropogenic clearance; the former would be indicated by a sharp decrease in forest taxa, an increase in light-demanding taxa followed by an increase in forest taxa while the latter would be indicated by the continued presence of light-demanding taxa, the appearance of garden forbs and an increase in non-forest components such as Poaceae, Cyperaceae and Pteridae. Figure 7.5 summarizes these and other possible trends which may be identified pollen analytically.

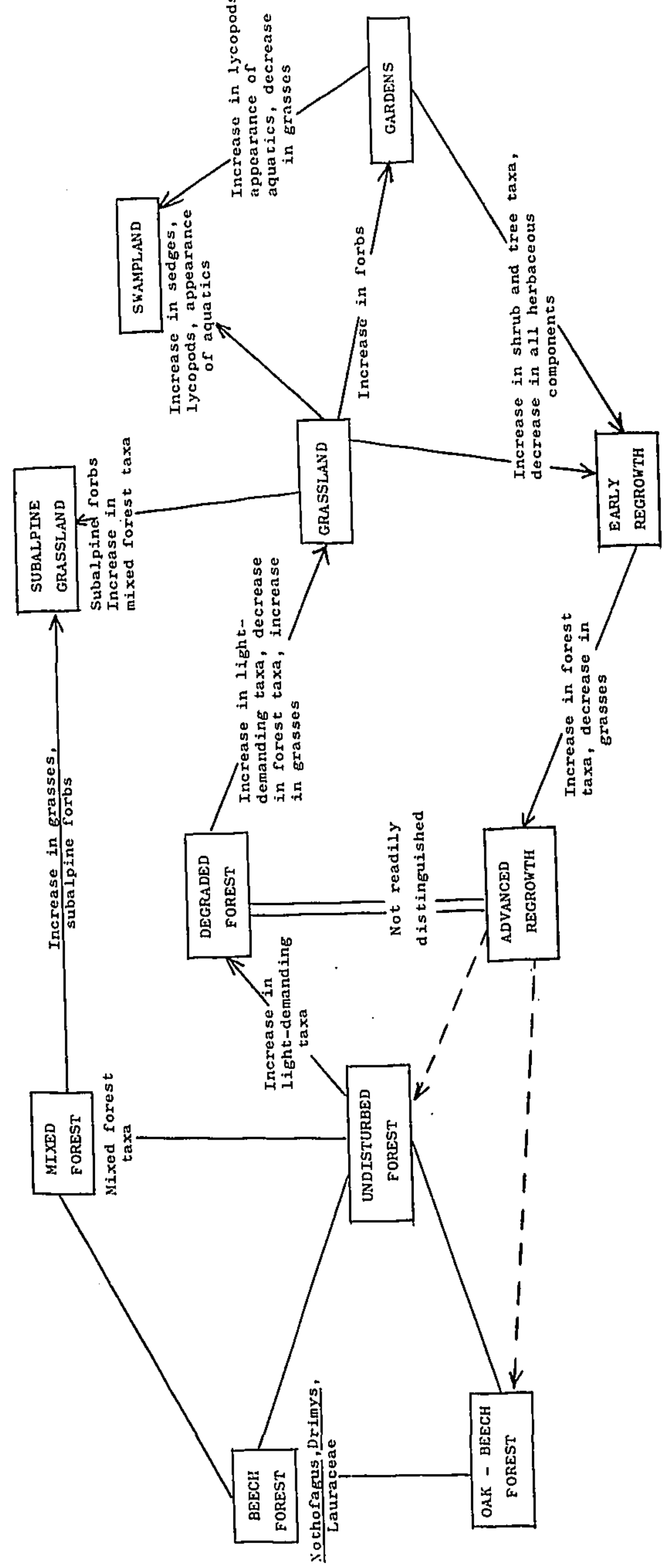


Figure 7.5 Possible trends in pollen spectra.

CHAPTER 8

THE MANTON SITE

The Manton site lies in a large area of swampland about 10 km (6 miles) east of Mount Hagen township. The site area was defined by the archaeological excavation. Figure 8.1 shows the site and surrounding vegetation (Plate 31A).

STRATIGRAPHY

The swamp is developed on alluvium derived from Mt Hagen; it presented a complex stratigraphy involving river gravels, sands and clays as well as peats (Plate 31B). If stratigraphic interpretation was to be useful to the archaeologists it had to be studied in detail near their excavation as well as observed over a greater area. Consequently boring was carried out at 1,2,5 or 10m intervals along transects across the archaeological site, using the Thomas and piston samplers. The tops of the boreholes were levelled and their positions correlated with the archaeological trenches on the site plan (Figure 8.2). Observations on stratigraphy over a wider area made use of freshly cut faces in modern drains.

Field description of the sediments followed Troels-Smith (1955) with regard to colour (nig.), stratification (strf.), elasticity (elas.), dryness (sicc.), humicity (humo) and component parts (Th,Sh,Ga, etc.), (Appendix 3). Figures 8.3 and 8.4 show the stratigraphy of the excavated and adjoining areas.

The basic stratigraphy over wide areas, as exemplified in Figure 8.3 by boreholes 25-32 and in Figure 8.4 by boreholes 1-5 and 19-24 can be described from top to bottom:

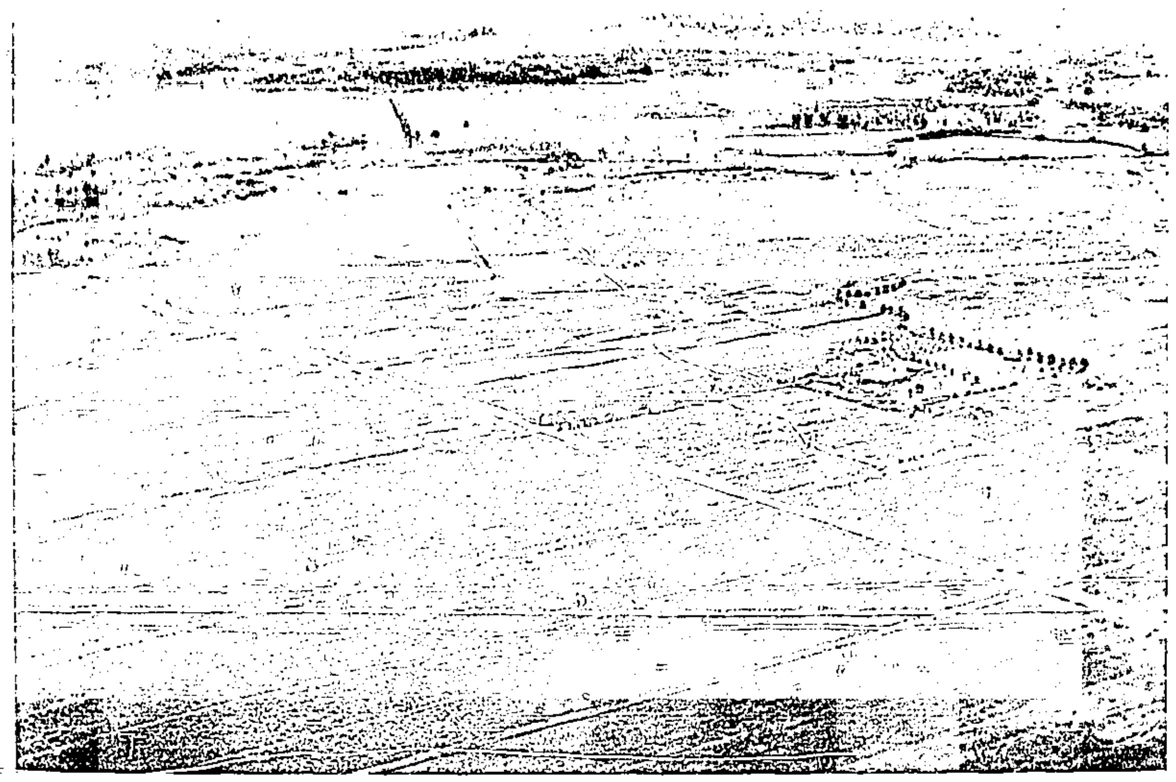
0-11 cm	red brown fibrous topsoil nig 3 elas 1 sicc 3 strf 1 humo 1 $Th^{1}4$ + Sh+
12-30 cm	yellow brown felted peat nig 1 elas 2 sicc 2 strf 2 humo 1 $Th^{?}3$ + Sh1
30-40 cm	brown felted peat nig 3 elas 1 sicc 2 strf 1 humo 3 $Th^{3}3$ + Sh1

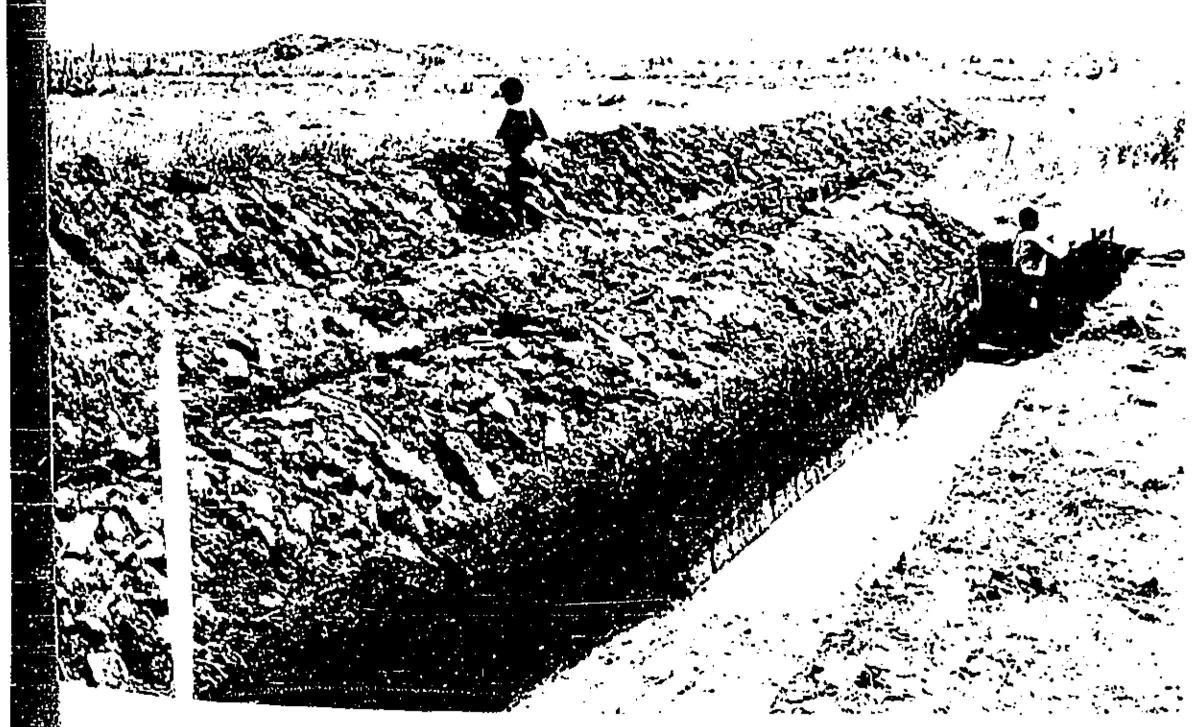
PLATE 31A

The Manton tea plantation and pollen analytical site.

PLATE 31B

An archaeological trench showing typical stratigraphy : peat overlying clay.





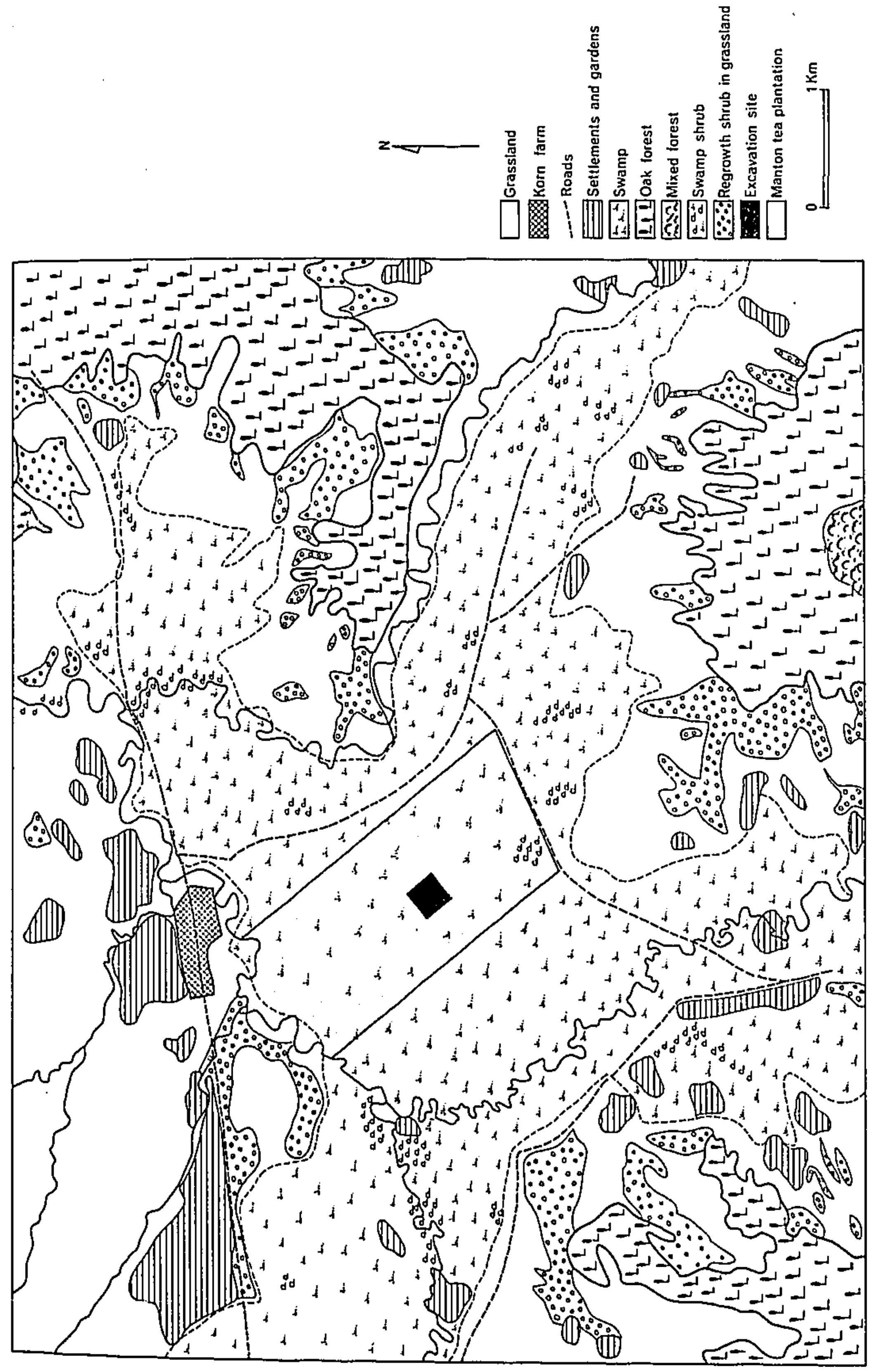


Figure 8.1 Sketch map of the Manton site and surroundings.

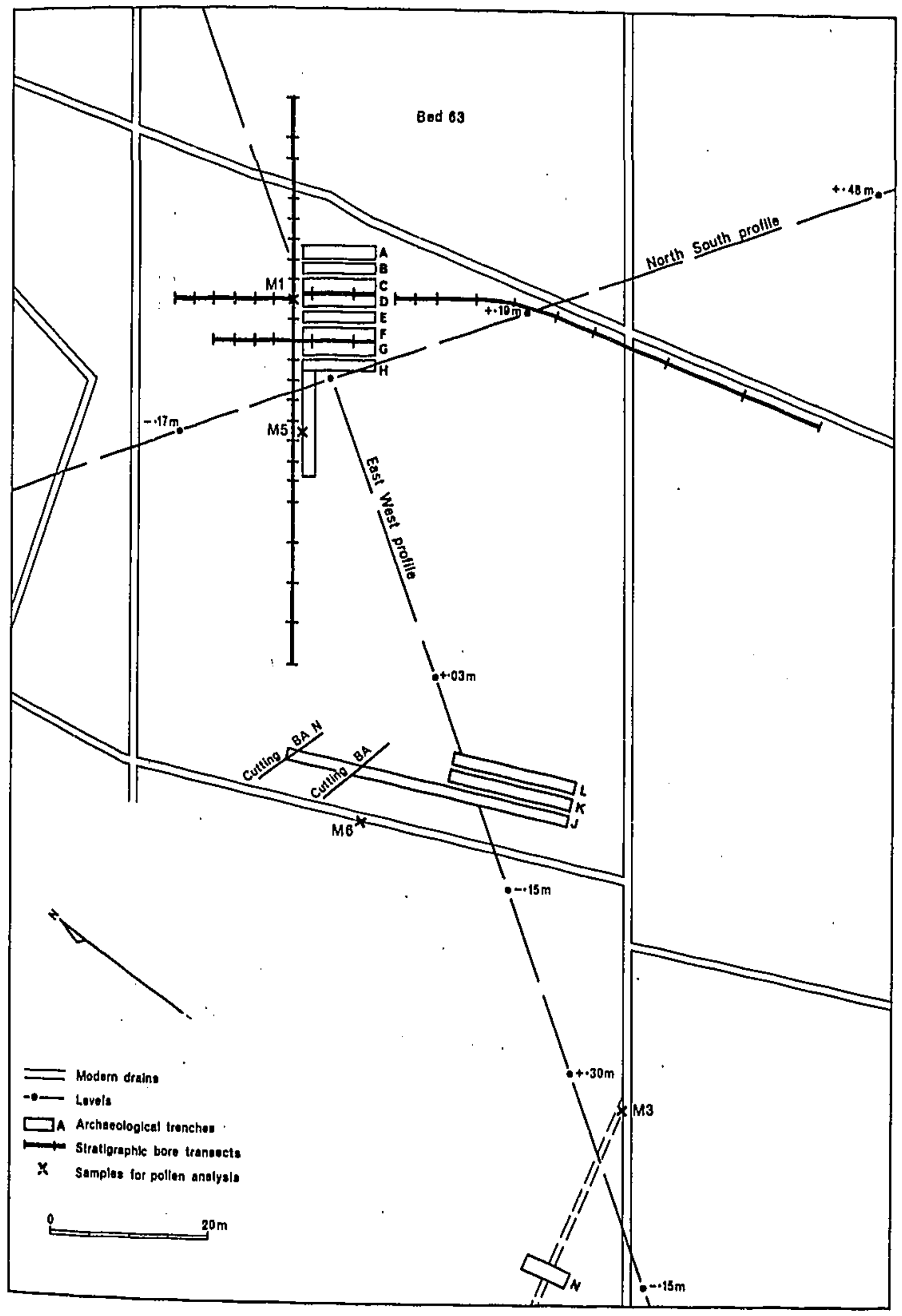


Figure 8.2   Site plan.

40-70 cm	black structureless mud
	nig4 elas 0 sicc 2 strf 0 humo 3-4
	Th^3+ + Sh4 + Ga+
70-100 cm	grey clay mixed with black mud
	nig 3 elas 0 sicc 2 strf 0 humo 3
	Ag2 + Sh2 + Th^3+
100-140 cm	grey clay
	Ag4
140- cm	grey blue clay, sand and gravel
	Ag2 + Gs1 + Gg1.

In areas where depressions occurred in the 'original' landscape, as indicated in Figure 8.3 between boreholes 33-40 and in Figures 8.4 between 14-18, an extra sediment has been deposited and typical stratigraphy is described as follows:

0-40 cm	as described above
40-90 cm	black structureless mud
	nig 4 elas 0 sicc 2 strf 0 humo 3-4
	Th^3+ + Sh4 + Ga+
90-100 cm	brown clay
	Ag4
100-140 cm	black structureless mud
	nig 3 elas 0 sicc 2 strf 0 humo 3-4
	Th^3+ + Sh4 + Ga+
140-210 cm	brown coarse peat and wood detritus
	nig 2-3 elas 1 sicc 2 strf 1-2 humo 3
	$Dl^3$2 + $Th^3$1 + Sh1
210-220 cm	grey blue clay
	Ag4
220-	grey blue sand and gravel
	Gs3 + Gg1

In some areas a very complex stratigraphy was found which appeared to involve inversions and interpolations of lower and higher sediments, for example between boreholes 6-11 in Figure 8.4 and near borehole 33 in Figure 8.3. In such cases a composite stratigraphy could be described as follows:

0-55 cm	as described above as 0-40 cm
55-110 cm	black structureless mud, as before
110-113 cm	brown clay mixed with black mud
	nig 3 elas 0 sicc 2 strf 0 humo 3
	Ag3 + Sh1

Figure 8.3 Stratigraphy of the Manton site: Transect I.

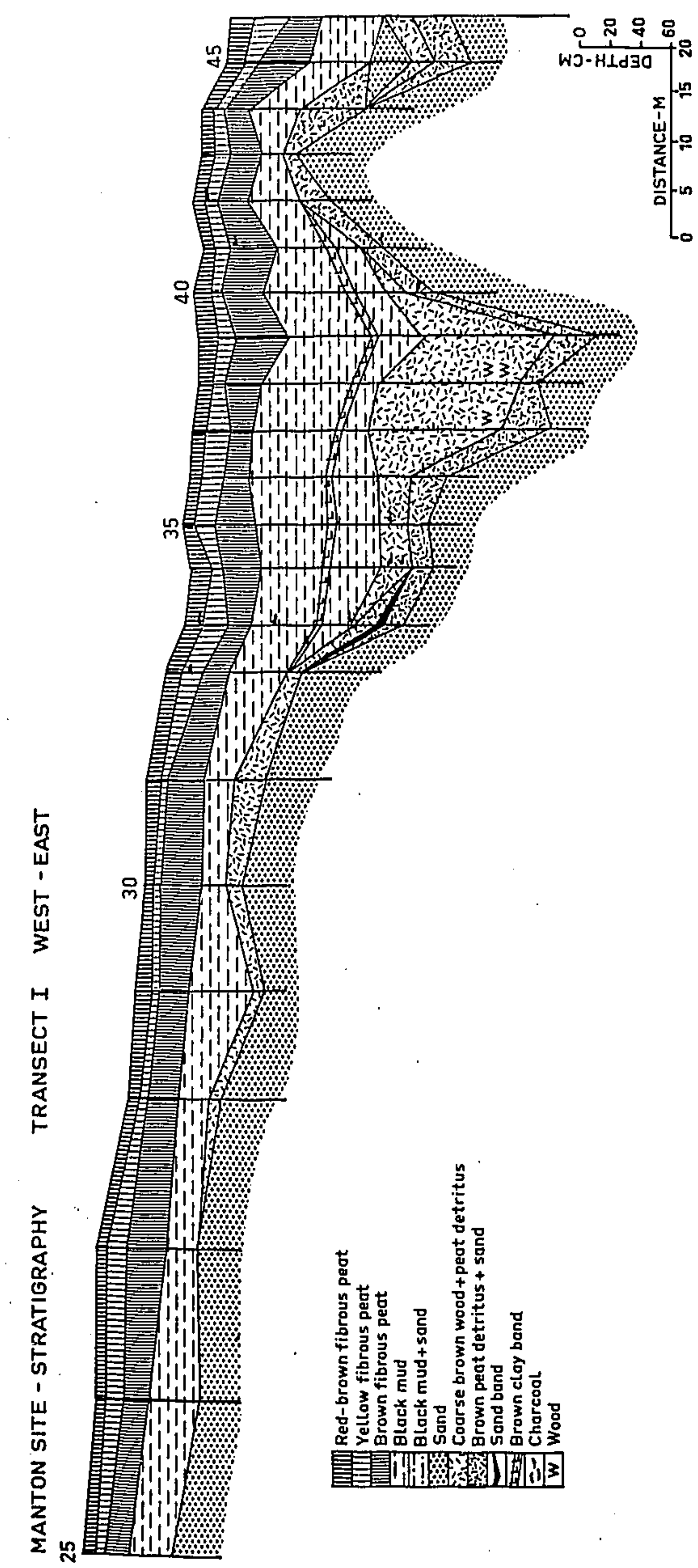
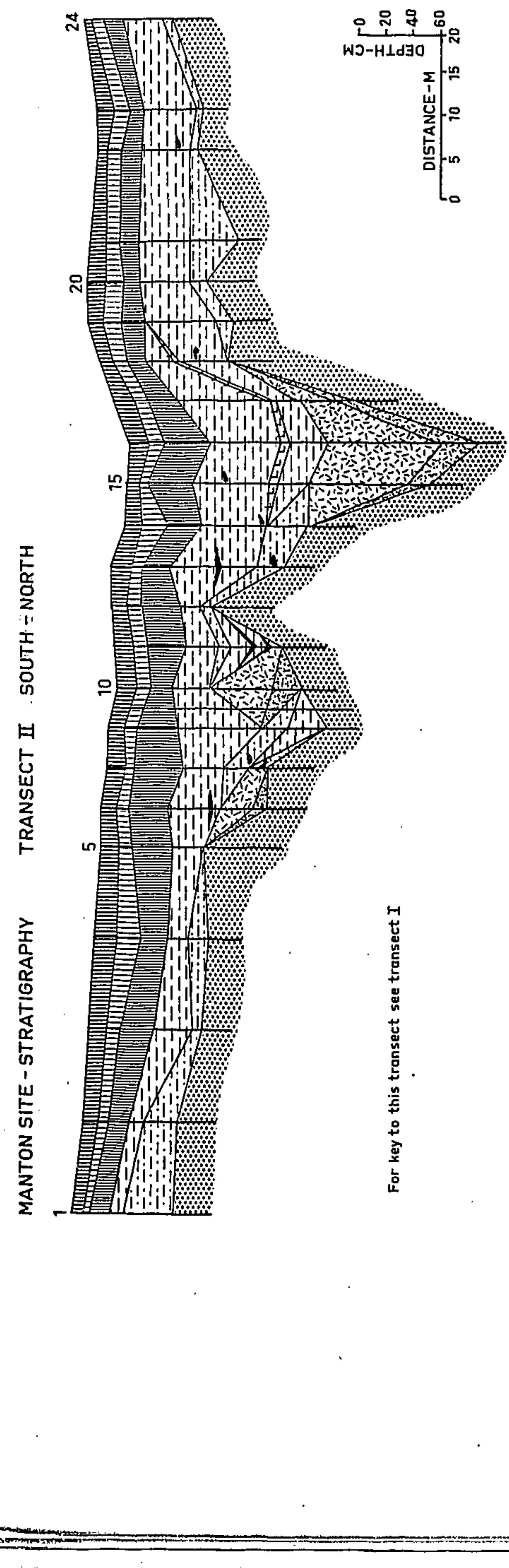


Figure 8.4 Stratigraphy of the Manton Site: Transect II.



113-140 cm	black structureless mud, as described
140-150 cm	blue grey sand Gs4
150-160 cm	black structureless mud and grey clay nig 2 elas 0 sicc 2 strf 0 humo 3 $Ag2 + Sh2 + Th^3 +$
160-180 cm	dark brown coarse wood and peat detritus nig 3 elas 1 sicc 2 strf 1 humo 3 $Dl^3 3 + Th^3 1 + Sh+$
180-190 cm	brown wood and peat detritus mixed with blue grey sand nig 2 elas 0 sicc 2 strf 0 humo 3 $Dl^3 2 + Th^3 + + Sh+ +Gs\ 2$
190-	blue grey sand and gravel Gs2 + Gg2.

These areas will be considered further below.

Analysis of Sediments

Several columns of material were collected for investigation in the laboratory. More detailed analyses of sediments are given for column M1, taken from near borehole 16 in the S-N transect (Table 8.1) and for column M6, taken from near the archaeological trench J (Table 8.2).

Using both the general and more detailed descriptions, some suggestions may be made about the origin of the deposits and the way in which they were laid down.

The basal materials are inorganic streambed deposits. In many areas they are moderately graded, horizontally bedded or gently sloping beds of gravels, sands and silts, presumably laid down in waters of gradually diminishing velocity; in other areas ridges of gravel predominate, formed by stronger flow. Over wide areas the coarse deposits are overlain by blue grey clays and grey or white clays, representing calm, backwater deposits. All these sediments have low water content and high ignition residue values.

Depressions within the basal inorganic deposits are filled with compacted brown peat and wood detritus, horizontally stratified and presumably waterlain. The material is coarsely structured, almost entirely organic with high water content and low

Table 8.1 Sediment characteristics of column M 1.

Depth(cm)	Appearance	% material of different grades (mm) >2	2 -0.25	0.24-0.06	<0.06	Avg. % Ignition Residue	Oxidation	Component parts
0 - 12	Redbrown topsoil	33	33	27	7	48	Non-Oxid.	Coarse and fine roots, Phragmites nodes, little charcoal, mainly
12 - 40	Yellow fibrous peat	70	12	11	7	40	Non-Oxid.	SH in fines; some iron oxide, stain brown.
40 - 68	Black mud	9	24	37	30	72	Oxid.	Coarse Phragmites, wood, fine tissues; SH predom., charcoal, quartz and mica sand, stain black.
68 - 76	Brown clay and black mud	0	23	18	59	70	Oxid.	Fine roots, grass tissues, charcoal abundant; SH predom., sand, stain brown-black.
76 - 125	Black mud & some sand.	9	33	28	30	54	Partly oxid.	Some coarse Phragmites, mat of fine roots; little wood; fine charcoal, some SH and sand; stain brown-black.
125 - 140	Black mud & sand	31	23	23	23	66	Oxid.	Coarse and fine grass roots, tissues, some wood; some charcoal, sand abundant; stain black.
140 - 170	Coarse wood & peat detritus	27	37	24	12	42	Non-Oxid.	Coarse wood and leaf detritus, Phragmites, 'bark', fine roots twigs; charcoal, little SH, stain
170 - 190	"	45	25	13	18	41	Non-Oxid.	brown.
190 - 210	Coarse wood & peat detritus & sand	14	20	20	46	68	Non-Oxid.	Wood, leaf and grass tissues, charcoal (wood and grass), sand abundant; stain brown.
210 - 225	Blue grey sand & wood	27	27	18	28	87	Non-Oxid.	Wood, Phragmites nodes, fine roots, charcoal flakes, predom. sand; stain grey brown or brown.

Table 8.2 Sediment characteristics of column M6.

Depth (cm)	Appearance	% material of different grades (mm) >2	2.0-0.25	0.24-0.06	<0.06	Average Water Content	Avg. % Ignition Residue		Component parts
0 - 11	Yellow brown well-structured peat	82	14	4	0	294	16	Non-oxidised	Phragmites stems, nodes, roots. Other grass tissues, fine root matt. Ground substance increasing with depth. Charcoal twigs, grass flakes present. No inorganic material. Stain brown.
12 - 20		76	20	3	1	297	28		
20 - 38		81	14	3	2	430	12		
42 - 50	Mixed peat and black mud	60	15	11	14	265	48	Oxidised	Coarse & fine grass tissues, fine roots. Ground substance plentiful. Charcoal twigs & flakes. Quartz, chlorite grains obvious. Oxidised material, brown-black stain.
54 - 90	Structureless Black mud mixed with sand in parts	3	21	25	51	112	80		Very few coarse components. Some fine grass stem tissues & roots. Predom. amorphous ground substance & quartz & chlorite grains as sand & silt. Charcoal twigs & flakes. Stain dark brown to black.
90 - 100		6	9	19	66	86	85		
100 - 121		7	22	33	38	88	86		
121 - 137	Black mud & sand & wood	15	28	29	29	84	90		Coarse & fine grass & wood tissues, charcoal, wood lumps & flakes. Predom. organic ground substance with some quartz, chlorite. Stain brown black.
137 - 150	Brown peat & wood detritus	25	45	21	9	791	10	Non-oxidised	Coarse Phragmites & wood tissues, long grass stems, fine grass & wood flakes, amorphous ground substance increasing with depth, wood charcoal & flakes. Very few flakes quartz & chlorite. Stain brown.
150 - 161		16	41	23	20	624	16		
162 - 168	"	25	30	23	23	664	7		
170 - 175	Cream Volcanic ash mixed with coarse peat & wood detritus	16	40	28	16	320	51		Wood & leaf detritus, Phragmites nodes, stems, general grass tissues, coarse & fine; amorphous ground substance. Wood & grass charcoal. Cream volcanic ash some quartz & chlorite, especially at base. Stain brown.
176 - 185		26	24	14	36	158	63		
186 - 190		17	33	17	33	172	72		

ignition residue values. It comprises predominantly *Phragmites* stems, nodes and finer grass tissues and roots together with some wood fragments, twigs, bark and leaves of woody plants. Small quantities of wood and grass charcoal are present and exocarp of the gourd (*Lagenaria siceraria*) was found at one point in this deposit (near the M1 column). The deposit could be considered as a relatively well-humified *Phragmites* peat but the amount of wood present, together with wood charcoal and gourd exocarp, suggests there is a detrital, washed in, fraction as well as material accumulated *in situ*.

Above the basal inorganic material and the intermittently developed organic deposit is a zone of black mud. This is unstratified and structureless, made up largely of amorphous ground substance with quartz and chlorite sand and silt in varying amounts. Water content is comparatively low, residue after ignition high, suggesting a high inorganic component. Some fine grass tissues and roots are present and, very occasionally, coarser *Phragmites* nodes. Charcoal twigs and grass flakes are recorded. The colour of the deposit and its dense black stain suggests that oxidation has occurred at some stage during its development. It may be a mixture of strongly oxidised peat with weathered clay minerals and some sand and silt.

In some areas the deposit is dark grey rather than black and more obviously a mixture of grey clay and black mud. A sample of grey clay was analysed spectrographically; it consisted of the clays, chlorite (ca 50%), kaolin (ca 20%) and vermiculite (trace) with quartz (<10%) and felspars (almost entirely kaolinitized). The material is considered to be an almost completely externally-derived backwater deposit (J.M.A. Chappell, pers. comm.).

The uppermost deposit, developed everywhere above the black mud zone, is a light coloured, coarse fibrous peat, comprising mainly coarse tissues and nodes of *Phragmites* together with finer grass roots and stems. Water content is high, ignition residue low. Some amorphous ground substance is present but inorganic silts and sands are absent. Little humification and no oxidation has taken place.

Alternating lighter and darker bands of peat, with iron oxide concentration in one case suggest changes in moisture conditions. Charcoal twigs and grass flakes are present throughout the deposit. It is an undisturbed Phragmites and mixed grass peat, developed at or near the surface of the water; charcoal has been washed in from surrounding areas.

ARCHAEOLOGY

The areas between boreholes 37 and 39 in the E-W transect and between 12-16 in the S-N transect were excavated by a series of archaeological trenches and artefacts were recovered from within the coarse brown woody detritus and the black mud immediately above it.

Recovered from the coarse brown woody detritus:

1-2 cooking stones
large amounts of wood
gourd exocarp

Recovered from the black mud:

1 paddle-shaped wooden spade
1 pointed wooden digging stick (from drain MII)
6 wooden stakes
8 axeblades
1 sharpening stone
cooking stones and charcoal were scattered throughout this layer
Casuarina tree stools were recorded at the top of this layer.

Other artefacts, recovered from prehistoric and modern drains outside the excavated area included:

8 paddle-shaped wooden spades
4 pointed wooden digging sticks
1 wooden club
2 wooden axe hafts
23 axe blades
30 sharpening stones

In all cases these artefacts were recovered from below the uppermost zone of fibrous yellow brown peat, mainly from the black mud, less frequently from the coarse brown wood and peat detritus and sand.[1]

[1] The above data has been provided by the archaeologists concerned; Professor J. Golson, Mr R.J. Lampert and Mr W.A, Ambrose.

The botanical identifications of several of the wooden artefacts are given in Table 8.3; they indicate that a number of different species were being used for specific purposes.

The stratigraphically disturbed area between boreholes 6-11 of the S-N transect was also excavated (Figure 8.5)[1], (Plate 32). The confusion of sediments is due to a series of ditches having been dug from different levels and subsequently infilled with various sediments. Three columns were cut from the side of the trench (Figure 8.5, column M5/A, M5/B and M5/C) and the sediments studied further in the laboratory. Tables 8.4 - 8.6 give details of stratigraphy and sediment characteristics.

Using these data, and interpreting the archaeological features present, the following sequence may be suggested:

Ditch I (column 5/A) is the oldest in the sequence; it cuts into the basal sands and gravel and is filled with a dark grey, clayey, peat, sealed by a grey sandy clay and later brown clay band. A wooden stake marks the edge of the ditch which is ca 1 metre wide at the top, 40 cm wide at the base and 40-45 cm deep.

Ditch II is also sealed by grey clay and may be of similar age to Ditch I. It was at least 60 cm wide at the top, 35 cm at the base and at least 25 cm deep. Sand fills the bottom with some bedded peat above; the whole is sealed by grey clay.

Ditch III (column 5/B) cut through the brown clay band sealing Ditch I and sand had been thrown out onto the sides. The bottom of this ditch was filled with coarse detritus, mainly wood but with some peat, and sealed above by dark grey black mud. It appeared to be about 40 cm wide at the base.

Ditch IV is the most recent in the sequence, cutting through the grey clay which sealed ditch II and filled with a coarse Phragmites peat together with some wood detritus. It appears to have been a very broad ditch compared with the others, measuring at least 120 cm across the base, possibly 220 cm across the top (if the

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[1] This figure has been redrawn from the field diagram of Professor J. Golson. The interpretation is the responsibility of the author.

PLATE 32

Disturbed stratigraphy at the Manton site.

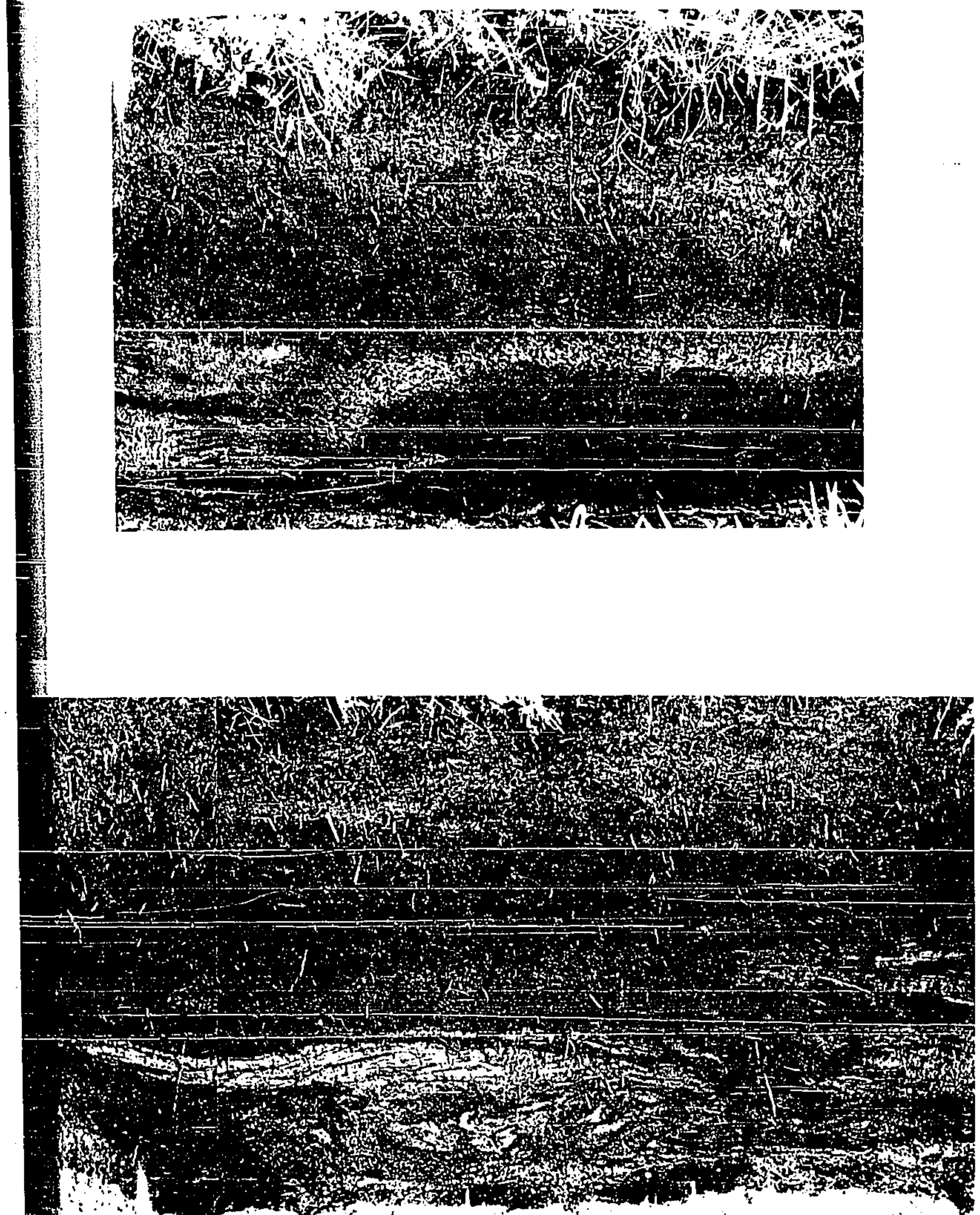


Figure 8.5 Archaeological Section showing position of M5 columns.

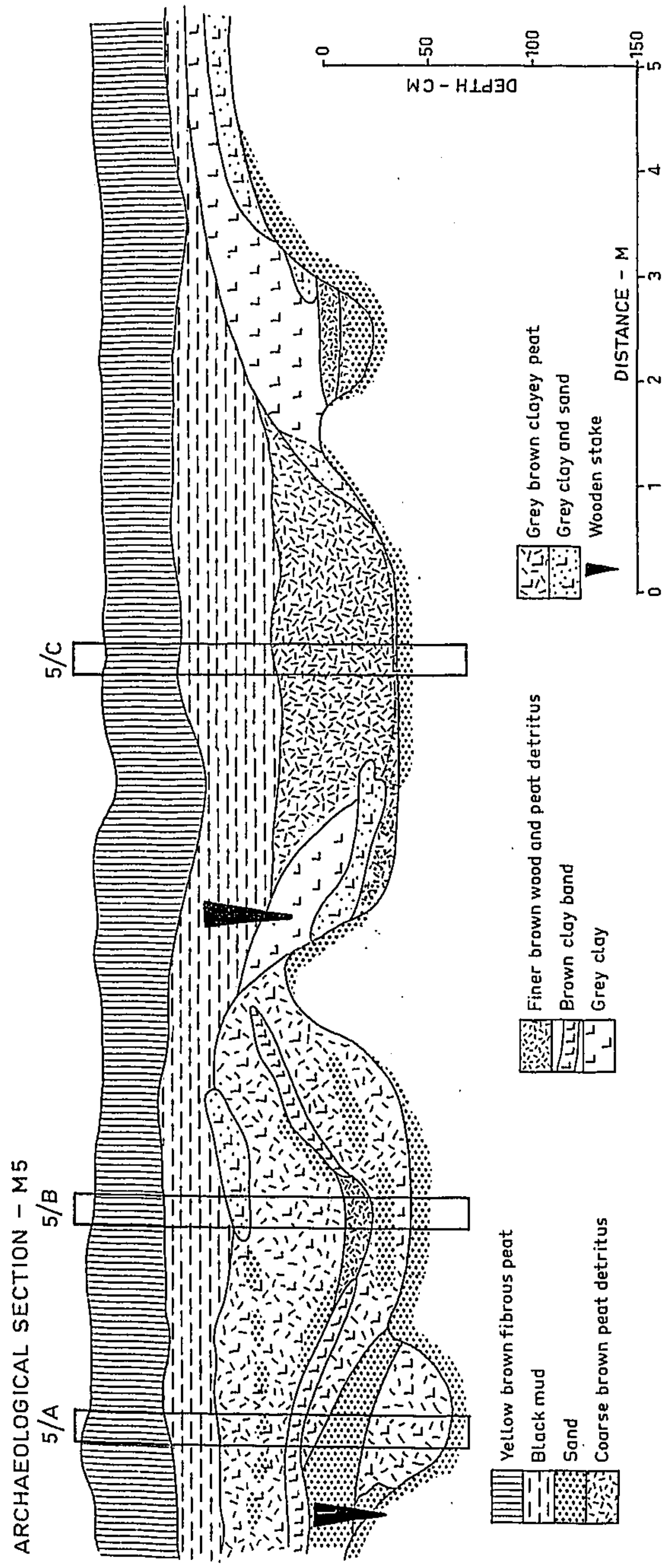


Table 8.3 Botanical identifications of artefacts recovered from the Manton site

(Det. K. Ingle)

No.	Artefact type	Stratigraphic position	Botanical identification
MTH 1	Paddle-shaped spade	From recut native ditch	Casuarinaceae - *Casuarina ?ogligodon*
MTH 3	"	" " "	" " "
MTH 45	"	" " "	" " "
MTH 26	Pointed digging stick	" " "	Euphorbiaceae - *?Phyllanthus* sp.
MTH 60	" "	From ditch MII, excavated area	" " "
MTH 42	Wooden club	From recut native ditch	Moraceae - *Ficus* sp.
MTH 11	Axe haft	" " "	Euphorbiaceae - *Glochidion* sp.
MTH 37	Stake (fence)	From junction of black mud and yellow fibrous peat	Casuarinaceae - *Casuarina ?oligodon*

Table 8.4 Sediment characteristics of column M 5/A.

Depth (cm)	Appearance	% material of different grades 2	2.0-0.25	0.24-0.06	0.06	Average Water Content	Avg. % Ignition Residue	Component parts
60 - 75	Black mud, brown clay & some sand	1	16	18	65	72	82	Fine grass tissues, some charcoal, SH 50-70%, sand 30%.
75 - 90	"	0	15	27	58	64	86	As above, charcoal common, seeds plentiful, 40% sand.
90 - 105	Brown clay, some black mud & sand	0	18	26	56	61	86	Coarse wood and grass tissues, seeds plentiful, charcoal common, 80% sand, 20% SH in fines.
105 - 120	Black mud, brown clay	1	17	22	60	67	85	Fine tissues 45%, SH 35%, 20% sand, charcoal common.
120 - 130	& sand	1	18	30	51	75	86	
130 - 143	"	0	10	30	60	64	90	Mainly sand, some fine tissues, charcoal common, seeds plentiful.

Table 8.5 Sediment characteristics of column M 5/B

Depth (cm)	Appearance	% material of different grades (mm) >2	2.0-0.25	0.24-0.06	<0.06	Average Water Content	Avg. % Ignition Residue	Component parts
40 - 46	Yellowbrown coarsely fibrous peat	54	35	6	5	416	53	*Phragmites* stems and coarse grass detritus, finer grass tissues predom., some charcoal flakes, sedge seeds, little SH; stain dark brown.
46 - 55	Black mud	12	36	18	34	162	69	Coarse *Phragmites*, wood (10%), finer grass tissues, some charcoal flakes, finer components 80% SH, 20% sand; stain very dark brown-black.
55 - 74	Black mud & grey clay	0	23	35	42	94	82	Fine roots and tissues, twig and grass charcoal, SH predom., some sand; stain brown-black, or black.
74 - 83	Black mud & sand	0	18	39	43	47	91	Predom. sand, some fine grass tissues, some SH, charcoal common; stain grey-brown.
83 - 100	Black mud with some	0	15	32	53	59	88	Predom. sand, some fine roots, grass tissues, charcoal and SH;
100 - 122	sand	1	12	25	62	65	87	stain grey-brown.
122 - 134	Coarse wood & peat detritus	35	33	16	16	217	29	Coarse woody detritus, some grass tissues, sedge seeds, little sand, finer components SH predom; stain brown.
134 - 142	Sand & black mud	3	41	23	33	91	87	Few coarse organic tissues, predom. sand, little charcoal; stain grey-brown.
142 - 151	Mixed mud & sand	13	21	37	29	72	90	Some coarse wood and peat tissues, sand and gravel predom.; charcoal common, some finer tissues; stain brown-grey to grey.

Table 8.6 Sediment characteristics of column M 5/C.

Depth (cm)	Appearance	% material of different grades (mm) >2	2.0-0.25	0.24-0.06	<0.06	Average Water Content	Avg. % Ignition Residue	Component parts
30 - 40	Fibrous, very dark brown peat/black mud	25	32	7	36	222	60	50:50 large *Phragmites* tissues, finer grass tissues, small pieces wood, wood charcoal, sedge seeds, finer components 90% SH, 10% tissues.
40 - 50	Black mud	7	44	12	37	189	65	Coarse *Phragmites* and other grass tissues, some large lumps of charcoal, finer components 90% SH, 10% tissues, charcoal flakes common, *Rubus* seeds.
58 - 85	Black mud	25	19	22	34	248	43	
85 - 93	Brown-black peat	26	35	15	24	482	11	Compressed wood and peat detritus, some charcoal.
93 - 110	Stratified brown woody peat	22	45	30	3	814	13	Compressed wood and peat detritus, some finer grass tissues, some charcoal; finer components SH predom.
110 - 138	Stratified brown woody peat	1	47	30	22	602	38	Coarse and fine grass and wood tissues, little SH, some sedge seeds, little charcoal.

wooden stake marks the upper part of its edge) and 65-70cm deep.

The artefacts and stratigraphy suggest that the area was used for gardening. The ditches were probably dug as drains and as boundary markers, the wooden spades and digging sticks used to prepare and till the soil; the wooden stakes found at the edges of ditches suggest fencing. Such explanations are supported by the author's observations on extant gardens and gardening practices (Chapters 2 and 5) and by a number of reports on these at the time of first European contact in the area (Williams 1937, Nilles 1942, Vicedom & Tischner 1943-48) and more recently by Heider's descriptions for the Dani of the Baliem Valley, West Irian (Heider, 1965).

The gourd exocarp may have been used artefactually since it did not contain seeds. The numbers of axeblades, hafts and sharpening stones found together indicate either a production and polishing site, as the stone had been quarried from areas nearby (J.M.A. Chappell, pers. comm.), or more simply their use in sharpening the digging tools and in everyday life.

The inclusion of artefacts in some of the deposits and their disturbance of stratigraphy in parts of the site may aid interpretation of the various sediments' origin.

Thus the brown coarse wood and peat detritus appears to be, at least partly, a wash-in material; over the area studied in detail it developed several times, in the bases of ditches as well as in apparently natural depressions. The intermittent brown clay which seals some of the earliest ditches was analysed by J.M.A. Chappell (pers. comm). Chlorite was the only identifiable clay mineral; it was poorly developed and did not constitute more than 5% of the sample. The plagioclase present was comparatively little weathered. The deposit was without doubt an <u>in situ</u> swamp material and was largely organic. The structureless black mud lying above the coarse detritus, or above clay or sand, seems now almost certain to be a very mixed and oxidized soil, possibly developed originally from a grass peat but subsequently well mixed with clays and sand.

RADIOCARBON DATES

Radiocarbon dates relevant to the site are as follows:

ANU 43 - MTH 60	Wooden digging stick embedded in black mud and sand in base of ditch at 115 cm below surface. 2300 ± 120 B.P.
ANU 44 - MTH 63C	Wood at the base of the black mud, at 135 cm below surface. 4560 ± 72 B.P.
ANU 251	Wooden stake embedded in black mud and sand at 128-136 cm below surface. Directly correlated with M6 pollen diagram. 980 ± 150 B.P.
ANU 252	Wood lying at the base of a zone of mixed coarse brown detritus and volcanic ash, at 195-200 cm below surface. Correlated with the M6 pollen diagram. 4900 ± 90 B.P.
ANU 289 - MTH 37	Wooden stake lying between 35-65 cm below surface; marking the junction of the black mud and yellow brown fibrous peat. 470 ± 75 B.P.
ANU 288 - MTH 34	Wood, lying within coarse brown wood and peat detritus at 195 cm below surface. 4880 ± 90 B.P.

POLLEN ANALYSIS

Columns M1 and M6 have been analysed pollen-analytically (Figures 8.6 and 8.7). Two columns were chosen because, although M1 was drawn from the deepest organic deposit, materials for radiocarbon dating were not collected with it; M6, on the other hand, although shorter and possibly more mixed was directly associated with datable wood. Additional materials collected from within 1m horizontally of column M1 (archaeological trench D) were later dated radiometrically (ANU 288, ANU 289) and may be correlated with the M1 pollen diagram.

The pollen frequencies in the diagrams are percentages of total pollen of woody plants, excluding Urticaceae. From the stratigraphy of the site itself there are no indications that forest ever grew on it; hence the forest taxa and the woody non-forest taxa (excluding Urticaceae) must represent 'extralocal' and 'regional' vegetation. The herbaceous taxa and the Urticaceae, on the other hand, are nowadays components of the local, extralocal and regional vegetation and must be considered in relation to each.

Ecological interpretation of the pollen diagrams is based on present plant distribution patterns and ecological groupings and to some extent on the content of the modern pollen rain derived from these (Chapter 7).

Stratigraphy, water content and ignition residue curves together with radiocarbon dates are shown on the left hand side of the diagram, sample positions and the summary diagram of forest against non-forest components next to them. The main pollen taxa recorded are plotted individually across the diagram and the total pollen count of the sample is shown on the right hand side.

Due to the scale of the diagram, values less than 1% are shown as 1%. Pollen calculated <u>within the sum</u> includes the forest taxa <u>Nothofagus</u>, <u>Castanopsis</u>, Podocarpaceae, Elaeocarpaceae, Myrtaceae and others grouped together, and the non-forest plants <u>Trema</u>, <u>Acalypha</u>, <u>Macaranga</u> and Euphorbiaceae, <u>Casuarina</u>, <u>Dodonaea</u>, <u>Saurauia</u>, Moraceae, Araliaceae and other minor types grouped together. Those calculated <u>outside the sum</u> include Urticaceae, Apiaceae, Asteraceae, Brassicaceae, <u>Amaranthus</u>, Lamiaceae, Commelinaceae, Caryophyllaceae, other forbs, Poaceae, Cyperaceae, Pteridae, Lycopodiaceae, aquatics and unrecognized grains.

<u>Interpretation of the Pollen diagrams</u>

The detailed interpretation of the pollen diagrams is based on comparison of overall composition weighted by the values for individual taxa of some indicator value (calculated both within and outside the sum) between adjacent spectra and groups of spectra. Indications of major and minor vegetation changes have been sought which could then be interpreted in climatic, natural autogenic successional or anthropogenic terms, or combinations of these.

The importance of human influence at the site is clearly indicated in the stratigraphy and by the contained artefacts. Because of this, explanations of pollen analytical changes which can be attributed to anthropogenic effects are the most economic available, particularly in the central parts of the diagrams. The upper and lower parts, covering apparently undisturbed sediments, are also more readily interpreted in anthropogenic terms than in any other. For instance there appears to be no consistent pattern of regeneration among the light-demanding taxa which could be correlated with known successional patterns; nor is there any pattern of increasing or decreasing beech, oak or mixed forest to which it is necessary to ascribe climatic control. Some of the fluctuations in the herbaceous taxa, on the other hand, may be interpreted in successional terms but even these are obscured due to their presumed origin from both dryland and swamp vegetation.

It is convenient for purposes of description to divide the diagrams into zones; these are characterized by different ratios of forest to non-forest taxa and the boundaries between zones by important changes in values of individual taxa. The two diagrams were zoned separately but the resultant zones compared and labelled so as to identify similarities of composition.

<u>Pollen diagram M6</u> (Figure 8.6)

The stratigraphic position of column M6 is shown in Figure 8.2. Five pollen zones are described covering a time period of 3500 - 4000 years. The oldest radiocarbon date correlated with this diagram is 4900 ± 90 years B.P. (ANU 252) for wood recovered from 195-200 cm depth. Because the wood itself might have been old at the time of its incorporation and because it lies below the lowest sample (161 cm) of the diagram, this date is a maximum for the base of the pollen diagram.

<u>Zone B: 162-152 cm</u>

Non-forest trees and shrubs dominate this zone; at its base they make up 70% of the total woody taxa and at the top, 95%. Herbs are not well represented.

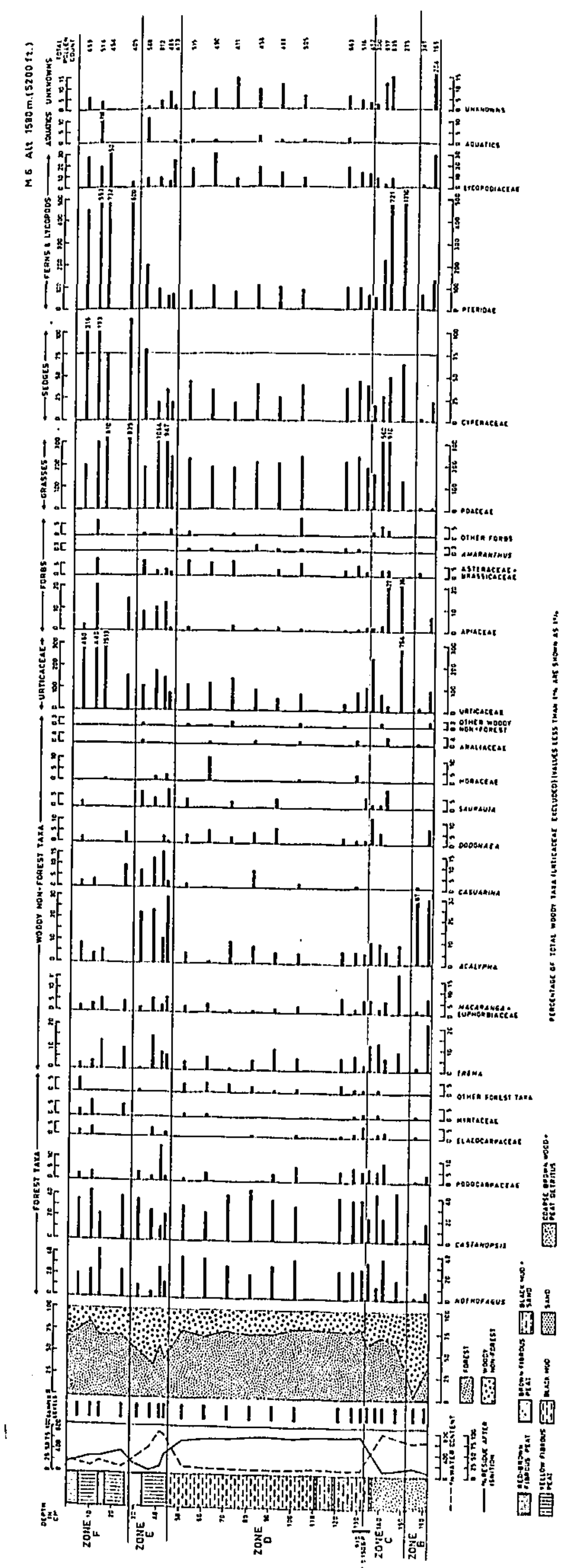


Figure 8.6 Pollen diagram of Column M6. Pollen sum is total of tree and shrub pollen excluding Urticaceae. The summary diagram shows forest and non-forest woody taxa as percentages of their joint sum.

The forest trees Castanopsis, Nothofagus and Podocarpaceae are present at the base of the diagram, Castanopsis in higher proportion than the others, suggesting that both oak and mixed oak-beech forests were in the area. The light-demanding Trema and Acalypha show very high values, Dodonaea and Macaranga slightly lower. At the top of the zone there is a drastic reduction in forest taxa and Acalypha dominates the woody non-forest. Trema and Macaranga appear to have been reduced but their lower values may be due in part to the dominance of Acalypha. Among the herbaceous taxa recorded, Urticaceae, Apiaceae, Cyperaceae, Pteridae and Lycopodiaceae have initially high values which are later reduced; Poaceae has very low values throughout.

The spectra suggest that at the time deposition began, both oak and beech forests grew on the slopes surrounding the site, but that large areas were dominated by light-demanding shrubs and trees. Grasses were virtually absent. This suggests degraded and locally cleared areas within the forest rather than wide expanses of grassland. Modern pollen rain equivalents are seen in the surface samples KW2 and KW1 which are drawn from degraded oak-beech forest in the Wurup-Manton area and garden fallow near forest on the Wurup slopes respectively. KW2 has high Trema values and dominance of non-forest taxa, while KW1 has high Acalypha values, dominance of non-forest taxa, Castanopsis values greater than Nothofagus, and low Poaceae values.

The low values of Poaceae make it difficult to explain the herbaceous complement in terms of local swampland, as suggested by the stratigraphy. Probably the site was open water during zone B and the herbaceous pollen is derived from neighbouring dry-land vegetation, part of the degraded forest communities on the surrounding slopes or, more likely, that of local stream bank, shingle and gravel ridges. Trema and Acalypha may also be important shrubs in such places. The suggestion of open water at the site at this time is supported by the abundance of Potamogeton fruit stones but it is surprising that no aquatic pollen was found.

Zone C: 152-133 cm

The forest values are high but somewhat fluctuating in this zone; they may reflect periods of regeneration and clearance. Many herbaceous taxa appear in high numbers at the beginning of zone C and these too fluctuate throughout the zone. They are thought predominantly to reflect local conditions but also, in part, the dry land vegetation.

The initial increase in Castanopsis and Nothofagus values and in Trema and Macaranga, with correlated decrease in Acalypha suggests regeneration of forest and scrub areas as a whole. At this time Pteridae dominate the herbaceous taxa and high values of Urticaceae, Apiaceae, Cyperaceae and Poaceae are recorded. These may indicate the maintenance of some of the earlier clearings or the development of grassy swampland locally or both. Similar high values are found today in the Manton swampland surface samples, such as WUR 8, collected from tall Phragmites swamp.

This is followed by a decrease in Castanopsis and in the non-forest shrubs Trema, Acalypha and Macaranga, while Nothofagus values increase and Podocarpaceae and Elaeocarpaceae reappear. As the total forest : non-forest ratio is 70 : 30 at this time at least some of the forest must have been regenerating. Clearance of Castanopsis and regrowth vegetation near the site may have occurred while Nothofagus forest regenerated undisturbed on the higher slopes. The light-demanding taxa Saurauia and Araliaceae appear at this time but little significance can be attached to them. Among the herbaceous taxa Poaceae increase together with Lycopodiaceae, and some forbs appear; all other herbs show reduced values. This could indicate the development of larger grassland areas in or near the forest, or it may reflect a lowering of the water table of the swamp. The surface sample WUR 2 shows similar values and this was collected from a rather drier situation than that of WUR 8, mentioned above.

Nearer the top of the zone, Castanopsis values increase once again, Dodonaea reappears and Trema and Acalypha increase. The forest : non-forest ratio is lowered slightly, however, and the reduced values of Nothofagus and Podocarpaceae must be considered significant. Saurauia, Araliaceae and Macaranga values decrease also. This may suggest further impact on the Nothofagus forest whilst regeneration occurred within oak stands and possibly former grassland areas. WK 3 appears as an equivalent surface sample; it represents Miscanthus grassland with Castanopsis groves nearby and other regrowth trees interspersed. Urticaceae show increased values at this point, together with forbs, while there is a decrease in Apiaceae, Cyperaceae, Pteridae and a slight decrease in Poaceae. The maintenance of relatively drier conditions on the swampland is perhaps indicated.

At the top of Zone C the forest : non-forest ratio falls to 60 : 40, due mainly to the decrease in Castanopsis. There is an increase in Macaranga and Dodanaea values and those of Acalypha and Trema are maintained. Among the herbaceous taxa high values of Urticaceae are recorded and Lycopodiaceae increase as well, while forbs, Poaceae, Cyperaceae and Pteridae decrease. This may suggest further exploitation of the Castanopsis forest but continued regeneration in the former grassland. The high values of Urticaceae, standing alone among the herbaceous taxa, are impossible to interpret in terms of the swampland alone and must indicate regeneration on dry land.

Zone D: 133-45 cm

Zone D covers the period during which the swamp was being gardened. The stratigraphy is disturbed and the sediments are mixed, as evidenced also by the constancy of the water content and ignition residue values. Archaeological materials were recovered from it. The stratigraphic confusion vitiates detailed interpretation of the pollen diagram. However, if tilling was reasonably shallow (except in the areas cut by ditches) then the lower part of the diagram is probably older than the upper part. Supposing this to be true it seems that the forest regenerated at the beginning of the zone (forest : non-forest = 80:20) and maintained itself thereafter.

Casuarina and Dodonaea appear more important in zone D as a whole than in zones B and C amd Moraceae are recorded for the first time. Casuarina stools were found at the top of the zone and may have been planted there. Dodonaea is often retained in mixed gardens today as an early regrowth shrub, while the Moraceae contains important fibre plants; possibly they were used in the same way during Zone D times. Among the forbs, Asteraceae and Brassicaceae are commoner in Zone D than in Zones B and C and Lamiaceae and Plantago lanceolata are represented. These may be indicative of garden fallow and some were possibly domesticates. Amaranthus, Anielema and Drymaria occur also; these are domesticates today and probably were used as such then.

The radiocarbon date of 980 ± 150 B.P. (ANU 251) for a wooden stake at the base of this zone is relatively too young compared with the other date available (ANU 43 : 2300 ± 120 B.P.); it may be stratigraphically displaced, or it may indicate initial use of this part of the swamp at a more recent time.

Zone E: 45-28 cm

The forest is again reduced in this zone with some recovery toward the top.

Initially there are low values of forest taxa compared to non-forest taxa. Nothofagus, Castanopsis, Podocarpaceae and Elaeocarpaceae are present, suggesting the persistence of both oak and beech forests within the area. Acalyphya dominates the light-demanding taxa at this point, Trema, Macaranga and Saurauia are well represented while Casuarina and Dodonaea show lower values. Among the herbaceous taxa Poaceae dominate and Lycopodiaceae are also high, while most of the other taxa are represented in lower numbers.

Probably there was renewed clearing of the slopes after abandonment of the swampland; early regrowth is indicated by the abundance of Acalypha. At the same time the swampy grassland developed.

Above, further reduction of Castanopsis occurs and Macaranga and Acalypha values are also reduced. Nothofagus and Podocarpaceae values increase and the forest : non-forest ratio becomes 60 : 40. The peak in Podocarpaceae is difficult to explain and as adjacent samples show low values it is probably not significant. Trema values are maintained, there is a slight increase in Dodonaea and Moraceae reappear; Casuarina values increase sharply. This suggests that further clearance of Castanopsis occurred but also that Trema was selectively retained and Dodonaea, Moraceae and Casuarina were planted or conserved as useful species. Among the herbaceous taxa the increase of Urticaceae, Apiaceae, Poaceae and Cyperaceae may indicate slightly wetter swamp conditions.

The middle of the zone shows further impact on the forest (forest : non-forest = 40 : 60). Nothofagus and Podocarpaceae values are reduced but regeneration of Castanopsis, Acalypha and Macaranga is indicated by increased values in these taxa and Trema increases further. Casuarina is slightly reduced and Dodonaea disappears. Such a spectrum suggests further cutting of beech forest while oak stands and regrowth vegetation regenerated elsewhere. The reductions in Casuarina and Dodonaea may be due to secondary regrowth taking over garden areas or to direct utilization of these plants. Locally Urticaceae, Poaceae, Pteridae and Lycopodiaceae increase, Apiaceae and Cyperaceae decrease slightly. Poaceae dominate. Well developed grass swampland is indicated possibly with a slightly lower water table than before.

At the top of the zone the forest : non-forest ratio is 55 : 45. Nothofagus, Castanopsis and Podocarpaceae all show increased values while Trema and Macaranga values decrease sharply and Casuarina and Acalypha values decrease slightly. This could mean that regrowth vegetation within gardens and former grassland was cut while the oak and beech forests were relatively little touched. Continued pressure on Casuarina is indicated. Locally Pteridae and Cyperaceae increase relative to Poaceae and aquatics are present in high numbers. At this stage the water table must have been well above the ground surface.

Zone F : 28-0 cm

The forest continues to increase in this zone; the forest : non-forest ratio is 85 : 15 at one point. There is no stratigraphic indication of human use of the swampland, however, and individual taxon values are not similar to those of Zone C.

Initially there is an increase in both Castanopsis and Nothofagus, together with Trema and Macaranga. Myrtaceae and Dodonaea appear in relatively high numbers and Casuarina increases. Acalypha is absent. General regeneration appears to have occurred and some species were planted. Among the herbaceous taxa Poaceae dominate; Pteridae, Cyperaceae, Urticaceae and Apiaceae all show increased values. Aquatics are absent.

Well-developed grass swamp is indicated, with a water table considerably lower than at the end of Zone E.

Higher in the zone reduced values of Castanopsis are recorded again, although the forest : non-forest ratio of 70 : 30 is retained. Trema values increase, Macaranga shows a slight increase and Acalypha reappears. Urticaeae are probably also important here. This suggests further cutting of oak forest or groves but continued regeneration of woody non-forest taxa in gardens and grassland areas. Beech forest also regenerated. Casuarina and Dodonaea have both disappeared, perhaps through exploitation. Locally, swamp conditions seem to have been stable if the dominance of Urticaceae is related to dry land circumstances; it is difficult to explain its high values in terms of the swampland alone.

Towards the top of the zone Castanopsis regenerates again and the forest : non-forest ratio reaches 85 : 15. The reduction in Nothofagus value is probably not significant. At the same time the regrowth taxa Trema, Macaranga and Acalypha show reduced values. Myrtaceae and Casuarina appear again. Urticaceae is also reduced. This may indicate a shift back to cutting of regrowth vegetation and development of gardens, while oak groves and the forest continued to regenerate. Locally the swamp became very wet with high values of aquatics recorded. Poaceae and Pteridae are reduced while Cyperaceae and Lycopodiaceae increase. Apiaceae and other forbs are present in relatively high numbers.

Finally, at the top of the zone there is reduction of both forest and non-forest taxa. Decreased values are recorded in Castanopsis, Nothofagus, Podocarpaceae, Trema and Macaranga. Acalypha shows increased values and Dodonaea and Saurauia appear again; Urticaceae values are also high. Casuarina decreases. This suggests that there has been further cutting of forest and exploitation of Casuarina. The increased values of Dodonaea and Acalypha indicate early regrowth in gardens. Locally the aquatics disappear but Cyperaceae increase, Pteridae and Poaceae decrease indicating a maintenance of wet conditions.

Summary

The beginning of the diagram witnesses the presence of degraded beech (Nothofagus) and oak (Castanopsis) forests, possibly with some garden clearings, which were further cleared and partly replaced by regrowth by the end of Zone B. During this time the pollen-analytical site was an open shallow-water pool. During Zone C the forest recovered somewhat but Nothofagus and Castanopsis components were each separately reduced at different times. It seems likely that the slopes became a patchwork of beech and oak forests, variously disturbed, with intervening areas of regrowth and probably some grassland. The former open water had been converted to a grassy swamp which became dryer toward the top of the zone. This change in valley hydrology may indeed have precipitated the use of the swamp for gardens which typifies Zone D. Afterwards, the swamp abandoned, the remnant forests and regrowth on the slopes were attacked yet again but perhaps more selectively and with some attention to reforestation and conservation. As a whole the forests did progressively better throughout Zone E than earlier and the balance which was achieved was more-or-less maintained through Zone F.

Pollen diagram M1 (Figure 8.7)

The stratigraphic position of column M1 is indicated in Figure 8.2. Four main pollen zones are present in this diagram but two of these include others, already distinguished in the M6 pollen diagram; they have been included here for comparative purposes.

A radiocarbon date of 4880 ± 90 B.P. (ANU 288) for wood, lying within coarse brown wood and peat detritus at 195 cm depth in archaeological trench D may be more or less directly correlated with samples near the base of the M1 pollen diagram.

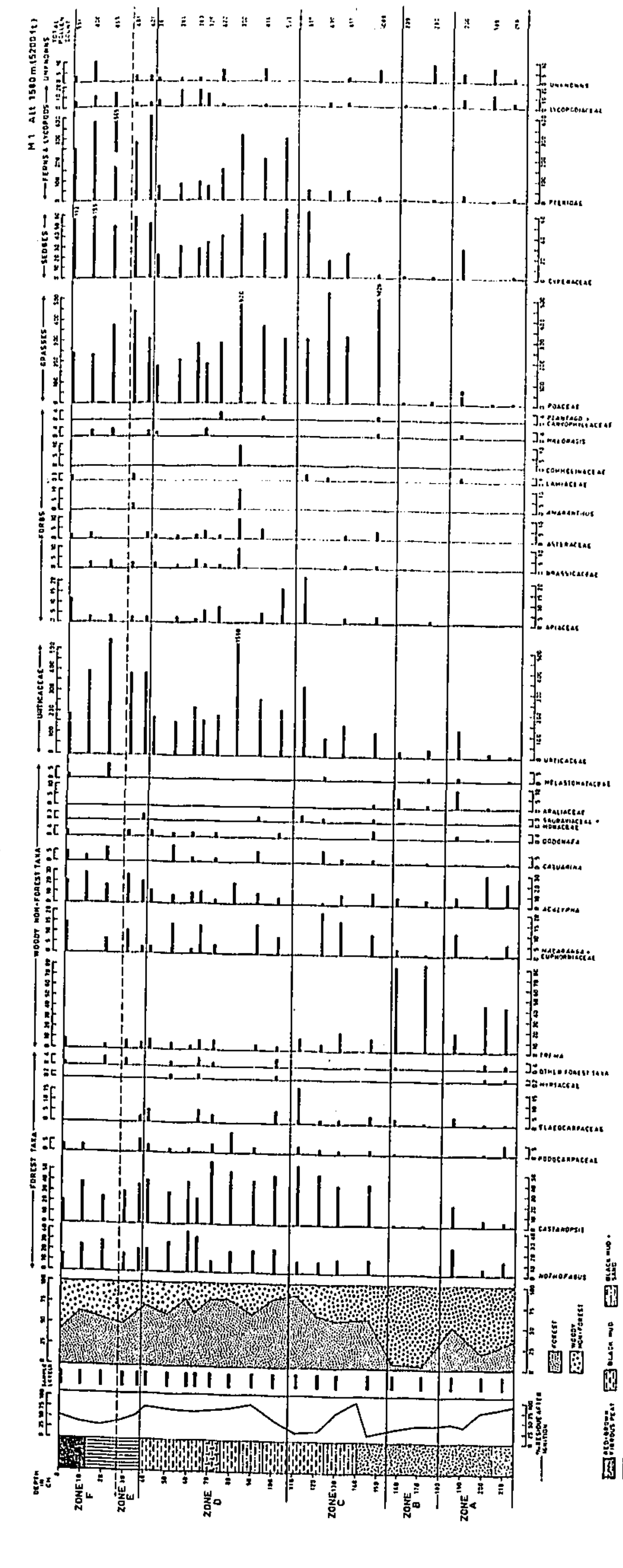
The time-span covered by the diagram then is ca 4500-5000 years.

Zone A: 215-180 cm

Woody non-forest dominates most of the zone; herbaceous taxa are poorly represented.

At the base of the diagram Nothofagus, Podocarpaceae, Castanopsis, Elaeocarpaceae, Myrtaceae and a few other forest taxa are present, Nothofagus in

Figure 8.7 Pollen diagram of Column M1. Pollen sum is total of tree and shrub pollen excluding Urticaceae. The summary diagram shows forest and non-forest woody taxa as percentages of their joint sum.



higher proportion than Castanopsis. Probably mixed oak-beech, pure beech and mixed forests were present in the area. The forests were largely degraded, however, or large areas had been previously cleared, as indicated by the dominance of non-forest taxa such as Trema, Acalypha and Macaranga and the presence in lower numbers of Casuarina and Melastomataceae. Among the herbaceous taxa low values of Poaceae, Cyperaceae, Pteridae, Lycopodiaceae and Urticaceae are recorded. The site was probably open water with a few herbaceous communities and shrubby communities on stream banks or gravel ridges nearby.

Towards the middle of the zone the forest decreases further (forest : non-forest = 20 : 80), due to reduced values of Nothofagus and Podocarpaceae. Castanopsis increases slightly and other forest taxa are maintained. Trema values stay as before, Macaranga decreases slightly but Acalypha increases. Dodonaea and Araliaceae appear. This suggests that there was further cutting of beech and mixed forest while Castanopsis was conserved, or regenerated in excess of cutting. In addition, there was some early regrowth in forest clearings or in former grassland areas.

At the top of the zone the forest recovers (forest : non-forest = 50 : 50); Nothofagus, Castanopsis and Elaeocarpaceae increase greatly together with Macaranga and Araliaceae. Acalypha and Trema show reduced values. The spectrum suggests that secondary regrowth and regeneration of the forests occurred. Among the herbaceous taxa Poaceae, Urticaceae, Cyperaceae and Pteridae values increase; probably there had been further development of grassland on the gravel and sand flats near the site.

This zone is not represented in the M6 pollen diagram.

Zone B: 180-155 cm

Zone B shows extreme dominance of non-forest taxa; forest : non-forest ratios are 5 : 95. Throughout the zone all forest taxa have very low values, while Trema dominates the non-forest taxa. Macaranga, Acalypha Araliaceae, Melastomataceae and Casuarina are present in low numbers. Herbaceous taxa are represented in very low numbers, and whether they are local or regional is unknown. The spectra suggest destruction of the forest near and around the site and the complete dominance of shrubs. The site itself remained open water.

This zone is comparable with Zone B in diagram M6.

Zone C: 155-118 cm

This zone is not so well represented as in the M6 diagram; over its upper part the stratigraphy indicates mixed sediments. It is characterized by a recovery of the forest.

Castanopsis, Nothofagus, Podocarpaceae and Elaeocarpaceae all show increased values, as do the light-demanding taxa Macaranga and Acalypha. Casuarina, Dodonaea, and Araliaceae reappear; Trema values are drastically reduced. The herbaceous taxa are well represented, with Poaceae dominant, Urticaceae, Cyperaceae and Pteridae recording lower values.

The spectra suggest that regeneration of forest had occurred and also that a grassy swamp developed locally.

Zone D: 118-40 cm

As in the M6 pollen diagram this zone covers the period during which the swamp was used for gardening purposes. Since the sediments are mixed changes in values of individual pollen taxa in adjacent spectra are meaningless but some interpretation of the zone as a whole may be attempted. The forest : non-forest ratios suggest that the forest recovered during the early part of the zone and maintained itself thereafter. Dodonaea and Urticaceae appear to be more important in this zone than in Zones A, B or C, and many forbs are represented. Brassicaceae, Asteraceae and Apiaceae are plentiful and isolated high values of Amaranthus and Anielema are probably significant; Lamiaceae, Caryophyllaceae, Plantago and Haloragis are recorded also. Most of these species are found today in gardens or garden fallow and regrowth areas.

A radiocarbon date of 470 ± 75 B.P. (ANU 289) for a wooden stake which marked the junction of the black mud and yellow fibrous peat layers in trench D may be correlated with the top of Zone D in the M1 pollen diagram. It may be considered as a maximum date for the abandonment of the swampland.

Zones E and F: 40-0 cm

Zones E and F of pollen diagram M6 are not readily separated in M1 and are therefore considered together. The composite zone is characterized by further reduction of the forest; the apparent fluctuations may represent periods of clearance and regeneration.

At the beginning of the zone, Nothofagus, Castanopsis, Podocarpaceae and Elaeocarpaceae are present among the forest taxa, Castanopsis in rather higher proportion than Nothofagus. Acalypha shows relatively high values among the light-demanding taxa, while Trema, Macaranga and Araliaceae are represented in lower numbers. Among the herbaceous plants Pteridae, Poaceae, Cyperaceae and Urticaceae show high values, Lycopodiaceae, Apiaceae, Asteraceae and Haloragis lower values. These data suggest that both oak and beech forest grew on the slopes surrounding the pollen analytical site and also that early regrowth in former grassland and garden areas was present. Locally the swampland was reasserted after abandonment.

The adjacent spectrum shows slightly reduced values of Nothofagus and Castanopsis and Elaeocarpaceae and Podocarpaceae are absent. Trema, Acalypha and Macaranga values increase and Dodonaea reappears. Urticaceae values remain high, Poaceae and Cyperaceae increase while Pteridae values decrease. This suggests that there has been an expansion of woody regrowth vegetation at the expense of the forest. Locally the swampy grassland is maintained. These two spectra probably represent Zone E of diagram M6.

Towards the centre of the zone the forest : non-forest ratio is 55 : 45. There is a decrease in Castanopsis, Macaranga and Acalypha but Nothofagus and other forest taxa show increased values. Casuarina reappears and Melastomataceae are also important. Urticaceae and Pteridae show increased values while Poaceae and Cyperaceae are slightly reduced. Possibly further cutting of Castanopsis and secondary regrowth took place whilst Nothofagus regenerated on the higher slopes.

This is followed by an increase in Castanopsis values and in Acalypha but by reduction in Trema, Macaranga and Casuarina. Among the herbs, Urticaceae are reduced, also Poaceae and Pteridae while Cyperaceae increase greatly. This may suggest Castanopsis regenerated in some areas while the secondary regrowth species were exploited in others. Acalypha is indicative of early regrowth within grassland. Locally, the swamp was wetter.

At the top of the zone both Nothofagus and Castanopsis show reduced values. Trema, Macaranga and Casuarina increase while Acalypha falls. Dodonaea and Melastomataceae reappear. Among the herbaceous taxa Urticaceae, Pteridae and Cyperaceae show reduced values while Poaceae increases slightly.

The spectrum indicates that there had been further exploitation of both oak and beech forests while secondary species were retained. Regrowth within garden and grassland areas had probably occurred also. The swamp water-table may have been slightly lower than before.

These spectra belong to Zone F in diagram M6.

Major features of the M1 and M6 diagrams correlate well. Some of the detailed fluctuations for which interpretation has been attempted in M6 are not found in M1. This may have arisen from the greater sampling interval in M1 or reflect the variation in pollen rain from place to place during a short time period.

MACROFOSSIL ANALYSIS

Macrofossils were recovered from the M6 sediments by flotation in ten per cent nitric acid. Quantities of sediments processed were only roughly equivalent depending upon availability of material. No identifications of leaves, twigs or insect skeletons were attempted. Seeds were identified by comparison with reference material collected from the Herbarium Australiense (C.S.I.R.O., Canberra) but as the collection was small identifications could only be tentative. The main types are shown in Plates 33, 34 & 35 and individual counts are given in Table 8.7. The zones designated are those of the pollen diagram.

PLATE 33

1, 2	Fossil	:	Poaceae, gen. 2
3, 4	Fossil	:	Poaceae, gen. 1
5, 6	Fossil	:	Poaceae, gen. 3
7	Fossil	:	Unknown 27 - ?Eleusine sp.
8, 9	Fossil	:	Unknown 20 - ?Echinochloa sp.
10	Fossil	:	Cyperaceae J - sim. Bulbostylis sp.
11	Type	:	Bulbostylis sp. (access. 2)
12	Fossil	:	Cyperaceae N - sim. Carex beccans
13	Type	:	Carex beccans (access. 9)
14	Fossil	:	Cyperaceae F - sim. Carex philippinensis
15	Type	:	Carex philippinensis (access. 6)
16	Fossil	:	Cyperaceae D - sim. Cyperus brevifolius
17	Type	:	Cyperus brevifolius (access. 3)
18	Fossil	:	Cyperaceae L - sim. Cyperus haspan
19	Fossil	:	Cyperaceae B - sim. Cyperus melanospermus
20	Type	:	Cyperus melanospermus (access. 13)
21	Type	:	Cyperus haspan (access. 15)
22	Fossil	:	Cyperaceae A - sim. Cyperus melanospermus
23	Type	:	Cyperus melanospermus (access. 14)
24	Fossil	:	Cyperaceae Q - sim. Eleocharis congesta
25	Fossil	:	Cyperaceae M - sim. Fuirena umbellata
26	Type	:	Fuirena umbellata (access. 20)
27	Type	:	Eleocharis congesta (access. 23)
28	Fossil	:	Cyperaceae P - sim. Lipocarpha chinensis
29	Type	:	Lipocarpha chinensis (access. 24)
30	Fossil	:	Unknown 46 - ?Cyperaceae

Magnification of all seeds is 12.5

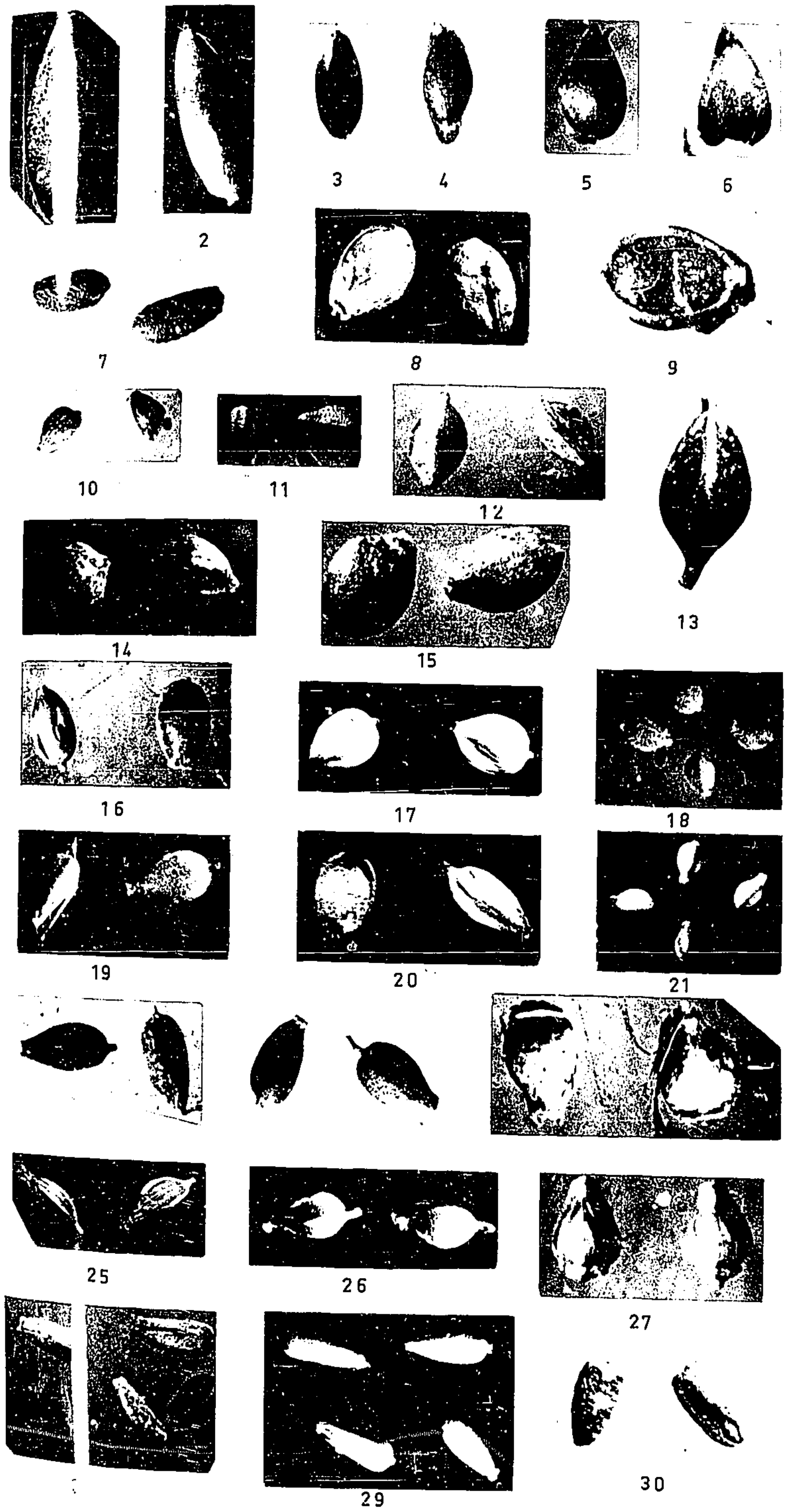


PLATE 34

31 Fossil : Cyperaceae G - sim. Scirpus mucronatus
32 Type : Scirpus mucronatus (access. 32)
33 Fossil : Cyperaceae gen. 1
34 Fossil : Cyperaceae gen. 2
35 Fossil : Apiaceae A - sim. Oenanthe javanica
36 Type : Oenanthe javanica (access. 60)
37 Fossil : Asteraceae gen. 1
38 Fossil : Asteraceae gen. 3
39 Fossil : Asteraceae gen. 4
40 Fossil : Asteraceae gen. 2
41 Fossil : Unknown 64 - ?Asteraceae
42 Fossil : Apiaceae B - sim. Hydrocotyle sibthorpioides
43 Fossil : Potamogeton sp.1
44 Fossil : Potamogeton sp.2
45 Type : Hydrocotyle sibthorpioides (access. 59)
46 Type : Solanum nigrum (access. 197)
47 Fossil : Solanaceae A - sim. Solanum nigrum
48 Fossil : Unknown 28 - ?Caryophyllaceae
49 Fossil : Unknown 29 - ?Caryophyllaceae
50 Fossil : Caryophyllaceae C - ?Caryophyllaceae
51 Fossil : Unknown 56 - ?Caryophyllaceae
52 Fossil : Unknown 54 - ?Caryophyllaceae
53 Type : Drymaria cordata (access. 94)
54 Fossil : Unknown 3 - sim. Dysophylla verticillata
55 Type : Dysophylla verticillata (access. 156)
56 Fossil : Unknown 52
57 Fossil : Unknown 47 - ?Scrophulariaceae
58 Type : Lindernia anagallis (access. 188)
59 Fossil : Unknown 12

Magnification of all seeds is 12.5

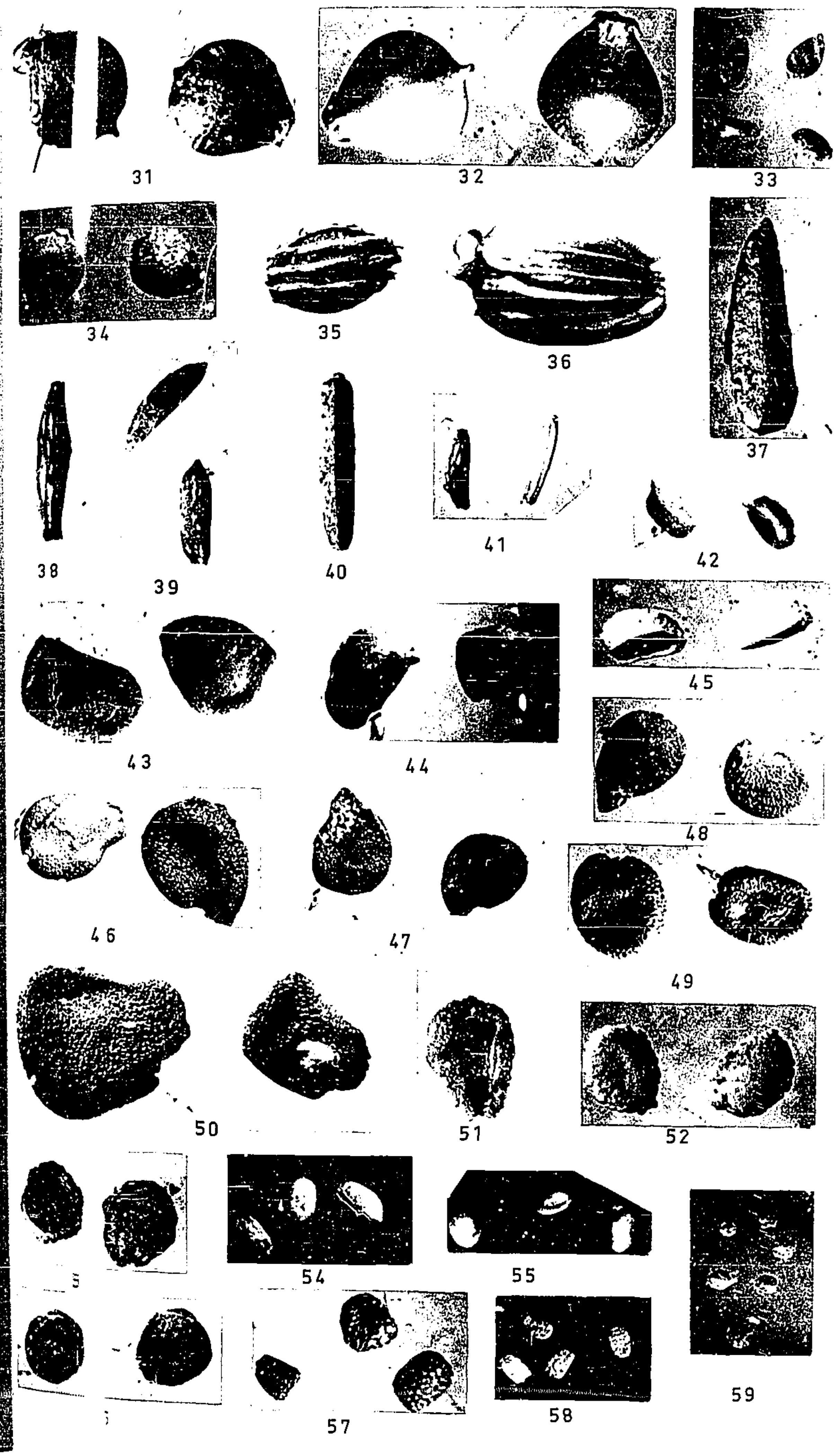
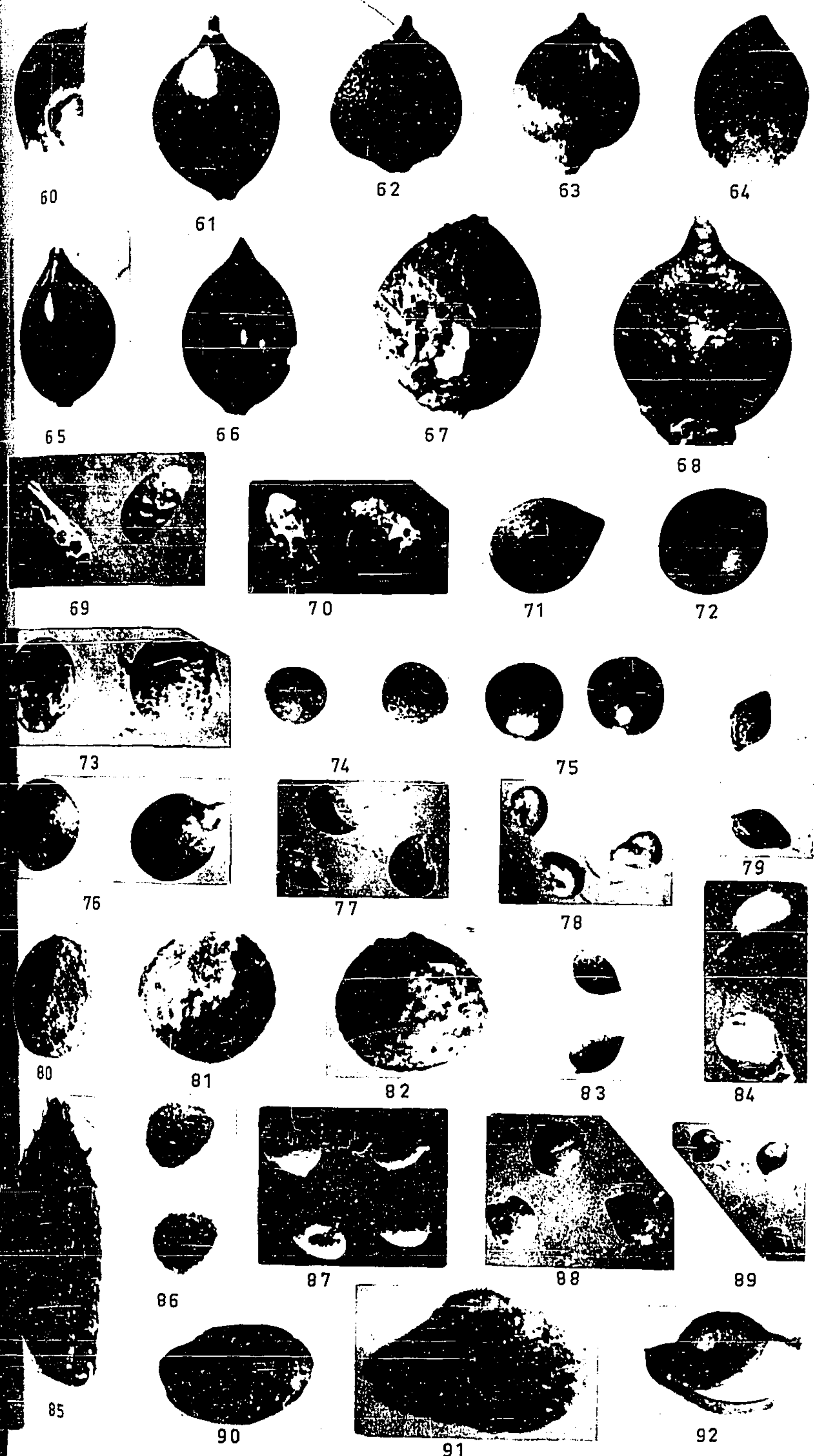


PLATE 35

60	Fossil	:	Polygonaceae A - sim. Polygonun minus
61	Type	:	Polygonum minus (access. 48)
62	Fossil	:	Polygonaceae B - sim. Polygonum nepalense
63	Type	:	Polygonum nepalense (access. 49)
64	Fossil	:	Unknown 55
65	Fossil	:	Polygonaceae D - sim. Polygonum longisetum
66	Type	:	Polygonum longisetum (access. 47)
67	Fossil	:	Polygonaceae C - sim. Polygonum attenuatum
68	Type	:	Polygonum attenuatum (access. 43)
69	Fossil	:	Rubus sp. - sim. Rubus rosifolius
70	Type	:	Rubus rosifolius (access. 194)
71	Fossil	:	Unknown 75 - sim. Viola arcuata
72	Type	:	Viola arcuata (access. 153)
73	Fossil	:	Unknown 71 - ?Lamiaceae - Coleus sp.
74	Fossil	:	Unknown 72 - ?Lamiaceae - Coleus sp.
75	Type	:	Coleus sp. (access. 163)
76	Type	:	Coleus sp. (access. 161)
77	Fossil	:	Unknown 23 - sim. Melastoma affine
78	Type	:	Melastoma affine (access. 168)
79	Fossil	:	Unknown 22
80	Fossil	:	Unknown 44 - sim. Trema sp.
81	Fossil	:	Unknown 26 - ?Trema sp.
82	Type	:	Trema sp. (access. 126)
83	Fossil	:	Unknown 13 - ?Moraceae - Ficus sp.
84	Type	:	Ficus wassa (access. 182)
85	Fossil	:	Unknown 19
86	Fossil	:	Unknown 30
87	Fossil	:	Unknown 60
88	Fossil	:	Unknown 2
89	Fossil	:	Unknown 69
90	Fossil	:	Unknown 30
91	Fossil	:	Unknown 8
92	Fossil	:	Unknown 57.

Magnification of all seeds is 12.5



Zone A: 190-162 cm

Below the lowest pollen sample various seeds were recovered. They included two types of Asteraceae, some ?Caryophyllaceae, and seeds of Solanum nigrum, Polygonum ?attenuatum, Rubus rosaefolius and two taxa of the family Lamiaceae, ?Coleus spp. Trema seeds were also present in low numbers and ?Ficus wassa, as well as a number unidentified. Oenanthe javanica and Hydrocotyle ?sibthorpiodes were common. Few grasses were recorded and only Cyperus melanospermus among the sedges. Potamogeton spp. were plentiful.

Of these taxa Oenanthe, Asteraceae and Lamiaceae are present on the swamp today, together with many grasses and sedges. The presence of Potamogeton indicates open water areas locally and the relative abundance of forbs, the lack of grasses and sedges and the presence of shrubs such as Trema and Ficus suggest vegetation on streambanks, gravel and sand flats and ridges as well. The Solanum, Polygonum spp. and Rubus are commonly found as garden weeds, and may suggest such use of nearby areas. The ecological tolerances of these taxa are not well enough known to make the suggestion other than tentative.

Zone B: 162-152 cm

Recorded from this zone are Asteraceae gen.1, Hydrocotyle ?sibthorpiodes, Polygonum minus, Rubus rosaefolius and ?Coleus sp. as small herbs, Melastoma affine as a shrub. One genus of grasses is represented and the sedge Cyperus brevifolius. Potamogeton spp. are not as plentiful as formerly but still common.

As far as can be judged the local environment appears to have been the same as in Zone A.

Zone C: 152-133 cm

Asteraceae gen 1 remains common in this zone and the other forbs Oenanthe javanica, Polygonum minus and P. nepalense are present; a number of others have disappeared. Grasses appear to have increased and the sedges Cyperus brevifolius, C. melanospermus and Scirpus mucronatus are recorded. Potamogeton spp. are still there but not so plentifully. Melastoma affine and ?Ficus wassa are also present.

Table 8.7 Fossil Seeds from column M6.

		Zone F			Zone E	Zone D					Zone C	Zone B	Zone A	
		0-11	12-20	20-29	29-38	45-53	58-82	82-90	90-115	115-133	133-150	150-161	161-175	175-190
Asteraceae	Gen. 1	12	5	3	8				3		7	15	9	2
	" 2						1						1	
	" 3	3							2					
	" 4						6		1	1	4		1	8
Apiaceae	Oenanthe javanica	4	3											
	Hydrocotyle sibthorpioides													
Caryophyllaceae		3			10			3	12					
	Unknown 56,54								1				3	4
	" 29					3	2		1	1				1
Lamiaceae	Dysophylla verticillata	23	27	4	25		1		1					
	Coleus sp.								5	7		2	11	23
	Unknown 12	12												
Melastomataceae	Melastoma affine						11	7	7	7	1	1		
Moraceae	? Ficus wassa	5				5	11	2	38	17	1		3	
?Nymphaceae							1		1	3	1	2	2	3
Polygonaceae	Polygonum minus					4		1	6		2	5		7
	Polygonum nepalense						2	1	6	2	1			
	Polygonum longisetum									1				
	Polygonum attenuatum	4												3
Rosaceae	*Rubus rosaefolius*					1	3	8	17	16		1	2	3
Solanaceae	Solanum nigrum						1	1	10				1	2
Ulmaceae	Trema sp.								4	2			3	2
Violaceae	Viola arcuata				2					1				
Poaceae	Gen.1	19	12		4	1	3							
	" 2	1				9	3		3	5				3
	" 3				2			2	1		7	3		
	? Echinochloa sp.	1	3		1									
	? Eleusine sp.		1			1			3	1				
Cyperaceae	? Bulbostylis sp.	11	2	3										
	Carex beccans.								5	4				
	Carex philippinensis	11	10	8	2				1	3				
	Cyperus brevifolius						2	1	8	11	1	1		
	Cyperus haspan	4	4											
	Cyperus melanospermus	14	14	3	5	3	4		10	12	1			1
	Eleocharis congesta	5	12						1					
	Fuirena umbellata	3	11					2	2					
	Liphocarpa chinensis							1	1					
	Gen. 1	5	5		2									
	" 2	20	28	2	2					3				
Potamogetonaceae	Gen. 1										2		3	150
	" 2										5	4	61	23
Unknowns	2	9	13	3	7	3	15	2	5	10	24	17	6	5
	30	38				1	3	3	2	2	1	8	154	25
	60							12		2	1	13	17	113
	69					2	16							
	8	11	7	3	1									
	19	3	6											
	74			1	1									
	57													1
	22								2	36	5			13
	72			1				1	1					

This may suggest the development of swamp locally but areas of open water and dry land are still indicated.

Zone D: 133-45 cm

In zone D there is a definite increase in Poaceae, with at least 4 genera represented, and in sedges with Carex beccans, C. philippensis, Elaeocharis congesta and Fuirena unbellata recorded as well as Cyperus brevifolius, C. melanospermus and Scirpus mucronatus. Potamogeton is absent. Asteraceae increase with 4 genera represented, Solanum nigrum is common, and Lamiaceae such as Dysophylla ?verticillata and ?Coleus spp. are recorded. Drymaria cordata and other ?Caryophyllaceae are present and Viola arcuata also. Polygonaceae are well represented, with Polygonum minus and P. nepalense common, P. longisetum less frequent. Rubus rosaefolius is particularly common throughout the zone. Seeds of Melastoma affine and of ?Ficus wassa are plentiful and a few of Trema are recorded also.

The abundance of Poaceae and Cyperaceae in the zone indicate development of grassland on the site itself at this time. Many of the other taxa recorded may be from gardens and regrowth vegetation also on the swamp.

Zone E: 48-28 cm and Zone F: 28-0 cm

Macrofossils of these two zones may be considered together as no differences are apparent in the table. Poaceae and Cyperaceae remain abundant. Two genera of Asteraceae, Oenanthe javanica and Drymaria cordata are common and Dysophylla ?verticillata abundant. Polygonum ?attenuatum and ?Ficus wassa are recorded at the top of Zone F.

These indicate well developed swamp grassland on the site.

RECONSTRUCTION OF THE HISTORY OF THE MANTON SITE

Stratigraphic, pollen-analytic and macrofossil data together with the archaeological evidence for use of the site itself in the chronological context provided by the radiocarbon dates allow the reconstruction of the history of the region.

The Manton site rests on Quaternary alluvium. Before 5000 years B.P. (radiocarbon dates ANU 252 and

ANU 288) it was possibly part of an actively aggrading alluvial plain with levees and backwater swamps. By 4900-5000 years ago drainage of part of the area was blocked so that extensive ponds and swamps developed. Woody non-forest vegetation was dominant on the surrounding slopes at that time. The partial clearance of the forest may have contributed to the disruption of the drainage of the valley by facilitating erosion of the slopes and increased deposition below them.

Disturbance of the forest continued over a considerable period of time whilst Phragmites swamp developed near the pollen-analytical site and probably more widely. Some parts remained as open water and elsewhere there was varied herbaceous and shrubby vegetation. Artefacts stratified in the pond sediments imply some human activity nearby.

Afterwards, when peat was probably widely developed over the area, the people moved onto the swamp and proceeded to drain and garden it. The radiocarbon date of a pointed digging stick in one of the earlier ditches indicates that this was about 2200-2400 years B.P. (ANU 43). The shift of gardening onto the swamp seems to have allowed the forest on the slopes to recover (Zone C) in spite of periodic, possibly selective, use.

Speculation about the reason for the move from hillside to swamp is idle before further investigation has been made, but it undoubtedly represented a major change in living pattern and economy.

That the swamp was used for agriculture is evidenced by the wooden artefacts recovered, which were similar to those in use as garden tools at the time of first European contact and are still remembered today by the older people (Chapter 2), and by the similarity between the prehistoric ditches and those used today for drains and boundaries (Chapter 5). The structureless, balck peaty soil of the period probably resulted from tilling and drying with oxidation; it is mixed with sand and clay in many places. The plant record for Zone D is also consistent with human activity nearby. Asteraceae, Brassicaceae, Apiaceae, Dysophylla verticillata, Coleus spp., Haloragis sp., Plantago lanceolata, Polygonum spp., Solanum nigrum, Rubus rosifolius, Amaranthus sp., Anielema sp. and Drymaria cordata are common garden forbs and herbaceous domesticates today and probably were then. Trema sp., Melastoma affine and Ficus ?wassa are often associated with settlement areas and Casuarina, Dodonaea, Saurauia and Moraceae were possibly conserved in garden fallows or planted for their useful products.

There is no evidence for many of the crops which are today associated with the taxa listed, for example, bananas (Musa spp.), taro (Colocasia esculenta), yams (Dioscorea spp.), beans (Psophocarpus tetragonolobus, Dolichos sp.)., sweet potato (Ipomoea batatas), gourd (Lagenaria siceraria) and Rungia klossii. The lack of evidence is not surprising considering the breeding system and phenology of these crops and native horticultural practices. Thus the bananas now grown are largely parthenogenetic; flowering is infrequent in yams, taro and gourds at altitudes above 1520m (5,000 ft) and these species, together with the beans and sweet potato, are entomophilous. The sweet potato flowers quite freely but the flowers are ephemeral, usually lasting only a few hours. Many of the small herbaceous domesticates are harvested before flowering and the chances of obtaining their pollen is slight. On the other hand, these crop plants may not have been present in the New Guinea highlands at the time; some are indigenous but others have been introduced into New Guinea from elsewhere (Chapter 10).

The area was used over a considerable period of time as indicated by the radiocarbon dates of 2200-2400 years B.P., 800-1000 years B.P. and 400-550 years B.P. for the wooden digging stick (ANU 43) and for two wooden fence posts (ANU 251 and ANU 289), in situ, at different levels in the layer. Whether cultivation was continuous or intermittent between the extreme dates can only be speculated upon. That it was intermittent is suggested by the series of ditches, cut from different levels and filled by different sediments and also by the depth of soil developed.

About 400-550 years B.P. (ANU 289) the swamp was abandoned, as evidenced stratigraphically by the change from structureless black mud to brown, fibrous Phragmites peat and by changes in the fossil seed content.' Renewed impact on the forests of the surrounding slopes is indicated in the pollen diagrams at this time.

The reasons for ceasing to garden the swamp are imponderable : difficulties of drainage, the incidence of malaria and other disease, the introduction of a new staple such as sweet potato or demographic changes may all have played a part.

Whatever the reason, it led to a great initial impact on the slope forests followed by their partial recovery (Zones E and F) associated with the apparent conservation of some species (for example, Trema, Dodonaea and Moraceae) and probably cultivation of others (Casuarina, Myrtaceae and Podocarpaceae). This argues for the beginnings of a more sophisticated pattern of land use than had been practised before.

The swamp remained a more-or-less undisturbed Phragmites fen until the present day.

CHAPTER 9

THE DRAEPI SITE

The Draepi site lies about 13 km (8 miles) NNW of Mount Hagen township on the Baiyer River Divide (Plate 36). Figure 9.1 shows the site and surrounding vegetation. The site rests on andesitic aggromerates and ash derived from Mt Hagen (Plate 37A). It comprises a swamp-filled depression and small pond, lying between irregular, slumped ridges and a cone shaped hill. The swamp is irregular in shape about 0.8 km (½ mile) long and 100m wide; the pond 90m long, 50m wide and 3m deep lies at its southern end. There are no inflow streams. The swamp surface is level and drainage is by seepage only, except in times of heavy rainfall when three drainage points become active : the northern end drains into the Monga Ck., the eastern extremity and the southern end into the Ogulg Ck. Over much of its length the swamp is bordered by gentle slopes (2 - 5°), some colluvial in origin, but where it swings northwest around the base of the cone, the slopes are much steeper (10- 30°). A clay bank separates the southern end of the pond from an adjoining swampy area. The swamp itself lies at 1885m (6200 ft) altitude, while the ridge on the western side is about 2005m (6600 ft) a.s.l., the cone summit 2035m (6700 ft) and the ridge on the north eastern side 2067m (6800 ft).

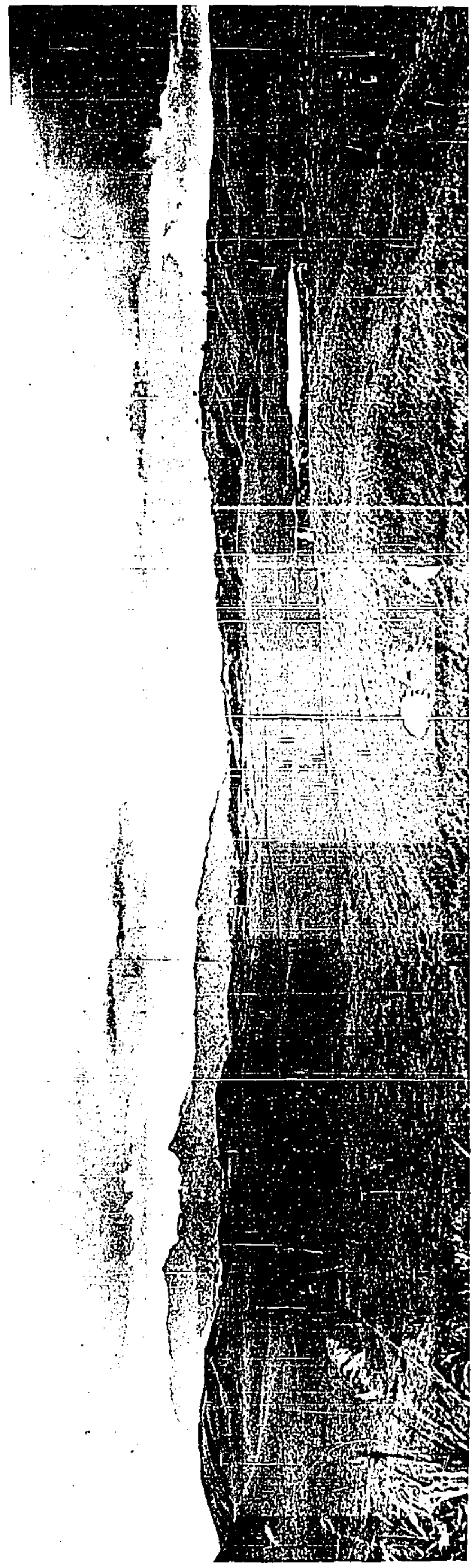
Initially only the southern half of the swamp was investigated but during the 1968 field work period the northern end was cleared and drained by Mr G. Detmers for development as Minjigina tea plantation. This led to the discovery of archaeological materials embedded in peat near the eastern end of the swamp and the extension of the investigations to cover the whole area. For convenience of description the northern half of the site is referred to as Minjigina, the southern half as Draepi.

STRATIGRAPHY

The stratigraphy of the whole site was investigated by boring along several transects using the Thomas and piston samples. Figure 9.2 shows the position of these transects and the points at which cores were taken for

PLATE 36

The Draepi pollen analytical site. The Minjigina area is on the left hand side. Weylk settlement area is in the background. Short grassland (<u>Themeda</u>) covers the surrounding hillslopes while the swamp is mixed sedge-grass.



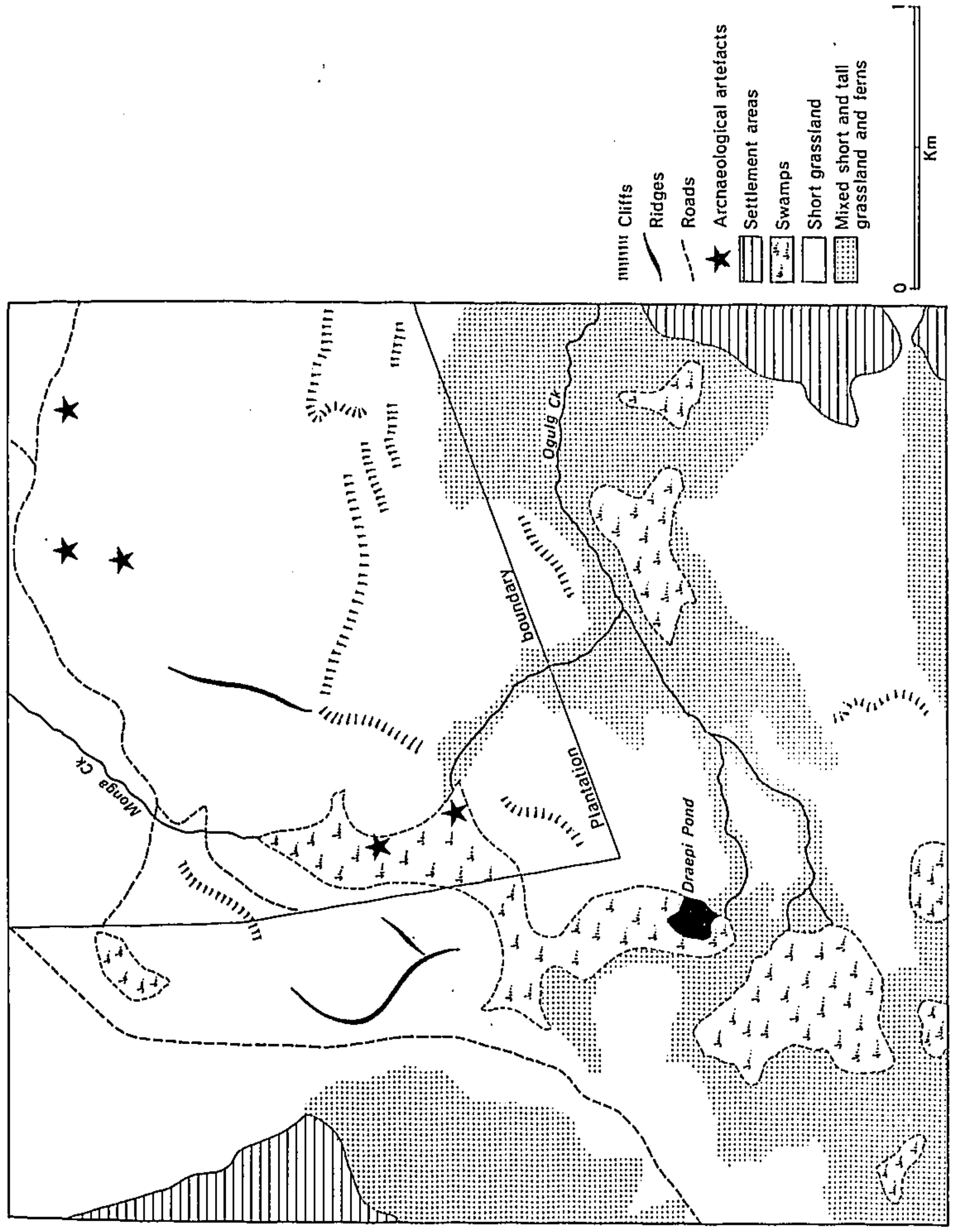


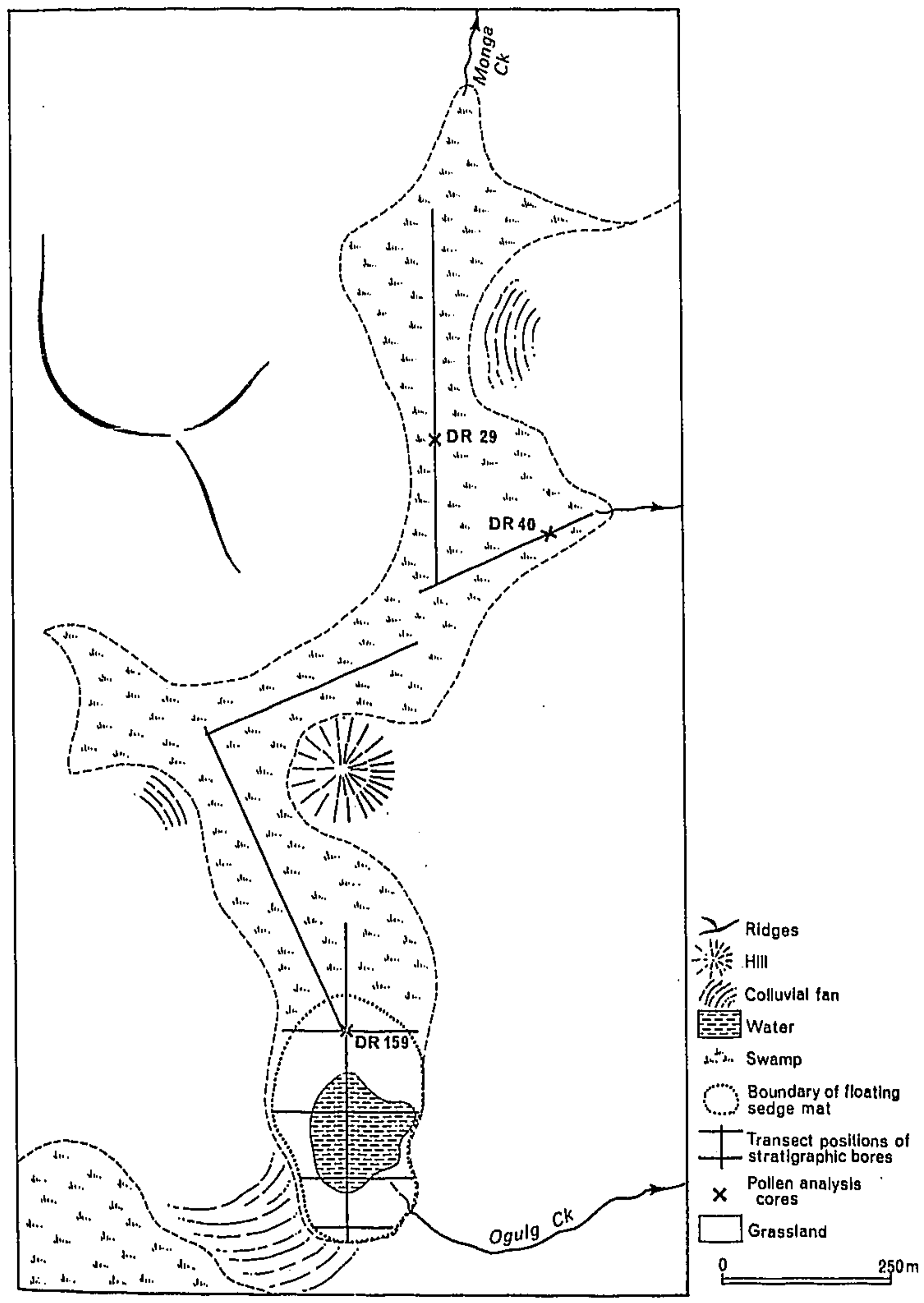
Figure 9.1 Sketch map of the Draepi site and surroundings.

pollen analysis. A raft was constructed for use on the pond and was moored in the correct position for coring by four ropes tied to poles driven into the basal deposits near the shore. The pond is surrounded by a floating vegetation mat; this and other very wet areas were sampled from slatted boards laid upon the swamp surface, Plate 38. A number of difficulties were encountered with the use of the samplers and the base board and some modifications were tried out during the second season of field work; these are outlined and discussed in Appendix 4. Depths were taken from water level during the first field season but the whole site was subsequently surveyed using a Kern dumpy level and staff.

Figure 9.3 gives the stratigraphy of the Draepi area and Figures 9.4 and 9.5 that of the Minjigina area. Stratigraphy is consistent over the whole site; only the upper sediment of the wet Draepi area differs slightly from that of the drier Minjigina area. The general stratigraphy of the Draepi area may be described from top to bottom:

0- 50 cm	coarse red-brown detritus pH 6.0 nig 2 strf 1 elas 1 sicc 0 humo 1 $Th^1 3$ + Sh 1.
50- 55 cm	grey-green volcanic ash nig 1 strf 0 elas 0 sicc2 humo 0 Ag 4.
55-140 cm	coarse red-brown detritus pH 6.0 nig 2 strf 1 elas 1 sicc 0 humo 1 $Th^1 4$ + Sh +.
140-220 cm	water
220-240 cm	finer red-brown detritus pH 6.0 nig 3 strf 1 elas 1 sicc 0 humo 2 $Th^1 3$ + $Th^2 1$ + Sh +.
240-380 cm	very fine black detritus mud pH 5.0 - 5.5 nig 4 strf 0-1 elas 0 sicc 2 humo 3-4 $Th^3 2$ + $Th^4 1$ + Sh 1.
380-410 cm	orange-brown clay pH 5.5 nig 1 strf 0 elas 0 sicc 3 humo 0 Ag 4.
410-450 cm	orange-brown clay mixed with brown black organic detritus pH 5.5 hetero. nig 2 strf 0 elas 0 sicc 2 humo 3 Ag 2 + $Th^3 2$ + Dl^3 +

Figure 9.2 Site plan showing position of stratigraphic bore transects and pollen analysis cores.



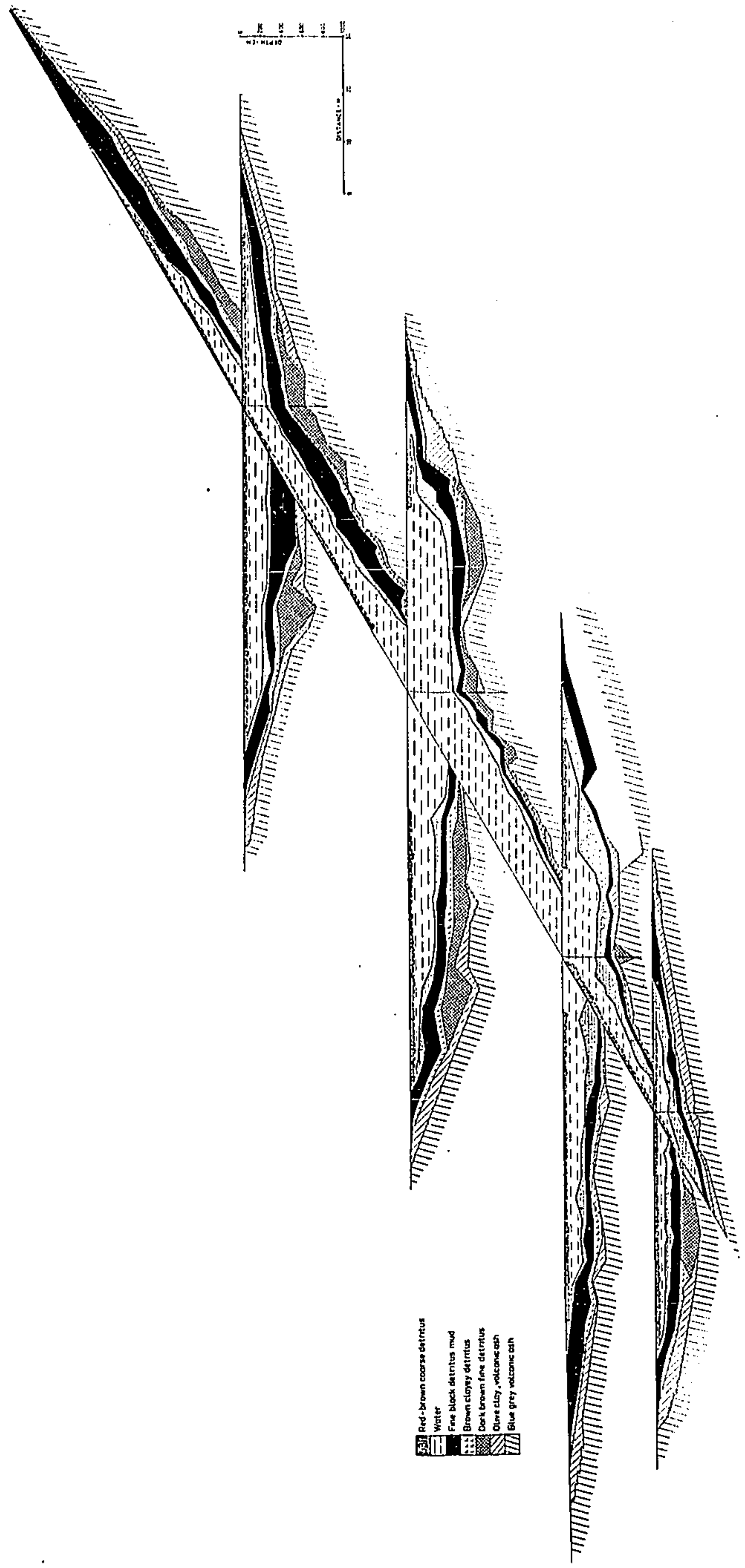


Figure 9.3 Stratigraphy of the southern end of Draepi. The pollen analytical core DR 159 was taken from the S-N transect.

Figure 9.4 Stratigraphy of the Minjigina area of Draepi: S-N transect, including the DR/II/29 pollen analytical core.

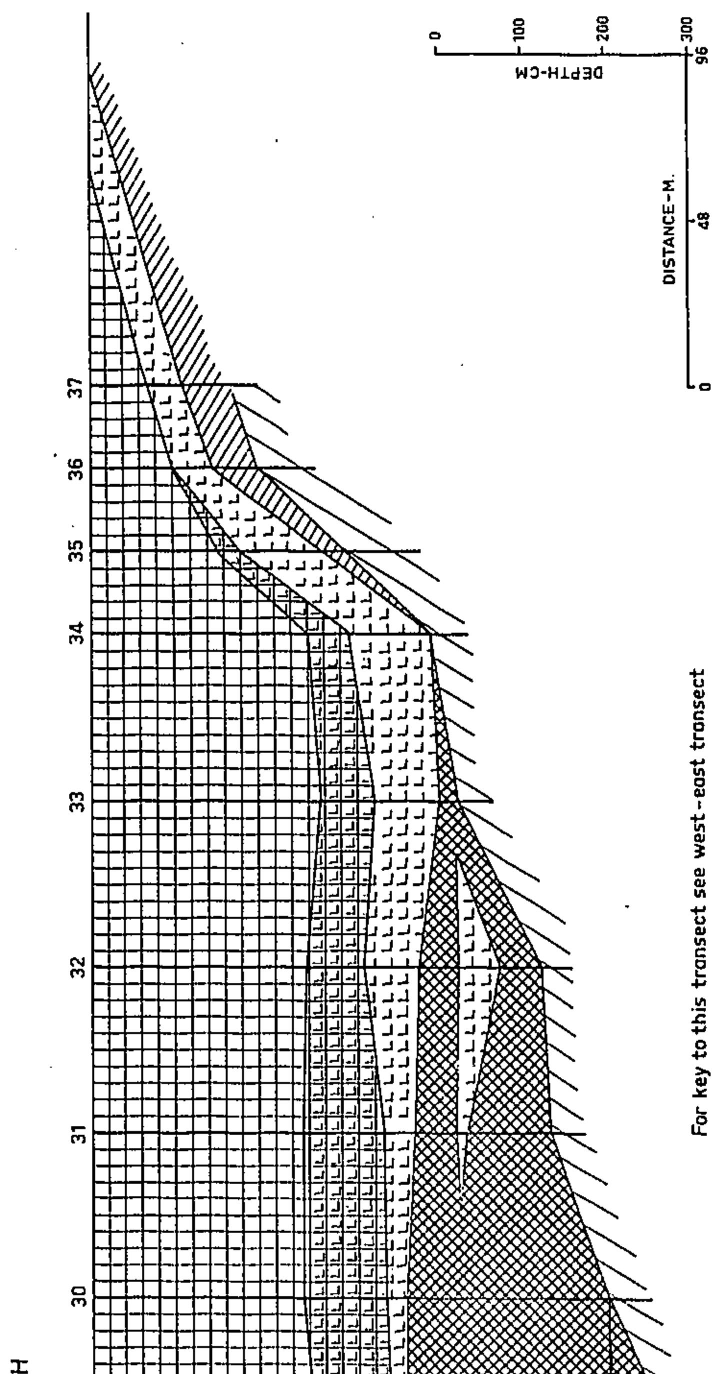


Figure 9.5 Stratigraphy of the Minjigina area of Draepi: W - E transect, including the archaeological site and DR 40 pollen analytical columns.

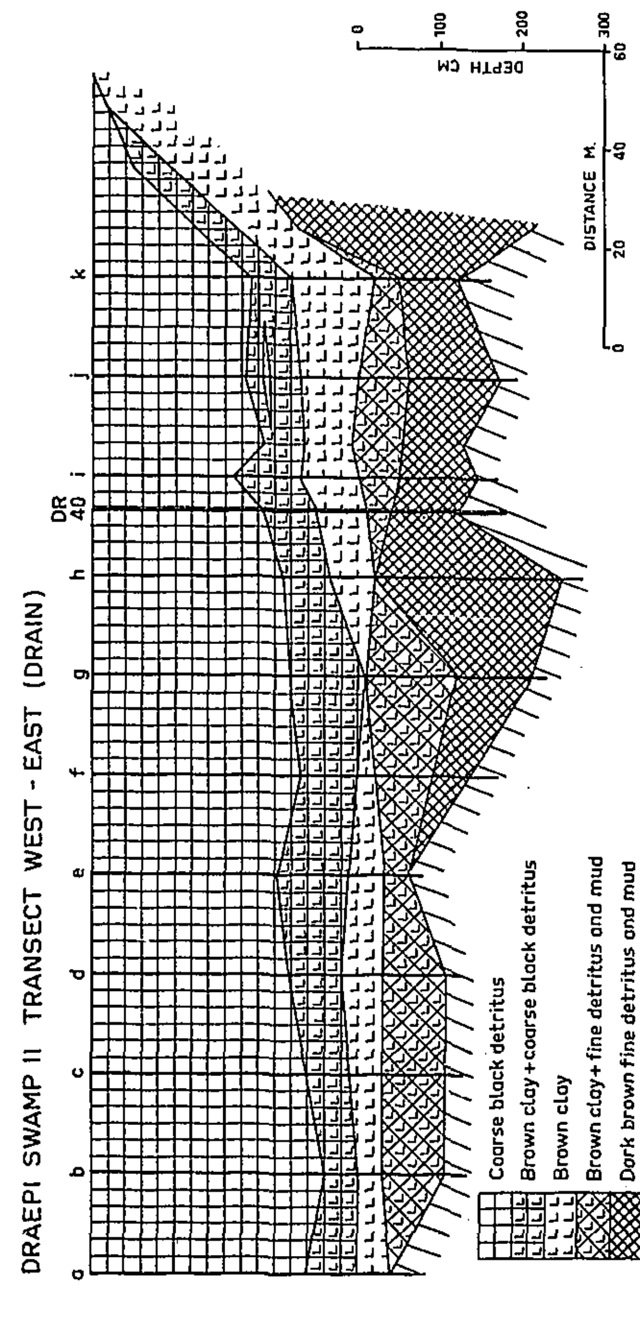


PLATE 37A

Volcanic lahar deposits near Draepi. These are typical of the Baiyer river divide area.

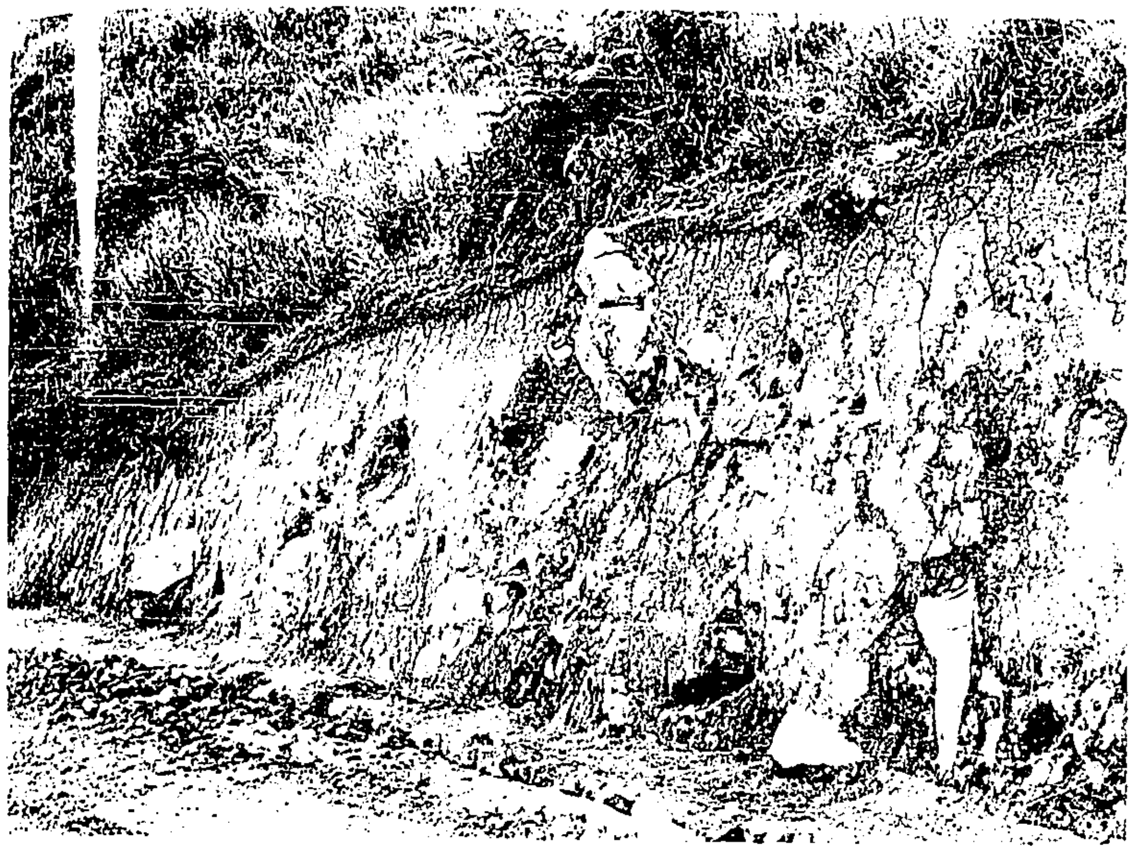


PLATE 37B

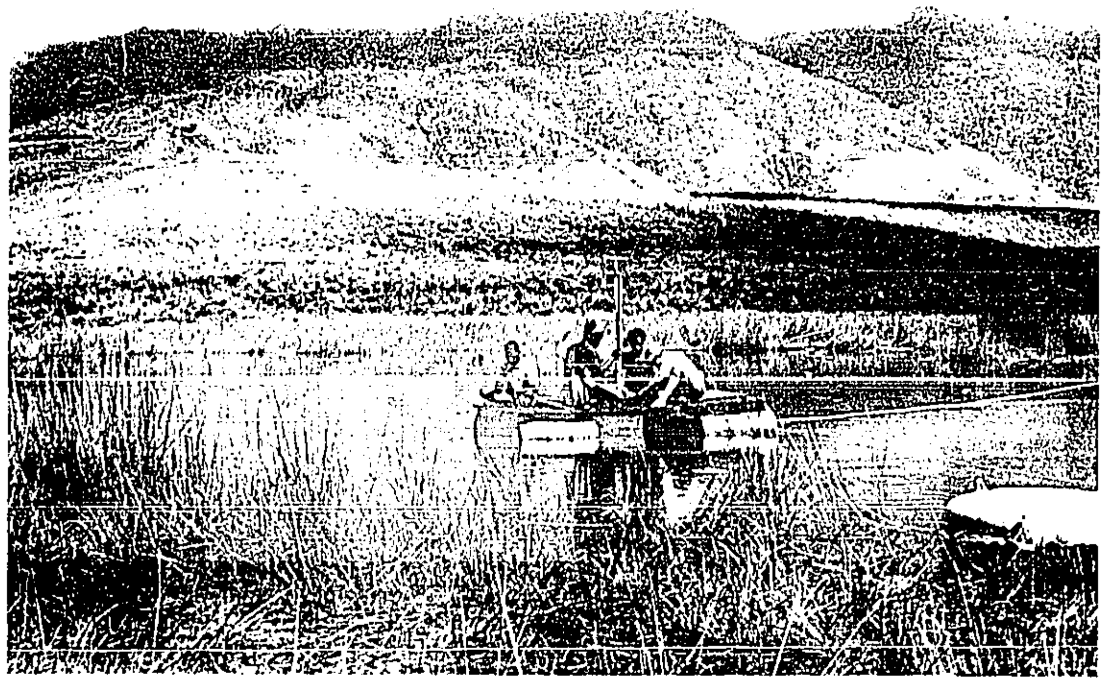
Prehistoric ditch cut through peat at Minjigina (DR 40).

PLATE 38

Bore-hole sampling at Draepi.

A. From the raft.

B. On the floating sedge mat.



450-580	cm	dark red-brown wood and leaf detritus pH 5.5
		nig 3 strf 2-3 elas 0 sicc 1 humo 3-4
		$Th^3 1 + Dl^3 1 + Sh\ 2$.
580-600	cm	wood Dl 4.
600-620	cm	coarse olive sandy clay pH 5.5 - 6.0.
		Gs 4.
620-	cm	fine blue-grey volcanic ash pH 6.5.
		Ag 4.

The uppermost sediments of the Minjigina area may be described as follows:

0-210	cm	coarse black detritus mud pH 5.5
		nig 4 strf 2 elas 1 sicc 1 humo 0-1
		$Th^2 3 + Sh\ 1$.
210-270	cm	finer black detritus mud pH 5.0 - 5.5
		nig 4 strf 1 elas 0 sicc 1 humo 3-4
		$Th^3 2 + Th^4 1 + Sh\ 1$.
270-300	cm	orange-brown clay pH 5.5.
		Ag 4. As described above.

The lower sediments at Minjigina are the same as described above.

<u>Sediment Analysis</u>

Several columns of material were collected for further investigation in the laboratory and for pollen analysis (Tables 9.1, 9.2). The basal deposits are inorganic blue-grey and olive volcanic ash, with very low water content and high ignition residue. Spectrographic analysis of the coarse olive ash indicates that it is mixed andesite and basalt ash with a light fraction of 'sub-equal basic pale green glass, clay aggregate, weathered plagioclase and minor biotite' and a heavy fraction of 'dominant green hornblende and minor oxyhornblende' (B. Ruxton, pers. comm.). The source of the ash is unknwon but it is presumed to have come from Mt Hagen.

Overlying this is an olive-grown clay, comprising 30 per cent chlorite and unweathered volcanic ash minerals, developed from the basal ash (J.M.A. Chappell). Water content is 200-280 per cent and residue after ignition 66-77 per cent dry weight on three samples analysed. Some wood is buried in this sediment and charcoal fragments are recorded.

A dark brown wood and leaf detritus, horizontally stratified and presumably laid down under wet conditions overlies this clay. Individual leaves seem similar to those of a small-leaved Nothofagus species but the material is too fragile for sectioning. Water content exceeds 800 per cent in some samples and ignition residues are low, namely 4-8 per cent dry weight. Twigs and other wood, leaves and bark, are common and some fern leaflets and grass stems and nodes are also present. Carbonised seeds and wood are recorded. The lower part of the sediment is an un-stratified very fine brown detritus mud which appeared to be entirely organic. Water content is 130-340 per cent, however, and ignition residue 55-86 per cent dry weight, indicating that some inorganic matter is present. The sediment comprises mainly homogeneous ground substance but some wood and grass tissues are recorded. The DR159 sediments in this layer have water contents of 510-560 per cent and ignition residue values of 33-39 per cent dry weight. The sediment probably represents a shallow lake deposit.

A zone of mixed brown clay and dark brown organic mud overlies the lowermost organic deposit. Water content varies between 260-650 per cent and ignition residue values between 27-64 per cent dry weight. The clay was analysed spectrographically : it contained poorly developed chlorite (<10%) and immature weathering products and is considered to be externally-derived (J.M.A. Chappell, pers. comm.). The organic material appears similar to the lower organic sediment. Leaf and wood tissues were recorded as well as some sedge and grass stems and nodes. Fragments of wood charcoal and grass flakes are also present. The two components of the sediment are considered to be derived from different places and are not contemporaneous. Probably the clay was washed in from the surrounding slopes and mixed with the uppermost part of the in situ lower organic sediment.

Above the mixed zone is a level of brown clayey detritus, redeposited material of hard, dry clay lumps embedded in a finer matrix. Water content values are between 250-300 per cent and ignition residue 51-64 per cent dry weight. Sedge and grass stems, nodes and roots are common and carbonized fragments plentiful. Very little wood is present. This is probably clay washed in

Table 9.1 Sediment characteristics of miscellaneous Draepi samples.

No.	Depth (cm)	Appearance	% Water content	% Ignition residue	Component parts
DR 4	0- 10	Coarse redbrown	1495	8.2	Predom. sedge and grass tissues, roots, charcoal flakes abundant, few seeds.
DR 9	0- 10	detritus,			
DR 16	0- 10	sedge & grass mat			
DR 7	230-270	Black, fine	400	49	Predom. SH, some coarse and fine sedge and grass tissues, charcoal common (wood and grass), some fine inorganic material.
DR 609	210-305	detritus	407	44	
DR 217	200-255	"	516	46	
DR 492	400-460	"	351	55	
DR 605	300-320	"	261	47	
DR 605	320-345	"	450	39	
DR 7	275-280	Green-brown volcanic ash	245	69	Fine volcanic ash mixed with some grass tissues.
DR 7	290-340	Brown clay	253	64	Predom. fine inorganic material, some coarse and fine sedge and grass stems, nodes, tissues, charcoal frequent, little wood.
DR 492	460-510	detritus	298	59	
DR 217	280-300	"	287	51	
DR 609	305-345	Mixed brown	407	44	Predom. organic, wood, bark, leaf tissues, some sedge and grass tissues, ?resin, little charcoal, fines predom. inorganic.
DR 17	300-345	clay and dark brown mud	261	53	
DR 605	440-520	Red-brown woody	851	4	Wood, twigs, bark and leaves, fern leaflets, seeds, some sedge and grass nodes, SH predom. in fines.
DR 217	345-455	detritus	848	8	
DR 609	345-400	"	834	5	
DR 605	570-595	Dark-brown woody	342	55	Wood, bark tissues, some sedge and grass tissues; charcoal common, 70% organic, 30% inorganic.
DR 605	630-645	detritus & brown clay	133	86	
DR 217	455-480	Olive clay	222	73	Predom. inorganic - weathered volcanic ash, some fine tissues, some charcoal.
DR 605	645-675	" "	278	66	
DR 7	350-370	" "	208	77	
DR 605	675-700	Coarse olive sand	81	91	Volcanic ash
DR 608	525-560	" " "	99	89	
DR 7	370-400	" " "	146	81	
DR 605	760-800	Blue grey volcanic	62	90	Volcanic ash
DR 608	560-600	ash	54	89	
DR 609	660-720	" " "	89	92	

Table 9.2 Sediment characteristics of column DR 159.

Depth (cm)	Appearance	% material of different grades (mm) >2	2.0-0.25	0.24-0.06	<0.06	Average Water Content	Avg. % Ignition Residue	Component parts
0 - 50	Coarse red-brown detritus	70	15	8	7	1000	14	Coarse and fine sedge and grass roots, nodes.
50 - 55	Grey-green volcanic ash					101	91	
55 - 75	Coarse red-brown detritus	69	12	9	10	1382	14	Coarse and fine sedge and grass roots, tissues, some SH, little charcoal (grass flakes).
75 - 145	"	78	8	7	7	1393	10	
145 - 245	Water							
245 - 300	Brown-black mud	18	33	25	24	633	27	Predom. SH, some grass roots and tissues, sedge and Asteraceae seeds, charcoal common.
300 - 375	" " "	8	49	22	21	706	26	Predom. SH, few tissues, some charcoal.
375 - 400	Orange clay & brown-black mud	2	16	22	60	227	64	Mainly SH, some amorphous mineral matter, woody tissues, grass and sedge tissues, ? wood charcoal.
400 - 438		1	13	23	63	240	68	
438 - 500	Brown-black fine detritus	14	23	21	42	510	39	Some coarse and fine wood tissues, leaves, predom. SH.
500 - 525	" " "	12	20	20	48	562	33	As above.
525 - 535	Wood							
535 -	fine blue grey silt					54	89	Volcanic ash

from the surrounding slopes, carrying plant materials from there with it.

Above this is well-humified organic material, fine brown-black detritus with a dark brown stain. It is mainly a homogenous ground substance ('substantia humosa', Troels-Smith 1955) together with fine sedge and grass tissues. Some fine mineral matter is present also. Grass charcoal is common and some wood charcoal is recorded. Water content varied in the samples analysed from 261 per cent to 516 per cent except in DR159 where values of 633-706 per cent were recorded and ignition residue values were respectively 39-55 per cent and 26-27 per cent dry weight. The sediment is a well humified swamp peat formed <u>in situ</u> from grasses and sedges. Mineral matter, and much of the charcoal present, may have been washed in; the water table was presumably at or near the surface at most times as is confirmed by horizontally-stratified clay and ash bands in some areas.

The uppermost organic sediment is a red-brown sedge peat, developing as a floating mat on the pond surface. <u>Machaerina</u> is the main contributing sedge genus. The peat comprises mainly coarse and fine sedge stems, roots and tissues together with some homogeneous ground substance. Charcoal flakes are frequently present. Water content is high, between 1000-1400 per cent in the DR159 samples, 1161-1576 per cent in the other samples, and ignition residue values are low, namely 10-14 per cent in DR159 and 8-13 per cent in other samples. Whether this sediment forms the black detritus mud with further humification is difficult to ascertain but seems unlikely as a clear stratigraphic boundary occurs between the two zones.

The Minjigina area sediments (Tables 9.3, 9.4, 9.5) are essentially similar except that the upper zone has developed under drier conditions. The uppermost level of the material is a very dark brown-black peat comprising non-humified coarse grass and sedge stems and finer roots in a matrix of homogeneous ground substance. Grass charcoal flakes are common. Water content is relatively low, namely 363-382 per cent and ignition residue 42-49 per cent. Material lower in the zone is more humified, although coarse sedge and grass stems and nodes are still

Table 9.3 Stratigraphic description of columns DR/II/40A, 40B, 40C.

DR 40/A		DR 40/B		DR 40/C	
0 - 20	Red-brown fibrous peat	0 - 18	Red-brown fibrous peat	0 - 20	Red-brown fibrous peat
20 - 42	Brown-black fibrous peat	18 - 50	Brown-black peat	20 - 50	Brown-black peat
42 - 44	Brown clay band	50 - 52	Brown clay band	50 - 52	Brown clay band
44 - 106	Brown-black fibrous peat	52 - 86	Brown-black peat	52 - 98	Brown-black peat
106 - 172	Mixed brown fibrous peat and grey volcanic ash	86 - 91	Green-grey volcanic ash band	98 - 100	Grey silt band
172 - 190	Brown-black peat	91 - 205	Brown-black peat	100 - 130	Brown-black peat
		205 - 250	Orange-brown clay	130 - 145	Charcoal, cooking stones at 135-145.
				145 - 195	Brown-black peat.

Table 9.4 Sediment characteristics of column DR 40/A.

Depth (cm)	Appearance	% material at different grades (mm) >2	2.0-0.25	0.24-0.06	<0.06	Average Water Content	Avg. % Ignition Residue	Component parts
0 - 20	Red-brown peat	29	29	24	18	394	43	Coarse grass & sedge tissues, some ground substance, little charcoal.
20 - 42	Brown-black peat	4	25	26	45	413	46	As above, some wood, 50:50 tissues & ground substance, some charcoal.
42 - 44	Brown clay band	-	-	-	-	-	-	Fine organic particles (SH)
44 - 70	Brown-black peat	18	40	23	19	569	29	Fine grass tissues, SH 60%, no charcoal.
70 - 93	" " "	30	38	19	13	673	32	90% fine tissues, 10% SH, little charcoal.
93 - 106	" " "	46	23	17	14	710	36	Almost entirely tissue material fine roots, charcoal flakes common.
106 - 120	Mixed brown peat, grey ash & clay	59	17	12	12	84	94	Coarse & fine tissues, charcoal grass, 60% clay & SH; 40% tissues.
120 - 172	Fibrous peat and volcanic ash	27	26	16	31	145	83	Coarse & fine tissues, common twigs & grass charcoal, some wood charcoal 50:50 clay SH: tissues.
172 - 190	Brown-black peat	1	51	32	16	761	21	90% fine tissues, little charcoal.

Table 9.5 *Sediment characteristics of column DR 40/B*

Depth (cm)	Appearance	% material of different grades (mm) >2	2.0-0.2	0.24-0.06	<0.06	Average Water Content	Avg. % Ignition Residue	Component parts
0 - 18	Red-brown peat	23	27	34	16	382	42	Coarse sedge & grass nodes, stems, roots
18 - 50	Brown-black peat	17	28	37	18	363	49	Coarse pitpit nodes, some ground substance, some charcoal
50 - 52	Brown clay band	-	-	-	-	-	-	Predom. inorganic clay particles, some fine tissues
52 - 86	Brown black peat	24	44	19	13	530	35	Coarse peat detritus, fine roots, little charcoal
86 - 91	Greenish volcanic ash band	52	22	9	17	61	93	Fine silt
91 - 125	Brown black peat	21	35	25	19	528	35	50-80% fine and coarse tissues, not well humified. Coarse sedge stems. Charcoal flakes.
125 - 150	" " "	1	27	36	36	537	21	Predom. tissues and ground substance ? No charcoal.
150 - 195	" " "	3	51	29	17	940	12	
205 - 250	Brown clay	-	-	-	-	-	52	Predom. inorganic clay particles, some tissues; charcoal common.

obvious. Water content is higher (528-537 per cent), and ignition residues lower (21-35 per cent). Less charcoal is present. Towards the base of the zone the sediment is predominantly homogeneous ground substance but some fine stems and tissues remain. Water content is 940 per cent, ignition residue 12 per cent. No charcoal is recorded.

The sediment is considered to be predominantly a grass peat developed under Ischaemum although other grasses and some sedges are also present. This is in contrast to the uppermost sediment of the Draepi area which is a Machaerina sedge-peat. The fine black detritus mud recorded below it appears more nearly equivalent to the Minjigina material.

History of the site

The history of the site may be hypothesized on the basis of the stratigraphy and the nature of the sediments. It is suggested that it was originally a small water-filled depression within the depositional landscape of volcanic ash and agglomerates. Forest grew nearby and leaf and wood detritus was deposited in the lake mud.

At some time the forest was destroyed, both near the site and on the surrounding hills. This led to increased runoff and clay was washed down into the valley bottom. It mixed with the lower organic sediment and resulted in the mixed clay-mud zone. The clay bank which separates the Draepi pond from the neighbouring swampy area may have formed at this time, blocking drainage of the southern part of the site. The fine black detritus mud lying above the clay zone suggests development of grass swamp locally. Horizontally stratified bands of clay and volcanic ash suggest that the water table was at or above the surface at certain times.

Further blocking of the drainage at the southern end of the site at some more recent time produced the present, 3m deep, pond, where a floating sedge mat is now forming a coarse red-brown peat. No analagous development occurred in the Minjigina area where a grassy mire persisted throughout the period.

MACROFOSSIL ANALYSIS

Fossil seeds, leaves and wood were recovered during stratigraphic and sediment analysis but time did not permit the identification of most of the material. Wood samples, collected mainly from the Draepi area, were sufficiently well-preserved to permit identification in only a few cases (Table 9.6).

Table 9.6. Wood identifications from the Draepi site (det. K. Ingle).

No.	Depth (cm)	Identification
DR 95A	360-390	Nothofagus section Bipartitae
DR 101	450-460	" " "
DR 103	420-450	" " "
DR 610	390-400	" " "
DR 611	350-360	" " "
DR 96	312-355	Gymnospermae cf Podocarpus
DR 610B	400-415	Gymnospermae ?Papuacedrus
DR 609	415-	Gymnospermae
DR 217	400-410	?Icacinaceae
DR 605	600-605	Piperaceae
DR 501	710-715	Dicotyledon
DR 610A	400-405	Dicotyledon

All of these samples came from levels within the lowest organic sediment or below it, lying within the olive sandy clay or on top of the blue-grey volcanic ash. This may suggest that there was a mixed Podocarp-Beech forest growing on the site at the time of the last volcanic ash showers, but more likely, it represents the remains of the forest destroyed at a later time by the event that led to the deposition of clay. Some charcoal is recorded from the same zone but no definite levels have been noted.

Wood was recorded at similar depths in the Minjigina area sediments but was not identified. However, in situ tree stools and roots between 70 cm and 140 cm depth below the present surface proved identifiable (Table 9.7).

Table 9.7. Wood identifications from the upper peat, Minjigina area (det. K. Ingle & J.C. Saunders).

No.	Identification	
DR/SW/II		
1, 17, 20, 22.	Loganiaceae	Fagraea ?racemosa
4, 5.	Lauraceae	?Cryptocarya
11, 23, 25.	Monimiaceae	Dryadodaphne ?crassa
13	Symplocaceae	Symplocos
14	Epacridaceae	?Styphelia
19	Dilleniaceae	Dillenia
24, 36.	Myrtaceae	Syzygium
32, 33.	Moraceae	Streblus
2, 3, 6-10, 15, 16, 18, 21, 26-31, 34, 35, 37.	Podocarpaceae	

These samples were collected from near the eastern extremity of the swamp; they indicate the presence of a Podocarp stand on what is thought to be a grass peat. Charcoal is extensively recorded in the same area at depths of 50 cm, 70 cm and 130-145 cm.

THE MINJIGINA ARCHAEOLOGICAL SITE

Preliminary investigation of the northern half of the Draepi swamp used modern drainage ditches cut to 1.5-2.0m depth through the coarse brown-black detritus. Flakes of charcoal were noted in the walls of the modern ditches and in one area, about 50m from the eastern extremity of the swamp, a concentration of charcoal and fire-blackened stones were found (Figure 9.2). Alongside this was another stratigraphic disturbance, apparently a ditch cut from ca 90cm below the present swamp surface and at an angle to the modern drain (Plate 37 B). Three columns of peat were cut from the sides of the drain: DR/II/40A, through the ditch on the south face, DR/II/40B alongside, through apparently undisturbed peat, and DR/II/40C from the north face through the charcoal-filled depression. Their stratigraphic position is indicated in Figure 9.5 and descriptions given in Tables 9.3, 9.4 and 9.5.

Macrofossils were extracted from Columns DR 40A and DR 40B but have not been identified; preliminary pollen diagrams have been prepared (Figures 9.9 and 9.8).

A 3 x 2m trench was excavated in the north face of the modern drain by R.J. Lampert (ANU, Dept. of Prehistory) and further material collected for macrofossil analysis. His report and drawn section are given in Appendix 5. Lampert confirmed the presence of the charcoal layer and depression, probably a cooking pit, at 130-140 cm depth and recovered a short, pointed, wooden digging stick from within the nearby ditch which was cut from 95 cm below the present surface. According to his excavation the ditch infill comprised three different sediments; a lower red-brown peat, a middle 10 cm thick dark brown silt layer and an upper light grey-brown clay, which also extended for some distance horizontally. This may suggest that the ditch is, in fact, a double feature; that it was cut originally from a lower level and later recut from 95 cm. This is supported also by the dimensions of the ditch (75 cm deep, 30 cm wide) and by the radiocarbon dates (see below).

Other, smaller ditches (30 cm deep, 40 cm wide) were observed on the lower slopes bordering the swamp and in a neighbouring flat area (Figure 9.1) and a small hastate spade (MIJ1) was recovered from the base of one of these. There is therefore incontrovertible evidence for prehistoric agriculture in the area. The cooking pit may have been associated with gardening or may be indicative of a nearby housesite, or both.

RADIOCARBON DATES

Radiocarbon dates relevant to the sites are as follows:

ANU 85	DR 159/250 Upper level of black peat, 250-260 cm depth.	1190 ± 70 B.P.
ANU 249	DR 159/365 Lower level of black peat, 365-375 cm.	3650 ± 85 B.P.
ANU 250	DR 159/440 Upper level of red-brown detritus, 440-450 cm.	18140 ± 370 B.P.
ANU 192	DR 159/525 Wood at junction or organic red-brown detritus and inorganic basal volcanic ash, 525-535 cm depth.	23040 ± 570 B.P.

ANU 253	DR/II/29/210 Lower level of brown-black peat, 210-220 cm depth.	5110 ± 100 B.P.
ANU 254	DR/II/29/385 Upper level of red-brown wood and leaf detritus, 385-395 cm depth.	34000 ± 2000/1500 B.P.
ANU 194	DR/II/29/695 Lower level of red-brown fine detritus, 695-705 cm.	31470 ± 900 B.P.
ANU 255	DR/II/40C/140 Charcoal from pit, 140-145 cm depth.	2310 ± 90 B.P.
ANU 276	DR/II/40A/180 Coarse brown-black peat from below archaeological ditch, 180-185 cm depth.	3880 ± 90 B.P.
ANU 277	DR/II/40A/160 Mixed peat and volcanic ash infilling ditch base, 160-165 cm depth	2280 ± 90 B.P.

POLLEN ANALYSIS

Pollen diagrams have been prepared for both the Draepi and Minjigina parts of the swamp (Figures 9.6, 9.7) in addition to preliminary diagrams for correlation with the archaeological section (Figures 9.8, 9.9). The pollen sum is total woody taxa. Calculated within the sum are the main forest taxa *Nothofagus*, *Castanopsis*, Podocarpaceae, Elaeocarpaceae, Cunoniaceae, Myrtaceae and *Pandanus*, other minor forest taxa grouped together, and the non-forest woody plants, such as *Trema*, *Dodonaea*, *Casuarina*, *Acalypha*, *Macaranga*, Euphorbiaceae, Araliaceae, Urticaceae and others grouped together. Calculated outside the sum are the Poaceae, Cyperaceae, Pteridae, Lycopodiaceae, the forbs Asteraceae, Brassicaceae, Lamiaceae, Apiaceae, *Astelia*, Haloragaceae and other minor taxa.

The diagrams have been zoned to aid description; zone boundaries are drawn at significant changes in forest : non-forest ratios or where changes in individual pollen frequencies occur which are considered significant. The diagrams DR159 and DR/II/29 were initially zoned separately and then compared; correlated zones are given the same designation. The DR/II/40 diagrams are stratigraphically closely correlated with the DR/II/29 diagram and may be zoned in the same way.

The diagrams have been interpreted in the same way as those from the Manton site, by considering both the overall species composition of a spectrum and changes in composition and abundance of individual taxa between two spectra and groups of spectra. Trends or drifts in pollen frequencies which could be interpreted in terms of changes related to climatic, successional and anthropogenic factors have been sought.

Pollen Diagram DR/II/29 (Figure 9.6)

The DR/II/29 core lies in the Minjigina area of Draepi (Figure 9.2). Six pollen zones are distinguished.

Zone F : 710 - 580 cm

The zone is characterised by a dominance of forest and by development of forest close to the site as well as regionally.

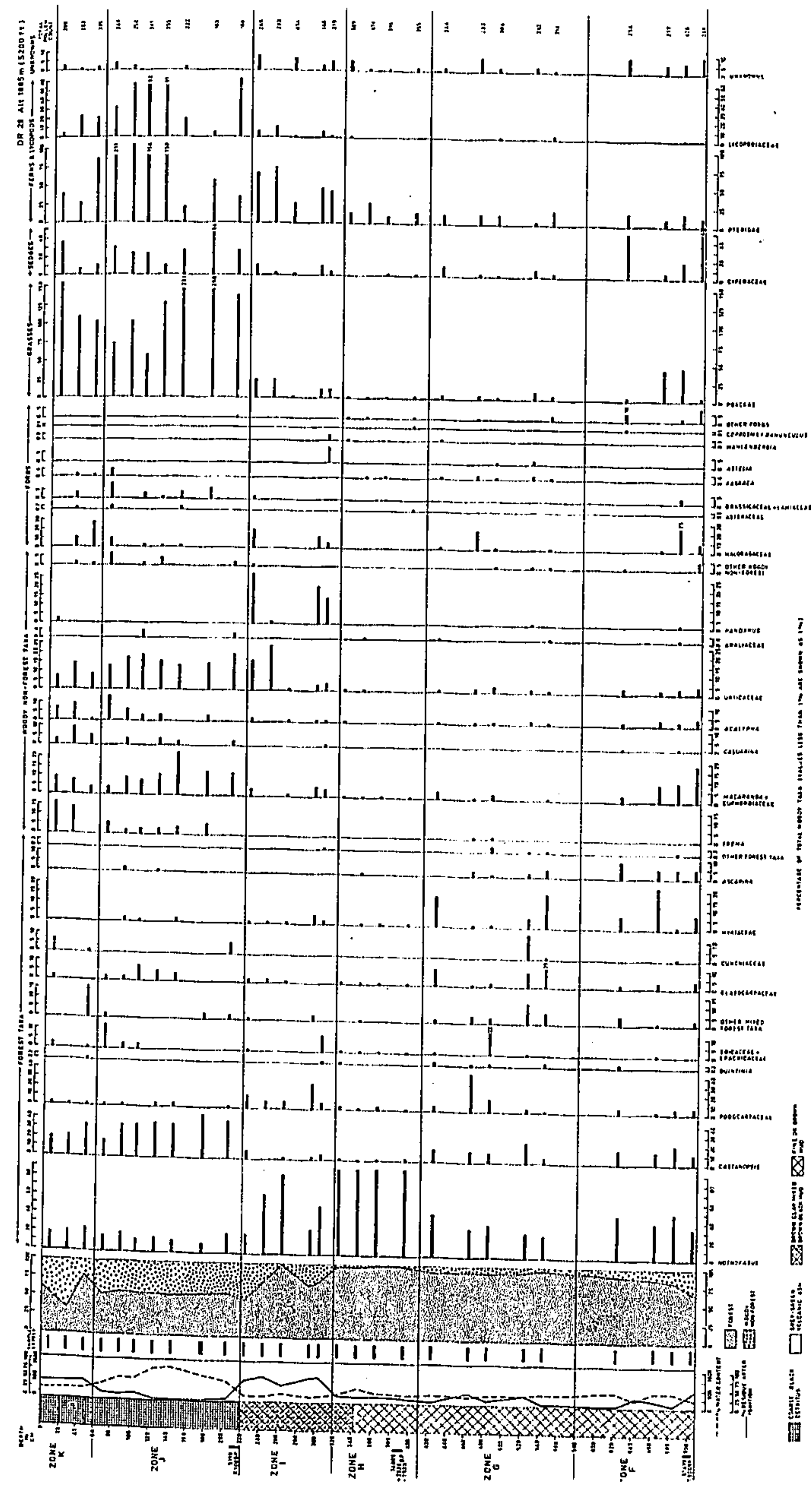
Forest taxa recorded at the base of the diagram include *Nothofagus*, *Castanopsis*, Podocarpaceae (*Phyllocladus* and 2 species of *Podocarpus*), Elaeocarpaceae, Myrtaceae, *Ascarina* and *Evodia*. *Nothofagus* values are higher than those of other taxa. Among the light-demanding plants, *Macaranga* shows high values, *Acalypha* and Urticaceae lower values. Cyperaceae dominate the herbs and Pteridae and Poaceae are recorded in lower numbers. Apiaceae and Haloragaceae are also represented.

Such a spectrum suggests that extensive beech forest and some mixed and oak forests were present in the region. The site was probably a shallow water pond, bordered by sedge swamp and shrubs, surrounded by forest.

The levels of most of the forest and woody non-forest taxa remain substantially the same through the zone; only *Macaranga* values fall systematically. Poaceae and Cyperaceae values fluctuate and Haloragaceae has an isolated peak.

The indications are that all forest types continued to contribute pollen to the site but that mixed forest perhaps became more important towards the top. The site remained a shallow pond bordered at various times by different proportions of sedges, grasses and shrubs.

Figure 9.6 Pollen diagram of core DR/II/29. The pollen sum is total of tree and shrub pollen. The summary diagram shows forest and non-forest woody taxa as percentages of their joint sum.



Zone G : 580 - 410 cm

Forest dominance is maintained through this zone (forest: non-forest = 90:10); woody non-forest taxa and herbs contribute little.

The big fluctuations of individual forest taxa through the zone are difficult to interpret. Through most of it Nothofagus is somewhat less abundant than before and the spectra are dominated successively by Elaeocarpaceae and Myrtaceae, Cunoniaceae, Ericaceae and Epacridaceae, and Podocarpaceae. Other mixed forest taxa such as Ilex, Rapanea, Evodia, Maesa, Symplocos and Quintinia are recorded in lower numbers. Castanopsis is present throughout but never dominates. In the top sample Nothofagus dominates but the Myrtaceae and Elaeocarpaceae also have relatively high values.

Together the spectra suggest that mixed forest was much more widespread in the region during this period than either beech or oak forest.

Some subalpine and high-altitude mixed forest forbs are recorded, namely, Astelia, Coprosma, Ranunculus and Fagraea. Together with the Epacrids, Styphelia and Trochocarpa, they support the suggested importance of mixed forests and may even indicate the presence of subalpine grassland nearer to the site than at present. The site itself was open water.

Zone H : 410 - 320 cm

Zone H records the complete dominance of forest over the whole region. Nothofagus is the most important tree by far (90-94 per cent); Castanopsis, Podocarpaceae, Epacridaceae and Ericaceae, Elaeocarpaceae, Myrtaceae, Quintinia and Ascarina, though present, are scarcely significant. Among the light-demanding taxa, Macaranga, Acalypha, Urticaceae and Araliaceae are recorded and, among the small shrubs and forbs : Fagraea, Coprosma, Wahlenbergia, Plantago and Solanaceae. Pteridae register comparatively high, Poaceae and Cyperaceae very low numbers.

The only possible interpretation of this zone is the obvious one; expansion of beech forest both locally and regionally at the expense of other types. The site itself remained as open water.

Two radiocarbon dates are available for the period covered by pollen zones F, G and part of H. The stratigraphically lowest date is 31470 $\pm$ 900 years B.P. (ANU 194), obtained from peat at 695-710 cm depth, while the upper date is 34000 $^{+2000}_{-1500}$ years B.P. (ANU 254) from peat at 385-395 cm depth. The ranges of the two dates, as defined by 2 standard deviations from each mean, overlap and hence the sediment may have been laid down between 29670 and 38000 years ago. However, the lower part of Zone H in column DR 159 is dated to 23040 $\pm$ 570 years B.P. (ANU 255) so that the youngest date possible for this position in DR/II/29 remains comparatively somewhat too old.

Zone I : 320 - 220 cm

The sediments in Zone I are mixed for which reason little can be said about the pollen spectra. By the end of the zone much of the forest had been destroyed and woody non-forest vegetation was widespread. Herbaceous taxa were also more important than previously.

Zone J : 220 - 60 cm

This sediment is undisturbed. Pollen analytically the zone is characterized by nearly equal values of forest and woody non-forest.

A radiocarbon date of 5110 $\pm$ 100 years B.P. (ANU 253) is available for peat at the base of the zone.

The bottom sample (224 cm) records the presence of the forest taxa Nothofagus, Castanopsis, Podocarpaceae, Cunoniaceae and Symplocos; Castanopsis shows higher values than the others. Among the light-demanding taxa Macaranga and Urticaceae show high values while Casuarina and Araliaceae are present in lower numbers. The herbs are dominated by Poaceae but Pteridae, Lycopodiaceae and Cyperaceae are also well represented.

The spectrum indicates that all of the forest types were still present in the region in various proportions but that regrowth shrub and grassland vegetation were extensive. The site itself had become a grass-sedge swamp.

Except for the uppermost sample (68 cm) Castanopsis is consistently the most abundant plant represented;

its values are higher than in any other part of the diagram. Nothofagus by contrast, is poorly represented. The indications are that, whatever the forests may have suffered in the previous zone, oak forest had regenerated and become more extensive than that of beech.

The Elaeocarpaceae are relatively well represented in the upper half of the zone and the Mrytaceae and Podocarpaceae occur intermitently. This might be interpreted as evidence of forest change but, equally, these plants may have been conserved near settlement areas. The Ericaceae also become important at the top of the zone and probably indicate Rhododendron shrubs growing in grassland rather than mixed forest.

The substantial, if in some cases erratic, representation of light-demanding and regrowth taxa (Casuarina, Macaranga, Trema, Acalypha and Urticaceae) provide strong testimony of continued human interference with the vegetation. Probably there was a mosaic of regrowth garden and grassland vegetation in the region which was used in various ways at different times.

The herbaceous taxa are well represented throughout the zone. Poaceae dominate the lower half but decrease slightly above, while Pteridae and Cyperaceae increase over the upper half. It seems likely that water-level changes occurred in the swamp throughout this period so that it was dominated at one time by grasses, at another by a mixture of sedges, grasses and ferns. Ferny grassland may have developed around the swamp edge.

Zone K : 60 - 0 cm

This zone is dominated by woody non-forest.

The lowest sample shows increased values of Nothofagus and Castanopsis and relatively high values of ?Maesa. Urticaceae, Macaranga and Acalypha show reduced values among the light-demanding plants while Casuarina values increase. Trema is absent. The other two samples show a maintenance of Nothofagus, slightly reduced Castanopsis values and absence of ?Maesa, while Macaranga, Trema, Acalypha and Casuarina values increase.

Among the herbs, Poaceae dominate and Pteridae, Cyperaceae and Lycopodiaceae have fluctuating lower values. Haloragaceae records an isolated peak.

There may have been a reassertion of forest conditions locally but, at best, this was temporary. Thereafter further exploitation occurred and regrowth vegetation became extensive. By the top of the zone the balance between forest and non-forest vegetation, already reached in Zone J, was reattained. The site itself remained much the same as before, a grass or mixed grass-sedge swamp.

Summary

At the base of the diagram extensive beech forests and some mixed and oak forest were present in the region; the site was probably a shallow-water pool, bordered by sedge-swamp and light-demanding shrubs. Later (Zone G) the mixed forest became much more widespread and possibly subalpine grassland grew nearer to the site than at present. The mixed forest was then replaced by beech forest which grew very close to the site, a small open-water pond, as well as regionally. More recently the forest was partly cleared and light-demanding trees and shrubs became widespread. Grassland patches developed and the pollen analytical site became a grass-sedge swamp (Zone J). A balance between forest and non-forest areas was achieved and maintained for some time, until recently (Zone K) further slight exploitation of the forest took place.

Pollen Diagram DR159 (Figure 9.7)

The DR159 core was collected from the southern end of the swamp (Figure 9.2). Four pollen zones, H, I, J and K are recognized in this diagram.

Zone H : 550 - 440 cm

90-95 per cent of the pollen is that of forest plants.

Nothofagus is the main taxon (72-80 per cent); Castanopsis, Podocarpaceae, Elaeocarpaceae and Myrtaceae occur in lower numbers and minor forest species such as Sphenostemon, Ericaceae, Epacridaceae, Rapanea, Quintinia, and Drimys are also present. The light-demanding Trema, Macaranga, Acalypha and Urticaceae are poorly represented and the herbs Poaceae, Cyperaceae and Pteridae occur in very low numbers.

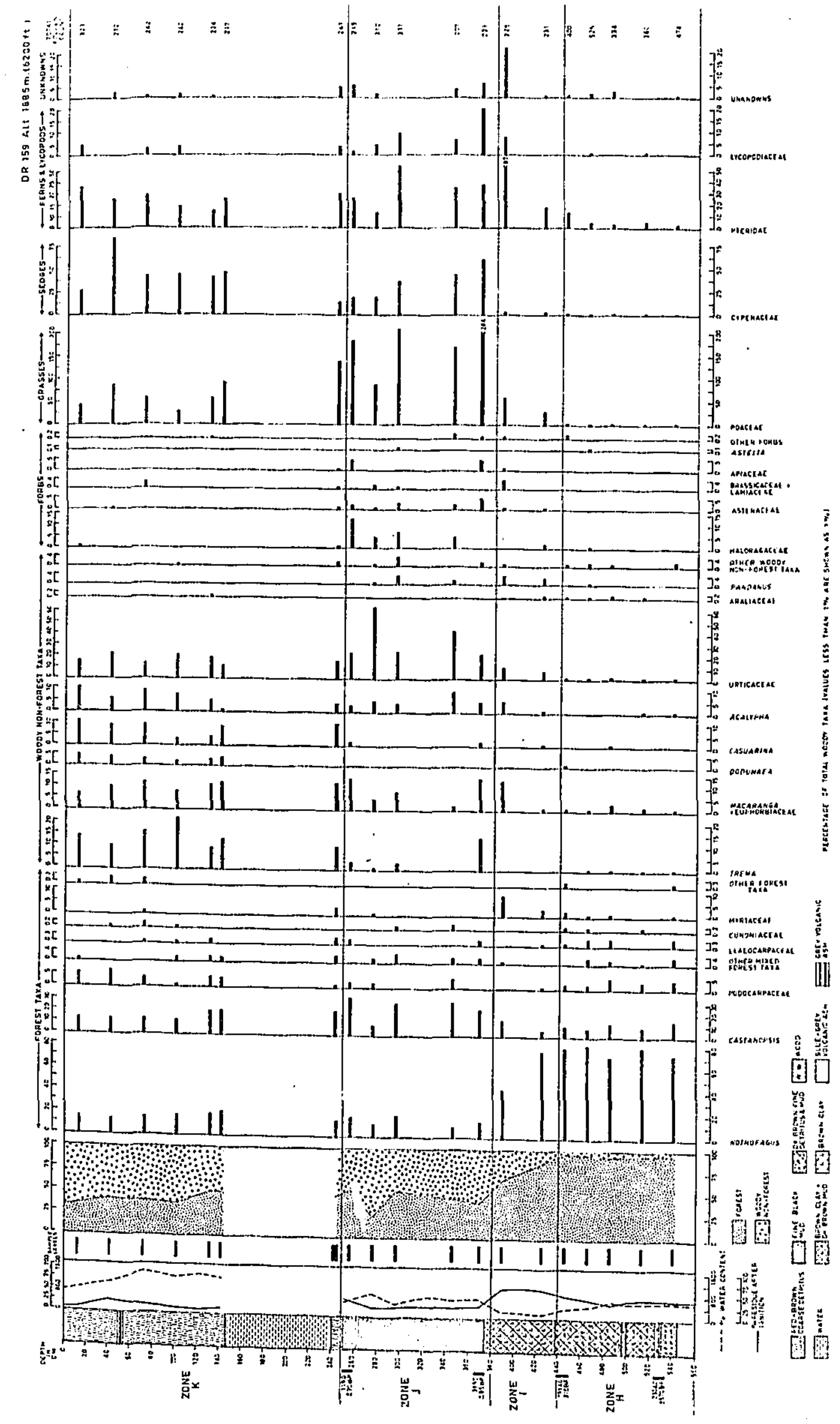


Figure 9.7 Pollen diagram of core DR 159. The pollen sum is total of tree and shrub pollen. The summary diagram shows forest and non-forest woody taxa as percentages of their joint sum.

The spectra indicate that forest was present both locally and regionally. Phyllocladus, Sphenostemon, Rapanea and Ericaceae together suggest that mixed forest was growing in the region as well as beech and oak forests, indicated respectively by Nothofagus and Castanopsis. Beech forest was far more widespread, however, than the others. The low values of light-demanding taxa and of herbs are consistent with both local and regional forest dominance. The site was possibly open, shallow, water at this time surrounded by forest with a few shrubs and herbs bordering the pond.

A radiocarbon date of 23,040 ± 570 B.P. (ANU 192) for wood at 525-535 cm depth provides a maximum age near the deposit base and the top of the zone is dated to 18,140 ± 370 years B.P. (ANU 250).

Zone I : 440 - 380 cm

The sediments of this zone are mixed and the radiocarbon dates from below (ANU 250) and above it (ANU 249): 3650 ± 85 B.P.) suggest either a long period without deposition or, more likely, deposition followed by erosion.

All that can be concluded from the pollen analysis is that forest seems to have lost ground to non-forest vegetation and to herbs but the local component in this cannot be determined.

Zone J : 380 - 250 cm

The sediments of this zone are undisturbed. It is characterized by increased representation of woody non-forest. The base of the zone is radiometrically dated to 3650 ± 85 years B.P. (ANU 249) and the top to 1190 ± 70 years B.P. (ANU 85).

At the base of the zone Castanopsis and Nothofagus are the main forest taxa, Castanopsis in higher proportion than Nothofagus. Trema, Macaranga, Acalypha and Urticaceae are important light-demanding taxa and Casuarina is recorded in low numbers. Poaceae dominate the herbs but Cyperaceae, Pteridae and Lycopodiaceae also show high values and forbs are recorded also. The spectrum suggests that grassland and shrub vegetations were present over much of the region and that oak forest had expanded relative to that of beech. The site had become a grass-sedge swamp.

Over most of the zone the levels of the various forest taxa remain substantially even, while those of the light-demanding plants (Trema, Macaranga, Urticaceae) fluctuate. The indications are that further impact was centred on the non-forest vegetation rather than the forest. The lower values of both Nothofagus and Castanopsis nearer the top of the zone (274 cm) may indicate that there was further exploitation of the forest at that time.

Herbaceous taxa values fluctuate through the zone but the site probably remained as a grass-sedge swamp.

Zone K : 250 - 0 cm

Zone K is dominated by woody non-forest (forest : non-forest = 40 : 60).

Values of most of the forest taxa remain substantially the same through the zone; Podocarpaceae increase slightly. Among the light-demanding taxa, Trema and Casuarina values increase at the beginning and, together with Macaranga, Acalypha and Urticaceae, remain high. Dodonaea rises slightly but systematically through the zone. The herbs show fluctuating high values throughout.

The spectra suggest that areas of forest and non-forest have become more or less stabilized with the forest slightly less extensive than in Zone J. The increased Podocarpaceae and Dodonaea may be attributed to settlement and garden areas while individual fluctuations in some other taxa may be due to selective use or conservation. Fluctuations of the herbs may only be the result of changing water levels on the swamp but their possible relation to events on dry land should not be overlooked.

The two pollen diagrams DR/II/29 and DR159 compare well from Zone H upwards in their main features. In detail the diagrams differ, probably as the result of both local forest differences and chance factors.

Pollen Diagrams DR/II/40A and DR/II/40B

The pollen diagrams of DR40A and DR40B were prepared to seek close correlation between vegetation history and archaeological materials including direct evidence of local gardening and crop plants. Time did not permit the very close sampling probably necessary to achieve this aim and macrofossil identification is still to be carried out. However, the diagrams are worth considering for the somewhat greater, if indirect, evidence of gardening they provide by comparison with diagrams DR159 and DR/II/29.

Pollen diagram DR/II/40B (Figure 9.8)

The diagram may be divided into 3 zones corresponding with Zones I, J and K of the other diagrams.

Zones I : 250-200 cm

The deposit is mixed but the data probably indicate reduction in forest and the development of woody non-forest vegetation. The spectrum at the top of the zone suggests that beech, oak and mixed forests were present at the time, beech forest more importantly than the others. Some woody non-forest and herbaceous vegetation was also present. The high values of *Pandanus* cannot readily be explained.

Zone J : 200 - 70 cm

In the bottom sample (189 cm) the forest is much reduced, thereafter it recovers and is maintained.

Initially *Nothofagus* values are low, Podocarpaceae are absent and Elaeocarpaceae and Cunoniaceae are few in numbers. *Castanopsis* shows relatively higher values. Urticaceae dominate the woody non-forest taxa and *Macaranga* values are also relatively high while *Acalypha* and *Trema* are present in lower numbers. Among the herbaceous taxa Poaceae and Cyperaceae share dominance, Pteridae and Lycopodiaceae are present in lower numbers. Brassicaceae and Lamiaceae are present among the forbs and *Xyris* as an aquatic. This spectrum suggests that beech forest was exploited while oak forest regenerated elsewhere. Early regrowth took place in former grassland patches and variously degraded forest. Locally a sedge-grass swamp developed and at times the water table may have been above ground level.

In the next sample both *Nothofagus* and *Castanopsis* show increased values, Elaeocarpaceae also increases and the

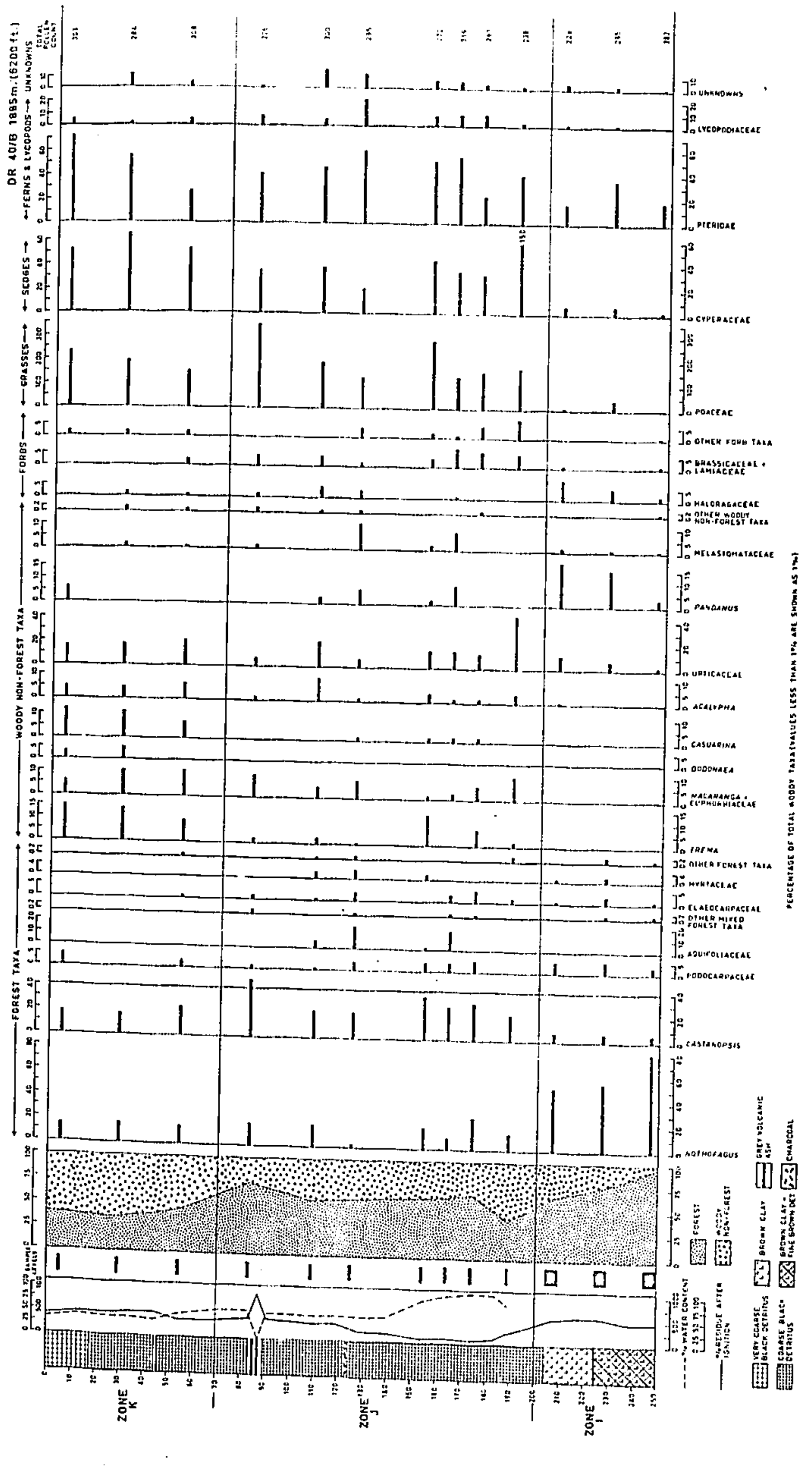


Figure 9.8 Pollen diagram of column DR/II/40 B.

Podocarpaceae reappear. Trema values increase while Urticaceae, Macaranga and Acalypha are reduced. Casuarina appears. Regeneration of degraded forest areas appears to have occurred. The Poaceae remain high and Lycopodiaceae values increase while Cyperaceae and Pteridae are reduced; the forbs are maintained. Probably the swamp remained much the same as before.

Throughout the rest of the zone the forest : non-forest ratios remain fairly stable. Fluctuations within the forest taxa suggest further exploitation of both beech and oak forest (either separately or together) at certain times but regeneration followed and the forest as a whole remained. The intermittent appearance and high values of Ilex (Aquifoliaceae) and Pandanus are difficult to interpret; they may have been planted or conserved near settlement areas.

Fluctuations among the light-demanding taxa are difficult to interpret. In most cases the Trema curve follows that of the forest taxa (in particular Nothofagus) while the Acalypha, Urticaceae and Melastomataceae fluctuations appear to coincide with the Poaceae changes. Macaranga varies independently. Probably there was a dynamic mosaic of grassland, regrowth and forest vegetation of which the diagram reflects different units at different times and in varying proportions.

Poaceae dominate the herbaceous taxa throughout the zone; their fluctuations and those of the Cyperaceae, Pteridae and Lycopodiaceae probably indicate changing water-tables on the mixed grass-sedge swamp as well as changing areal extent of grassland on the slopes. The Brassicaceae and Lamiaceae are well represented throughout the zone and other forbs recorded include Plantago lanceolata, Asteraceae, Apiaceae, Haloragis and ?Utricularia. Some may be indicative of garden areas, others of swampland or both.

Zone K : 70 - 0 cm

This zone is characterised by the dominance of woody non-forest vegetation (forest : non-forest = 35 : 65).

At the base of the zone both Nothofagus and Castanopsis show reduced values, while Podocarpaceae and Elaeocarpaceae remain low. Urticaceae, Acalypha and Casuarina values increase greatly, Macaranga is maintained. Poaceae and Pteridae show lower values, while Cyperaceae increase; Lycopodiaceae are maintained.

More forest was destroyed and regrowth vegetation expanded over former forest and grassland. Locally the sedge-grass swamp persisted.

During the rest of the zone Nothofagus and Castanopsis values are maintained; other forest taxa are unimportant. Among the light-demanding plants Trema and Casuarina increase and Dodonaea appears. Macaranga decreases slightly at the top while Acalypha and Urticaceae slowly fall. Poaceae increase, Pteridae increase and the Cyperaceae fluctuate.

The spectra suggest that a balance between forest and non-forest areas has been established and also that some species may have been intentionally planted or conserved. Some further areas of grassland may have developed on the slopes and locally, the site remained a grass-sedge swamp.

Pollen diagram DR/II/40A (Figure 9.9)

The stratigraphy of the two columns leads to the expectation of close similarity between diagrams DR 40A and DR 40B, except that the lowermost half metre of DR 40B is not represented in DR 40A. The pollen curves of the two diagrams are, indeed, very similar and allow zones J and K to be identified on DR 40A, the zone boundary falling at 75 cm depth. The close correspondence of the spectra at 190 cm on both diagrams is taken to confirm the cessation of disturbance of the lower deposits by the time represented by that level in both.

A sample from just above this level has been radiometrically dated in DR 40A to 3880 $\pm$ 90 B.P. (ANU 276).

Pollen was recovered from the lowermost (164-165 cm, 154-155 cm) and the uppermost (104-105 cm) samples of infill but no crop plant pollen was recovered. The plants which were possibly, but not necessarily, associated with gardening in the area were Brassicaceae, Lamiaceae, Apiaceae, Haloragis, Pandanus and Casuarina.

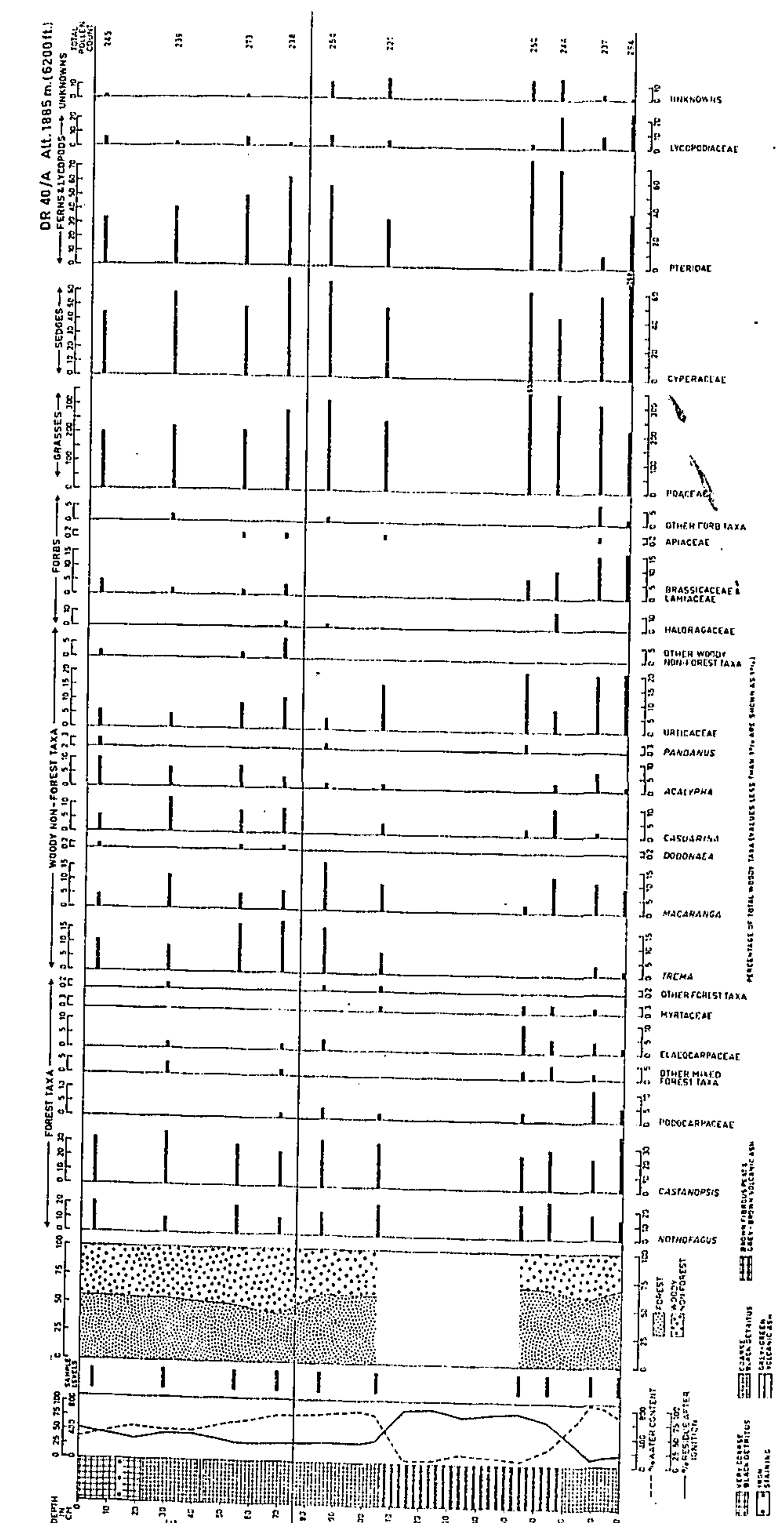


Figure 9.9 Pollen diagram of column DR/II/40 A.

The upper part of the diagram shows similar features to that of DR 40/B although fluctuations occur in most taxa; the differences are presumably due to chance variation in pollen deposition.

RECONSTRUCTION OF THE HISTORY OF THE DRAEPI SITE.

The stratigraphic, pollen analytical, macrofossil and archaeological data considered in the chronological context provided by the radiocarbon dates allow the following reconstruction of the history of Draepi.

The site rests on Quaternary volcanic ash deposits. Between 29670 - 38000 years B.P. (radiocarbon dates ANU 194, ANU 254) it may have been a shallow water lake. Forest was dominant on the surrounding slopes at that time. Initially, beech forest seems to have been most extensive but this was replaced over much of the area by mixed forest; some small areas of subalpine grassland may also have been present then. Between 23000 - 18000 years B.P. (ANU 192, ANU 250) beech forest was dominant, both locally and regionally. By 5100 years B.P. (ANU 253) part of the forest had been cleared and non-forest was an important component of the regional vegetation.

Between 18000 and 5000 years B.P. there is a stratigraphic break in the sediments. It seems likely that clearance of the forest on the surrounding slopes facilitated increased run-off and led to erosion of surface materials there and at the pollen analytical site. Later, clay was deposited and mixed with the upper part of the remaining lake muds. Afterwards, a mixed sedge-grass swamp developed on the pollen-analytical site. Disturbance of the forest continued but a balance between forest and non-forest vegetation was achieved and maintained.

Charcoal in a cooking pit dated to 2310 years B.P. (ANU 255) is the first direct indication of human use of the area. Gardening of part of the site was undertaken at about the same time as evidenced by the radiocarbon date of earliest in-fill of a ditch (ANU 277 : 2280 ± 90 B.P.) which contained a pointed wooden digging stick near its base. More recent gardening is indicated by the upper fill of the same ditch, re-cut from a higher level but so far undated. There is no evidence of the crops grown but some plants, such as *Casuarina*, *Dodonaea*, *Trema*, *Pandanus* were probably planted or conserved in garden fallows and around settlement areas whilst others, such as Brassicaceae, Lamiaceae, Asteraceae and *Plantago* were probably garden weeds or domesticates.

CHAPTER 10

DISCUSSION

The purpose of this thesis has been to investigate the impact of man on the vegetation of the Mt Hagen region, now and in the past. The chosen area of the New Guinea highlands proved suitable for both parts of the work: a fairly large indigenous population practise subsistence agriculture there and sites suitable for pollen analysis were available. In addition the discovery and excavation of archaeological material stratified into organic deposits provided evidence of prehistoric human activity which could be correlated directly with the vegetation history.

The present vegetation

The present vegetation types, their species composition, areal extent and distribution and possible successional status have been described and discussed in Chapters 3 to 5. Forests occupy ca 10 per cent of the total study region, covering the altitudinal range 1820m - >3345m in parts of the region. Above 3345m on Mt Hagen there is subalpine tussock grassland (with small patches of forest included) and below 1820m a mosaic of non-forest vegetation types.

The upper limit of continuous forest may be climatically controlled but the firing of subalpine grassland during trading expeditions, the presence of burnt tree stumps and grassy patches at the forest margin and the abundance of pathways across the summit area all suggest that, even here, human influences are important determinants of the vegetation.

Species distribution in the forests appears to be related mainly to altitude and it is presumably controlled by some correlated climatic factor such as temperature. On the basis of species composition and dominance three main forest types have been distinguished: mixed forest, growing between 2585m and 3345m altitude, beech forest, between 2130m and 2745m altitude and oak forest below 2130m. In areal extent the beech forest is the most widespread at the present time, while mixed forest and oak forest occupy similar areas, each about one third to two fifths that of the beech forest.

Human impact on the forests is widespread. Even the highest forests are used for hunting and gathering and cut tree stumps have been recorded at all sampled sites. Below 2560m on Mt Hagen and 2230m on the Wurup slopes of the Kubor range, the forests are largely degraded, by general or selective felling, and their relics left amongst the regrowth vegetation. The lower limit of the forests at the present time is controlled by human influences as evidenced by its uneven altitudinal position from one part of the study region to another, by the degradation of the forests immediately above it and the presence of subsistence gardens both at the forest margin and below.

The rate of forest destruction cannot be determined, but it may not be as rapid as suggested for some other parts of the highlands (Bowers 1968, Waddell 1968) as present populations are not concentrated at the forest edge but rather are widespread over a large area of rolling and flat land at the base of Mt Hagen and on the slopes bordering the Upper Wahgi valley. Positive measures are also taken to conserve the productivity of current garden areas.

Non-forest vegetation covers 90 per cent of the study region. Grassland is widespread, covering ten times the area occupied by swampland and six times that of shrubby regrowth and vegetation associated with settlements. The mosaic of types below 1820m altitude, although classified into various entities for descriptive purposes, in fact merge, one into another. Some types, such as the sweet potato and mixed crop gardens, their associated fallows, and other settlement area plantings are the direct products of human activity, while others, such as the mixed stands of relict and regrowth trees and shrubs on steep slopes and the shrubby regrowth vegetation in grassland are perhaps less obviously anthropogenic; the distribution of almost all, however, is determined by human influences. Most non-forest species are widely distributed. Only the subalpine taxa and those associated with the swamps are restricted; in the latter species distribution appears related, at least in part, to water depth.

The present system of subsistence agriculture is intensive with some land cultivated more-or-less permanently and other gardens shifting within certain well-defined limits. A short-term grass fallow may follow sweet potato gardening, a longer woody fallow follows mixed cropping. Each of these fallows may be used again for gardens, become pig paddocks, be burnt over during hunting or left little-touched for a period of several years. Further work is required to establish details of secondary succession after gardening and other types of land use but the outlines established (Chapter 5) for succession towards short grassland, shrubby regrowth and secondary forest may be used to relate many of the non-forest vegetation types, one to another, and to establish the dynamic status of the non-forest vegetation as a whole.

The rate at which grassland develops after gardening has not been determined but appears to be very slow indeed. In fact, given the intensive cultivation methods, the controlled fallow periods and the well-defined unit of land use (socially determined) it seems likely that today the balance is in favour of regeneration of shrubby regrowth over formerly more extensive grassland and garden.

On the whole, it seems that, although human impact on the natural vegetation is obvious and continuing, it is not now rapid; it is offset by planting of some species and preservation of others, by sophisticated conservationist horticulture and the ability to re-use areas of grassland and shrubby regrowth.

Knowledge of species composition of extant vegetation types was a basic requirement for interpretation of the vegetation history of the region. Indicator species for different vegetation types were sought through comparison of species composition and abundance at different sites. In the forests species with relatively restricted distribution could be found and used as indicators of mixed, beech and oak forests. Indicators of non-forest vegetation types were more difficult to define due to the wide distribution of many of the woody and herbaceous taxa there; nevertheless some indicators were established, in particular for subalpine grassland and mires, for swampland and for gardens.

The modern pollen rain

The equation of modern pollen rain spectra with extant vegetation types permits more controlled interpretation of pollen diagrams. Comparison of the floristic compositions of modern pollen rain samples with those of nearby vegetation plots (Chapters 6 and 7) allowed some generalizations about pollen representation to be made and also indicated the range of variation of pollen content to be expected within and between groups of samples collected from one vegetation type or another.

The composition of the modern pollen rain samples could be explained mainly in terms of local and extra-local pollen transfer. Variations in representation of taxa suggested that a number of factors were involved in pollen transfer from source to sedimentation site, however, and it was concluded that the most important mechanisms were probably short-distance wind transfer and rainout of the regional component.

The value of possible indicators of certain vegetation types for pollen analytical interpretation was tested by seeking them in appropriate numbers in modern pollen rain samples collected from appropriate vegetation. In most cases the indicators were upheld (for example, in the forests, swamps and subalpine vegetation) but in others (gardens and fallow vegetation) their pollen was scarce or absent.

Further examination of groups of pollen taxa permitted general principles to be laid down to guide interpretation of fossil diagrams. It was also suggested that, given both the previously established relationships of vegetation to environment and of pollen rain to vegetation, certain trends in pollen diagrams might be explained in environmental terms.

The past vegetation

The two sites studied pollen analytically, Manton's and Draepi, lie 23km (14 miles) apart and at 1580m and 1880m altitude respectively. The pollen diagrams from both sites, considered together, should allow reconstruction of the regional vegetation history.

In all diagrams indications of major and minor vegetation changes have been sought which could then be interpreted in climatic, natural (autogenic) successional or anthropogenic terms, or combinations of these. The general knowledge of present vegetation and of modern pollen rain undoubtedly aided the interpretation of the pollen diagrams but, even so, this was hampered by the lack of detailed knowledge of the ecological tolerances of many of the plants and by the lack of pollen morphological differentiation at both generic and species level. However, the diagrams from each site show similar trends and differences between diagrams are acceptable, given the degree of variation in the modern pollen rain samples.

The facts of human occupation and agriculture were clearly indicated in the stratigraphy and contained artefacts of certain parts of both sites and the ascription of anthropogenic causes to pollen analytical changes at associated levels therefore provided the most economic explanations of them. Changes elsewhere in the Manton diagrams were also more readily interpreted in anthropogenic terms than any other, while changes in the lower parts of the Draepi diagrams may be ascribed to climatic effects. In all diagrams, changes in herbaceous taxa may be interpreted in successional terms, although these are somewhat obscured due to their presumed origin in both dryland and swamp vegetation.

Together the diagrams cover a period of several thousands of years. Those from Draepi indicate that from possibly 38000 years B.P. to 18000 years B.P. forests preponderated both locally and regionally. An extension of mixed forest, and possibly of subalpine grassland, relative to beech forest is indicated in the lower part of the DR/II/29 diagram (Zone G) and this may have been climatically induced; it is not accurately dated but the change probably occurred before 30000 years B.P.

The presence of mixed forest near the pollen analytical site would imply a shift in vegetation zones of about 700m altitudinally from the present day position; similarly an extension of subalpine grassland to near the site would imply an altitudinal shift of 1200m. Some 80 km westward, Flenley (1967) found evidence for a 500m vegetation movement at a later time, namely 12000 - 8500 years B.P.. There is indubitable evidence for glaciation of New Guinea's high mountains in the past (Reiner 1960, Bik 1967); in particular Loefler (pers. comm.) estimates the snowlines to have lain at 3500m and 3000m on Mt Hagen and Mt Giluwe respectively. It is conceivable, then, that the vegetation changes recorded are related to the temperature changes which doubtless accompanied the waxing and waning of this ice.

The beech forest recovers above ca 29760 years B.P. in the DR/II/29 diagram and is well established between 23040 and 18000 years B.P. (Zone H) according to the DR 159 diagram.

By 5100 years B.P. at Draepi part of the forest had been cleared and non-forest was an important component of the local and regional vegetation. Between 18000 and 5100 years B.P. there is a stratigraphic break in the sediments. It seems likely that clearance of the forest on the surrounding slopes facilitated increased runoff and led to erosion of surface materials there and at the pollen analytical site.

The lowest sediments at the Manton site also date from 5000 years B.P. and here too the pollen diagrams show that the forest was largely degraded or partly cleared at that time. Disturbance of it continued into more recent times but the Draepi diagrams suggest that a balance between forest and non-forest vegetation was achieved at a relatively early date and maintained thereafter.

At both sites there is direct stratigraphic and archaeological evidence for agricultural use of the swamp 2200 - 2400 years ago which continued at the Manton site, perhaps intermittently, until 400 - 550 years B.P. At Draepi more recent gardening is also indicated stratigraphically but is so far undated. No direct evidence of the major crops grown was forthcoming. However, a number of both woody and herbaceous taxa appear, or show increased pollen values, during the period of use of the swamp itself and afterwards; these are important settlement plants and domesticates today and may well have been then.

Renewed impact on the forest is indicated in the Manton diagrams after abandonment of the swamp but later a balance between forest and non-forest vegetation was achieved and maintained.

The development of highlands agriculture

The data support and extend the relevant parts of the Bulmers' hypothetical reconstruction of highlands prehistory (S. & R. Bulmer 1964, S. Bulmer 1964). Firstly, forest had been extensively cleared in the Mt Hagen region by 5000 years B.P. and had almost certainly been cleared before then. This implies shifting agriculture at least in the region at that time and equates with the Bulmers' Phase II of highlands prehistory. This was characterized by the presence of lenticular-sectioned axe-adzes and waisted flaked blades and extrapolated forest clearance and agriculture; it dated from ca 4000 B.C. to at least 3000 B.C.

Secondly, by 2200 - 2400 years B.P. people were gardening the swampland at both 1580m and 1880m altitude and they continued to do so more recently, and up to 400 - 550 years B.P. at the Manton site. Use of the slopes may have continued but the impact on them was not as great as before. Even if the swamps were used intermittently the evidence of their use on a regional scale may imply the presence of fairly large populations in the area at that time. Flenley's (1967) evidence that reduction of forest, probably due to human activities, started about 2000 B.P. at Lake Birip (1900m altitude) and about 1600 B.P. (inferred age) at Lake Inim (2550m altitude), both sites west of Mt Hagen, gave intimations of the same thing. This equates in part with the Bulmers' Phase III, dated from after 3000 B.C. to ca 1930 A.D., and characterized by the presence of the planilateral-section axe-adze, pottery making in the eastern highlands and by more specialized agricultural practises, including the cultivation of sweet potato. It differs somewhat from their view in that the presence of fairly large populations cultivating areas up to 2000m altitude and possibly higher may be implied from the data.

Gardening of the swampland itself, involving as it does, careful water control, may represent a technical advance compared with simple migratory shifting agriculture but whether such a development occurred in the Hagen region itself or was introduced from elsewhere, perhaps with a new crop or set of domestic plants which required it, is unknown. Because the wooden digging sticks recovered from the excavation were similar to those used for gardening at the time of European contact (in 1933) a system of agriculture similar to that seen today may in fact have been used then. The pollen diagrams indicate the presence of certain useful plants, such as Casuarina, Dodonaea and Moraceae and a number of forbs which today are domesticates and garden weeds and it is possible that they were already domesticated by then.

The problem remains, however, of determining the main crops grown at that time, since the staple today, sweet potato (Ipomoea batatas), is unlikely to have reached New Guinea before the sixteenth century, following its introduction into the Philippines by Spaniards (Dixon 1932, Yen 1963, Conklin 1963). Amongst the other crops grown today, sugar cane (Warner, 1962) and bananas of the Australimusa group (Simmonds, 1962) are probably New Guinea cultigens and, together with many of the small herbs such as Saccharum edule, Setaria palmifolia, Rungia klossii, Amaranthus spp. and members of the Apiaceae and Brassicaceae, were domesticated there. Others, such as yam and taro are of Asiatic origin; their transfer is considered to have taken place at a very early period but direct evidence is so far lacking. Similarly, the date of introduction of Lagenaria siceraria and the beans Psophocarpus tetragonolobus and Dolichos sp. is unknown. The present study indicates that Lagenaria cf siceraria had been introduced into New Guinea by at least 2200 years B.P. Pueraria lobata may have been an important root crop in the past in the New Guinea highlands as well, although little-used today (Watson 1964, 1968, Bowers 1964, Barrau 1965, Strathern 1969).

It seems likely that taro (Colocasia esculenta) was the main crop grown on the swampland; it may have been planted as a pure crop or mixed with others such as bananas, sugar cane, yams, Saccharum edule, Rungia klossii, Lagenaria siceraria, Amaranthus spp., and so on. Similar complex cropping has been described by Serpenti (1965) for Frederik Hendrik Island and is probably quite widespread in both lowland and highland areas.

The date of 400 - 550 years B.P. for the abandonment of the Manton swampland may be significant in relation to the entry of the sweet potato. If it was introduced then into a swamp taro horticulture it might first have been grown with that crop and its associates. Today, at Pureni in the Southern Highlands, taro plants grow on the sides and edges of small and large drainage ditches with sweet potatoes in the intervening plots; a similar gardening scheme has been reported for the Baliem Valley (Brookfield & White, 1968). Later, for agricultural or totally unrelated reasons, the swamps may have been abandoned and the sweet potato found suitable for the surrounding slopes.

Whatever the true sequence of events as they affected the staple, many other useful plants were retained until the present day. <u>Casuarina</u> and <u>Dodonaea</u> show increased values from about 1200 years ago in the Draepi diagrams and from 400 - 550 years ago in the Manton diagrams. In addition, the pollen diagrams from the Manton site in particular suggest that over the last 400 - 550 years a more sophisticated system of land use developed, involving selective cutting of either forest or secondary regrowth and conservation or planting of extra trees (<u>Trema</u>, Myrtaceae, Podocarpaceae).

There is no evidence, in the present data, to support Watson's (1965a, 1965b) suppositions that there were widespread and rapid changes in agricultural practices, and rapid growth and redistribution of populations to higher altitudes following the introduction of the sweet potato (cf Brookfield & White, 1968). Similarly, although there is as yet no comparable evidence from the Eastern Highlands, the time depth established for human interference with the vegetation of the Mt Hagen region renders Robbins' (1963a, 1963b) hypothesis of an east-west spread of agricultural activity less likely.

Flenley (1967) established that the vegetation of parts of the New Guinea Highlands had changed during the past 12000 years and that the kinds of changes that had taken place since 2000 B.P. were not inconsistent with an anthropogenic explanation. The present work has established the fact of human interference through the interpretation of dated pollen diagrams directly correlated with stratified artefacts and has shown there to be strong evidence for a history of interference considerably longer than Flenley supposed. Much remains to be done before the record of the interplay between man and the natural vegetation of the New Guinea highlands is complete, but the availability of the appropriate materials, and the applicability of the methods, refined though they need to be, is now beyond question.

BIBLIOGRAPHY

Aitchison, T.G. (1963). The pig and its place in the impact of the New Guinean on vegetation. In UNESCO symposium, The Impact of Man on the Humid Tropics Vegetation, Goroka, 1960, pp.158-167.

Andersen, S.T. (1967). Tree-pollen rain in a mixed deciduous forest in South Jutland (Denmark). Rev. Palaeobot. Palynol., 3, pp.267-75.

Anderson, D.J. (1965). Classification and ordination in vegetation science: controversy over a non-existent problem? J. Ecol., 53, pp.521-6.

Ashton, P.S. (1964). Ecological studies in the mixed dipterocarp forests of Brunei State. Oxford Forestry Memoirs, 25. Clarendon Press, Oxford.

Ashton, P.S. (1965). Some problems arising in the sampling of mixed rain forest communities for floristic studies. In UNESCO Symposium on Ecological Research in Humid Tropics Vegetation, Kuching, Sarawak, 1963, pp.235-40.

Atkinson, I.A.E. (1962). Semi-quantitative measurements of canopy composition as a basis for mapping vegetation. Proc. N.Z. Ecol. Soc., 9, pp.1-8.

Aubréville, A. (1950-1). Le concept d'association dans la forêt dense équatoriale de la basse Côte d'Ivoire. Bull. Soc. Bot. Fr., 97, pp.145-58.

Austin, M.P. and P. Greig-Smith (1968). The application of quantitative methods to vegetation survey. II. Some methodological problems of data from rain forest. J. Ecol., 56, pp.827-44.

Austin, M.P. and L. Orloci (1966). Geometric models in ecology. II. An evaluation of some ordination techniques. J. Ecol., 54, pp.217-27.

Barrau, J. (1958). Subsistence Agriculture in Melanesia. B.P. Bishop Museum Bulletin.

Barrau, J. (1959). The bush-fallowing system of cultivation on the continental island of Melanesia. Proc. 9th Pac. Sci. Cong., 7, pp.53-5.

Barrau, J. (1965). Witnesses of the past: notes on some food plants of Oceania. Ethnology, 4, pp.282-94.

Bartlett, H.H. (1956). Fire, primitive agriculture and grazing in the tropics. In W.L. Thomas, ed. Man's Role in Changing the Face of the Earth, pp.692-720. Univ. Chicago Press.

Baylis, G.T.S. and A.F. Mark (1963). Vegetation studies on Secretary Island, Fiordland. Part 4: Composition of the Beech-Podocarp forest. N.Z. Journ. Bot., 1, pp.203-7.

Beard, J.S. (1953). The savanna vegetation of Northern Tropical America. Ecol. Monogr., 23, pp.149-213.

Benninghoff, W.S. (1962). Calculation of pollen and spore density in sediments by addition of exotic pollen in known quantities. Pollen et Spores, 4, 332-3.

Benninghoff W.S. and R.O. Kapp (1962). Suggested notations to indicate identification status of fossil pollen. Pollen et Spores, 4, p.332.

Bent, A.M. and H.E. Wright (1963). Pollen analysis of surface materials and lake sediments from the Chuska Mountains, New Mexico. Geol. Soc. Amer. Bull., 74, 491-500.

Bharucha, F.R. (1958). Methods for the study of tropical vegetation. In UNESCO, Symposium, Study of Tropical Vegetation, Ceylon, 1956, pp.89-92.

Bik, M.J.J. (1967). Structural geomorphology and morphoclimatic zonation in the Central Highlands, Australian New Guinea. In J.N. Jennings and J.A. Mabbutt, ed. Landform Studies from Australia and New Guinea.

Birdsell, J.P. (1949). The racial origin of the extinct Tasmanians. Rec. Queen Victoria Mus., Launceston, 2, pp.105-22.

Boaler, S.P. (1966). Ecology of a miombo, Lupa North Forest Reserve, Tanzania. II. Plant communities and seasonal variation in the vegetation. J. Ecol., 54, pp.465-79.

Bormann, F.H. (1953). The statistical efficiency of sample plot size and shape in forest ecology. Ecology, 34, pp.474-87.

Bowers, N. (1964). A further note on a recently reported root crop from the New Guinea Highlands. Journ. Polynes. Soc., 73, pp.333-5.

Bowers, N. (1965). Agricultural practices and successional vegetation in the Upper Kaugel Valley, Western Highlands, Australian New Guinea. Mimeographed.

Bowers, N. (1968). The ascending grasslands: an anthropological study of ecological succession in a high mountain valley of New Guinea. Unpubl. Ph.D. Thesis, Columbia University.

Braidwood, R.J. and B. Howe (1960). Prehistoric Investigations in Iraqi Kurdistan. Studies in Ancient Oriental Civilization, No.13. Univ. of Chicago Press.

Brass, L.J. (1941). The 1938-9 expedition to the Snow Mountains, Netherlands New Guinea. J. Arnold Arbor., 22, pp.271-342.

Brass, L.J. (1956). Results of the Archbold expeditions No.75. Summary of the fourth Archbold expedition to New Guinea (1953). Bull. Amer. Mus. Nat. Hist., 111, pp.77-152.

Brass, L.J. (1964). Results of the Archbold expeditions. No.86. Summary of the sixth Archbold expedition to New Guinea (1959). Bull. Amer. Mus. Nat. Hist., 127, 215 pp.

Braun-Blanquet, J. (1951). Pflanzensoziologie. 2nd edition. Vienna.

Bray, J.R. and J.T. Curtis (1957). An ordination of the upland forest communities of Southern Wisconsin. Ecol. Monogr., 27, pp.325-49.

Brookfield, H.C. (1961). The highlands people of New Guinea: A study of distribution and localization. Geogr. Journ., 127 pp.436-48.

Brookfield, H.C. (1962). Local study and comparative method: an example from Central New Guinea. Ann. Assoc. Amer. Geog., 52, pp.242-54.

Brookfield, H.C. (1964). The ecology of Highland settlement: some suggestions. Amer. Anthrop. 66, 2, pp.20-38.

Brookfield, H.C. and P. Brown (1963). Struggle for Land: agriculture and group territories among the Chimbu of the New Guinea Highlands. Oxford Univ. Press, Melbourne.

Brookfield, H.C. and D. Hart (1966). Rainfall in the Tropical Southwest Pacific. Research School of Pacific Studies, Dept. of Geography Publication G/3. ANU Press, Canberra.

Brookfield, H.C. and J.P. White (1968). Revolution or evolution in the prehistory of the New Guinea Highlands: A seminar report. Ethnology, 7, pp.43-52.

Bryan, W.W. (1963). The effects of grazing by the domestic animals of early man on the vegetation of the humid tropics. In UNESCO Symposium, The Impact of Man on Humid Tropics Vegetation, Goroka, 1960, pp.151-6.

Budowski, G. (1956). Tropical savannas, a sequence of forest felling and repeated burnings. Turrialba, 6. pp.23-33.

Bulmer, S. and R.N.H. Bulmer (1964). The prehistory of the Australian New Guinea Highlands. Amer. Anthrop., 66, 2, pp.39-76.

Bulmer, S. (1964). Radiocarbon dates from New Guinea. Journ. Polynes. Soc., 73, pp.327-8.

Bulmer, S. (1966). Pig bone from two archaeological sites in the New Guinea highlands. Journ. Polynes. Soc., 75, pp.504-5.

Cantlon, J.E., F.E. Egler and others (1968). The continuum concept of vegetation: responses. Bot. Rev., 34, pp.253-332.

Carrol, G. (1943). The use of bryophytic polsters and mats in the study of recent pollen deposition. Amer. Journ. Bot., 30, pp.361-6.

Cavalli-Sforza, L.L. and A.W.F. Edwards (1964). Analysis of human evolution. In Genetics Today, pp.923-33. Pergamon Press, London.

Cavalli-Sforza, L.L. and A.W.F. Edwards (1967). Phylogenetic analysis: models and estimation procedures. Evolution, 21, 550-70.

Cavanaugh, L.G. (1957). Resource Survey, Western Highlands. Unpubl. Dept. of Forests, File No. 90.14.5.

Cavanaugh, L.G. (1959). Forest Inspection - Western Highlands. Unpubl. Dept. of Forests File No. 90.14.1.

Champness, L.T., O. Kooptzoff and R.J. Walsh (1959). A study of the population near Aiome, New Guinea. Oceania, 30, 294-304.

Chang, K.C. and M. Stuiver (1966). Recent advances in the prehistoric archaeology of Formosa. Proc. Nat. Acad. Sci., 55, pp.539-43.

Chevalier, A. (1953). Ce qu'il faut penser des associations végétales du systhème Braun-Blanquet. Rev. Int. Bot. Appl. Agr. Trop., 33, pp.323-4.

Chinnery, E.W.P. (1934a). Mountain tribes of the Mandated Territory of New Guinea from Mt Chapman to Mt Hagen. Man, 34, pp.113-21.

Chinnery, E.W.P. (1934b). The central ranges of the Mandated Territory of New Guinea from Mount Chapman to Mount Hagen. Geogr. Journ. 84, pp.398-412.

Clapham, A.R. (1932). The form of the observational unit in quantitative ecology. J. Ecol., 20, pp.192-97.

Clark, J.D. (1962). The spread of food production in sub-saharan Africa. Journ. African Hist., 3, pp.211-28.

Clark, J.D. (1967). The problem of the Neolithic culture in Subsaharan Africa. In W.W. Bishop and J.D. Clark, ed. Background to Evolution in Africa, pp.601-27. Univ. of Chicago Press.

Clarke, P.J. and F.C. Evans (1954). Distance to nearest neighbour as a measure of spatial relationships in populations. Ecology, 35 : pp.445-53.

Clarke, P.J. and F.C. Evans (1955). On some aspects of spatial pattern in biological populations. Science, 121, pp.397-8.

Clarke, W.C. and J.M. Street (1967). Soil fertility and cultivation practices in New Guinea. Journ. Trop. Geog. 24, pp.7-11.

Clayton, W.D. (1958). Secondary vegetation and the transition to savanna near Ibadan, Nigeria. J. Ecol., 46, pp.217-37.

Coetzee, J.A. (1964). Evidence for a considerable depression of the vegetation belts during the upper Pleistocene on the East African mountains. Nature, 204, pp.564.

Coetzee, J.A. (1967). Pollen analytical studies in East and Southern Africa. Vol.III of Palaeoecology of Africa, ed. E.M. van Zinderen Bakker.

Cole, S. (1963). The stone age of East Africa. In R. Oliver and G. Mathew, ed. History of East Africa. Vol.I. Oxford, Clarendon Press.

Conklin, H.C. (1957). Hanunoo agriculture, an example of shifting cultivation in the Philippines. Unasylva, 11, pp.172-3.

Conklin, H.C. (1957a). Hanunoo agriculture: A report on an integral system of shifting cultivation in the Philippines. FAO Forestry Devel. Paper 12, Rome.

Conklin, H.C. (1959). Shifting cultivation and the succession to grassland climax. Proc. 9th Pac. Sci. Congr., 7, pp.60-62.

Conklin, H.C. (1963). The Oceanian-African hypotheses and the Sweet Potato. In J. Barrau, ed. Plants and the Migrations of Pacific peoples, pp.129-36. Bishop Museum Press.

Conroy, W. (1963). The evolution of the agricultural environment in Papua and New Guinea. UNESCO Symposium, The Impact of Man on Humid Tropics Vegetation, Goroka, 1960, pp.94-7.

Coon, C.S. (1966). The Living Races of Man. Lowe and Brydone, London.

Cottam, G. and J.T. Curtis (1949). A method for making rapid surveys of woodlands by means of pairs of randomly selected trees. Ecology, 30, pp.101-4.

Cottam, G. and J.T. Curtis (1956). The use of distance measures in phytosociological sampling. Ecology, 37, pp.451-60.

Cottam, G., J.T. Curtis and B.W. Hale (1953). Some sampling characteristics of a population of randomly dispersed individuals. Ecology, 34, pp.741-57.

Coupland, R.T. (1961). A reconsideration of grassland classification in the northern Great Plains of North America. J. Ecol., 49, pp.135-68.

Curtis, J.T. (1950). Original forest structure. Paper at AAAS Symposium on Structure of plant communities. Cleveland.

Curtis, J.T. (1959). The Vegetation of Wisconsin. Univ. Wisconsin Press.

Daubenmire, R. (1966). Vegetation: identification of typal communities. Science, 151, pp.291-8.

Daubenmire, R. (1968). Ecology of fire in grasslands. Adv. Ecol. Res. 5, pp.209-66.

Davies, O. (1967). West Africa before the Europeans : archaeology and prehistory. Metheun, London.

Davis, M.B. (1963). On the theory of pollen analysis. Amer. J. Sci., 261, 897-912.

Davis, M.B. (1965). A method for determination of absolute pollen frequency. In B. Kummel and D. Raup, Handbook of Paleontological Techniques. Freeman, San Francisco. pp.674-86.

Davis, M.B. (1965). Phytogeography and Palynology of Northeastern United States. In H.E. Wright and D.G. Frey, ed., The Quaternary of the United States Princeton University Press, pp.377-401.

Davis, M.B. (1966). Determination of absolute pollen frequency. Ecology, 47, pp.310-1.

Davis, M.B. (1967). Late-glacial climate in Northern United States : A comparison of New England and the Great Lakes Region. In E.J. Cushing and H.E. Wright, ed., Quaternary Paleoecology. Yale Univ. Press, pp.11-43.

Davis, M.B. and J.C. Goodlett (1960). Comparison of the present vegetation with pollen spectra in surface samples from Brownington Pond, Vermont. Ecology, 41, pp.346-57.

Dekker, F.E. and I.G. Faulks (1964). The geology of the Wabag area, New Guinea. Bur. Min. Resourc., Geol. & Geophys. Rec. 1964/137. Unpubl.

De la Rue, E.A. (1958). Man's influence on Tropical vegetation. Proc. 9th Pac. Sci. Congr., 20, pp.81-93.

Denevan, W.D. (1966). The aboriginal cultural geography of the Llanos de Mojos of Bolivia. Ibero-American, No.48. Berkeley.

De Rosayro, R.A. (1958). Tropical ecological studies in Ceylon. In UNESCO symposium on Study of Tropical Vegetation, Ceylon, 1956, pp.33-39.

De Rosayro, R.A. (1963). The nature and origin of secondary vegetational communities in Ceylon. In UNESCO Symposium on the Impact of Man on Humid Tropics Vegetation, Goroka, 1960, pp.279-306.

Dewar, H.S.L. and H. Godwin (1963). Archaeological discoveries in the raised bogs of the Somerset Levels, England. Proc. Prehist. Soc., 29, pp.17-49.

Dimbleby, G.W. (1957). Pollen analysis of terrestrial soils. New Phytol., 56, pp.12-28.

Dimly, A. (1963). The effect of fire used by early man on the vegetation of the Humid Tropics. In UNESCO Symposium on the Impact of Man on Humid Tropics Vegetation, Goroka, 1960, pp.119-122.

Dixon, R.B. (1932). The problem of the sweet potato in Polynesia. Amer. Anthrop. n.s. 34, pp.40-66.

Dow, D.B. and F.E. Dekker (1964). The geology of the Bismarck Mountains, New Guinea. Bur. Min. Resourc., Geol. & Geophys. Report No.76.

Dozy, J.J. (1937). Geologie and Topografie. In A.H. Colign, Naar de eeuwige sneeuw van tropisch Nederland. Amsterdam, pp.231-53.

Dunn, D., O. Kooptzoff, A.V.G. Price and R.J. Walsh (1956). The blood groups of a third series of New Guinea natives from Port Moresby. Oceania, 27, pp.56-63.

Emberger, L. (1950). Observations phytosociologiques dans la forêt dense equatoriale. Arch. Inst. Grandducal Luxemb. 19, pp.119-23.

Erdtman, G. (1943). An introduction to pollen analysis. Chronica Botanica.

Faegri, K. (1966). Some problems of representativity in pollen analysis. Palaeobot., 15, pp.135-40.

Faegri, K. and J. Iversen (1950). Textbook of Pollen Analysis. Munksgaard, Copenhagen. 168pp.

Faegri, K. and J. Iversen (1964). Textbook of Pollen Analysis. Munksgaard, Copenhagen. Second edition.

Fagerlind, F. (1952). The real signification of pollen diagrams. Botanisk Notiser, 105, pp.185-224.

Fitzpatrick, E.A. (1965). Climate of the Wabag-Tari area. Part IV. In Lands of the Wabag-Tari area, Papua-New Guinea, Part IV, pp.56-69. CSIRO, Land Research Series No.15.

Fitzpatrick, E.A., D. Hart and H.C. Brookfield (1966). Rainfall seasonality in the Tropical Southwest Pacific. Erdkunde, 20, pp.181-94.

Flenley, J.R. (1967). The present and former vegetation of the Wabag region of New Guinea. Unpubl. Ph.D. Thesis, ANU, Canberra.

Fosberg, F.R. (1958). Vegetation of the islands of Oceania. In UNESCO Symposium on Study of Tropical Vegetation, Ceylon, 1956, pp.54-8.

Fosberg, F.R. (1962). Tropical pacific grasslands and savannas. Proc. 9th Pac. Sci. Cong. 4, pp.118-23.

Frenzel, B. (1966). Climatic change in the Atlantic/ Sub-Boreal transition on the Northern Hemisphere : botanical evidence. In World Climate from 8000 to 0 B.C. Royal Met. Soc., London, pp.99-123.

Germain, R. and C. Evrard (1956). Étude écologique et phytosociologique de la forêt a Brachystegia laurentii. Publ. INEAC, Sér. Scient. 67.

Gitlow, A.L. (1947). Economics of the Mt Hagen Tribes, New Guinea. Augustin, New York.

Gittins, R.T. (1965a). Multivariate approaches to a limestone grassland community. I. A stand ordination. J. Ecol., 53, 385-401.

Gittins, R.T. (1965b). Multivariate approaches to a limestone grassland community. II. A direct species ordination. J. Ecol., 53, pp.403-409.

Gittins, R.T. (1965c) Multivariate approaches to a limestone grassland community. III. A comparative study of ordination and association analysis. J. Ecol., 53, pp.411-25.

Godwin, H. (1934). Pollen analysis. An outline of the problems and potentialities of the method. Part I. Technique and interpretation. New Phytol. 33, pp.278-305.

Godwin, H. (1944). Age and origin of the 'Breckland' heaths of East Anglia. Nature, 154, p.6.

Godwin, H. (1956). The History of the British Flora : A Factual Basis for Phytogeography. Cambridge Univ. Press.

Godwin, H. (1967). Pollen-analytic evidence for the cultivation of Cannabis in England. Rev. Palaeobot. Palynol., 4, pp.71-80.

Goodall, D.W. (1952). Quantitative aspects of plant distribution. Biol. Rev. 27, pp.194-245.

Goodall, D.W. (1953). Objective methods for the classification of vegetation. I. The use of positive interspecific correlation. Aust. J. Bot., 1, pp.39-63.

Goodall, D.W. (1954a). Minimal area : a new approach. 8th Int. Bot. Congr. Rapp. Commun. Sect. 7, pp.19-21.

Goodall, D.W. (1954b). Objective methods in the classification of vegetation. III. An essay in the use of factor analysis. Aust. J. Bot., 2, pp.303-24.

Goodall, D.W. (1961). Objective methods for the classification of vegetation. IV. Pattern and minimal area. Aust. J. Bot., 9, pp.162-96.

Gower, J.C. (1966). Some distance properties of latent root and vector methods used in multivariate analysis. Biometrika, 53, pp.325-38.

Gregory, P.H. (1961). The Microbiology of the Atmosphere. Leonard Hill, London.

Greig-Smith, P. (1952). Ecological observations on degraded and secondary forest in Trinidad, British West Indies. II. Structure of the communities. J. Ecol., 40, pp.316-30.

Greig-Smith, P. (1964). Quantitative Plant Ecology. Butterworths, London.

Greig-Smith, P. (1965). Notes on the quantitative description of humid tropical forest. In UNESCO Symposium on Ecological Research in Humid Tropics Vegetation, Kuching, Sarawak, 1963.

Greig-Smith, P., M.P. Austin and T.C. Whitmore (1967). The application of quantitative methods to vegetation survey. I. Association analysis and Principal component ordination of rain forest. J. Ecol., 55, pp.483-503.

Haantjens, H.A., J.A. Mabbutt and R. Pullen (1965). Environmental influences in the anthropogenic grasslands in the Sepik Plains, New Guinea. Pacific Viewpoint, 6, pp.215-9.

Haantjens, H.A., J.J. Reynders, W.L.P.J. Mouthaan and F.A. van Baren (1967). Major Soil Groups of New Guinea and their Distribution. Comm. No.55, Dept. Agric. Res., Royal Tropical Institute, Amsterdam.

Haantjens, H.A., E. Reiner, R.G. Robbins, J.R. McAlpine, J.C. Saunders (In press). Lands of the Goroka - Mt Hagen Area, Territory of Papua and New Guinea. CSIRO, Land Research Series.

Hansen, H.P. (1949). Pollen content of moss polsters in relation to forest composition. Amer. Midl. Nat., 42, pp.473-9.

Hanson, H.C. (1958). Principles concerned in the formation and classification of communities. Bot. Rev., 24, pp.65-125.

Hasel, A.A. (1938). Sampling error in timber surveys. Journ. Agr. Res. 57, pp.713-36.

Havinga, A.J. (1967). Palynology and pollen preservation. Rev. Palaeobot. Palynol., 2, pp.81-98.

Havinga, A.J. (1963). A palynological investigation of soil profiles developed in cover sand. Mededel. Landbouwhogeschool Wageningen, 63, pp.1-93.

Havinga, A.J. (1964). Investigation into the differential corrosion susceptibility of pollen and spores. Pollen et Spores, 6, pp.621-35.

Heim, R. (1950). Sur la foret de basse Cote d'Ivoire. Bull. Soc. Bot. Fr., 97, pp.162-7.

Helbaek, H. (1959). Domestication of food plants in the old world. Science, 130, pp.365-72.

Hewetson, C.E. (1955). A discussion on the 'climax' concept in relation to the tropical rain and deciduous forest. The Empire Forest. Rev., pp.274-91.

Heyligers, P.C. (1965). Vegetation and ecology of the Port Moresby - Kairuku area. Part VIII. pp.146-73, in Lands of the Port Moresby - Kairuku Area, Territory of Papua and New Guinea. CSIRO, Land Research Series. No.14.

Hitchcock, W.B. (1964). An introduction to the natural history of a New Guinea Highland community. The Emu, 63, pp.351-72.

Hole, F., K.V. Flannery and J. Neely (1965). Early agriculture and animal husbandry in Deh Luran, Iran. Curr. Anthrop., 6, pp.105-6.

Holmes, C.H. (1951). The grass, fern, and savannah lands of Ceylon, their nature and ecological significance. Imperial Forestry Institute, Paper No.28. Univ. of Oxford.

Hoogland, R.D. (1958). The alpine flora of Mt Wilhelm (New Guinea). Blumea, suppl. 4, 2, pp.220-38.

Hopkins, B. (1957). The concept of minimal area. J. Ecol., 45, pp.441-9.

Howells, W.W. (1943). The racial elements of Melanesia. Papers Peabody Mus., Amer. Archaeol. & Ethnol., 20, pp.38-49.

Iversen, J. (1949). The influence of prehistoric man on vegetation. Danm. Geol. Under., 4, 3, pp.1-25.

Iversen, J. (1952). Origin of the flora of western Greenland in the light of pollen analysis. Oikos, 4, pp.85-103.

Ivimey-Cook, R.B. and M.C.F. Proctor (1966). The application of association - analysis to phytosociology. J. Ecol., 54, pp.179-92.

Ivimey-Cook, R.B. and M.C.F. Proctor (1967). Factor analysis of data from an East Devon heath : A comparison of principal component and rotated solutions. J. Ecol., 55, pp.405-13.

Janssen, C.R. (1967). A comparison between the recent regional pollen rain and the subrecent vegetation in four major vegetation types in Minnesota (U.S.A.). Rev. Palaeobot. Palynol., 2, pp.331-42.

Janssen, C.R. (1967). A floristic study of forests and bog vegetation, Northwestern Minnesota. Ecology, 48, pp.751-65.

Jenkin, W. and J.C. Lowien (1963). Resource Survey, Western Highlands. Kuna River area. Unpubl. Dept. of Forests File No.90.14.14.

Jones, E.W. (1955). Ecological studies on the rain forest of southern Nigeria. IV. The plateau forest of the Okumu forest reserve. J. Ecol., 43, pp.564-94.

Jørgensen, S. (1963). Early postglacial in Aamosen. Geological and pollen-analytical investigations of Maglemosian settlements in the West-Zealand Bog Aamosen. Danm. Geol. Under. 11., 87, 2 vols.

Jørgensen, S. (1967). A method of absolute pollen counting. New Phytol. 66, pp.489-93.

Keleny, G.P. (1963). Notes on the origin and introduction of the basic food crops of the New Guinea people. In UNESCO Symposium on the Impact of Man on Humid Tropics Vegetation, Goroka, 1960, pp.76-85.

Kellman, M.C. (1967). Ecological studies on the secondary vegetation of a tropical montane habitat in Mindanao. Unpubl. Ph.D. Thesis, ANU, Canberra.

Kershaw, K.A. (1964). Quantitative and Dynamic Ecology. Arnold, London.

King, J.E. and R.O. Kapp (1963). Modern pollen rain studies in eastern Ontario. Canad. J. Bot., 41, 243-52.

Kirk, R.L. (1966). Population genetic studies in Australia and New Guinea. In P.T. Baker and J.S. Weiner, ed., The Biology of Human Adaptability. Clarendon Press, Oxford, pp.395-430.

Kirk, R.L. (1968). Genetic evidence and its implications for Aboriginal prehistory. Unpubl. Seminar paper, ANU, Canberra.

Komarek, E.V. (1964). The natural history of lightning. Tall Timbers Fire Ecol. Conf. 3, pp.139-83.

Kostermans, A.J.G.H. (1963). The influence of Man on the vegetation of the humid tropics. In UNESCO Symposium on the Impact of Man on Humid Tropics Vegetation, Goroka, 1960, pp.332-8.

Kowal, N.E. (1966). Shifting cultivation, fire and pine forests in the Cordillera Central, Luzon, Philippines. Ecol. Monogr. 36, pp.389-419.

Kreiger, A.D. (1964). Early man in the new world. In J.D. Jennings and E. Norbeck, ed. Prehistoric Man in the New World. Univ. Chicago Press, pp.23-81.

Lambert, J.M. and W.T. Williams (1962). Multivariate methods in plant ecology. IV. Nodal analysis. J. Ecol., 50, pp.775-802.

Lambert, J.M. and W.T. Williams (1966). Multivariate methods in plant ecology. VI. Comparison of information-analysis and association-analysis. J. Ecol., 54, pp.635-4.

Lane-Poole, C.E. (1925). The Forest Resources of the Territories of Papua and New Guinea. Report to the Parliament of the Commonwealth of Australia, 1925.

Lea, D.A.M. and P.G. Irwin (1967). New Guinea : the Territory and its People. Oxford Univ. Press, Melbourne.

Leahy, M.J. (1936). The central highlands of New Guinea. Geogr. Journ., 87, pp.229-62.

Lewis, D.M. (1962). Airborne pollen sampling and pollen rain. Pollen et Spores, 4, p.361.

Lewis, D.M. and E.C. Ogden (1965). Trapping methods for modern pollen rain studies. In B. Kummel and D. Raup, ed., Handbook of Paleontological Techniques. Freeman, San Francisco, pp.613-26.

Lichti-Federovich S. and J.C. Ritchie (1965). Contemporary pollen in central Canada. II. The forest-grassland transition in Manitoba. Pollen et Spores, 7, pp.63-87.

Lichtwardt, R.W. (1952). A new light-weight shaft for peat samplers. Palaeobot., 1, pp.317-8.

Lindsey, A.A., J.D. Barton and S.R. Miles (1958). Field efficiencies of forest sampling methods. Ecology, 39, pp.428-44.

Livingstone, D.A. (1967). Postglacial vegetation of the Ruwenzori Mountains in equatorial Africa. Ecol. Monogr., 37, pp.25-52.

Livingstone, D.A. (1968). Some interstadial and postglacial pollen diagrams from Eastern Canada. Ecol. Monogr., 38, pp.87-125.

McAdam, J.B. (1951). The forests of the Territory of Papua and New Guinea. Aust. Timb. Journ., 18, pp.674-705.

McAlpine, J.R. (In press). Climate of the Goroka - Mount Hagen area. Part IV in Haantjens et al, Lands of the Goroka - Mount Hagen area, Territory of Papua and New Guinea. CSIRO, Land Research Series.

McAndrews, J.H. (1966). Postglacial history of prairie, savanna, and forest in northwestern Minnesota. Mem. Torrey Bot. Club, 22, pp.1-72.

McIntosh, R.P. (1967). The continuum concept of vegetation. Bot. Rev., 33, pp.130-87.

McIntyre, G.A. (1953). Estimation of plant density using line transects. J. Ecol., 41, pp.319-30.

MacLennan, R., O. Kooptzoff and R.J. Walsh (1959). A survey of the blood groups and haemoglobin values of natives of the Mt Hagen area, New Guinea. Oceania, 30, pp.313-20.

Macintosh, N.W.G., R.J. Walsh and O. Kooptzoff (1958). The blood groups of the native inhabitants of the Western Highlands, New Guinea. Oceania, 28, pp.173-98.

Macintosh, N.W.G. (1959). A preliminary note on skin colour in the Western Highland natives of New Guinea. Oceania, 30, pp.279-93.

Macneish, R.S. (1964a). Ancient mesoamerican civilization. Science, 143, pp.531-7.

McVean, D.N. (1968). A year of weather records at 3480m on Mt Wilhelm, New Guinea. Weather, 23, pp.377-81.

McVean, D.N. and D.A. Ratcliffe (1962). Plant communities of the Scottish Highlands. London.

Maher, L.H. (1963). Pollen analyses of surface materials from the southern San Juan Mountains, Colorado. Bull. Geol. Soc. Amer., 74, pp.1485-1504.

Maher, L.H. (1964). Ephedra pollen in sediments of the Great Lakes region. Ecology, 45, pp.391-5.

Mangelsdorf, P.C., R.S. Macneish and W.C. Galinat (1964). Domestication of Corn. Science, 143, pp.538-45.

Mangenot, G. (1950a). Les forets de la Cote d'Ivoire. Bull. Soc. Bot. Fr., 97, pp.156-7.

Mangenot, G. (1950b). Essai sur les forets de la Cote d'Ivoire. Bull. Soc. Bot. Fr., 97, pp.159-62.

Mark, A.F. (1963). Vegetation studies on Secretary Island, Fiordland. Part 3 : The altitudinal gradient in forest composition, structure and regeneration. N.Z. Journ. Bot., 1, pp.188-202.

Mark, A.F., G.A.M. Scott, F.R. Sanderson and P.W. James (1964). Forest succession on landslides above Lake Thomson, Fiordland. N.Z. Journ. Bot., 2 pp.60-89.

Martin, P.S. (1963). The Last 10,000 Years : A Fossil Pollen Record of the American Southwest. Univ. Arizona Press, Tucson.

Mehringer, P.J. (1965). Late pleistocene vegetation in the Mohave Desert of Southern Nevada. Arizona Acad. Sci. Journ., 3, pp.172-88.

Michelmore, A.P.G. (1939). Observations on tropical African grasslands. J. Ecol., 27, pp.282-312.

Morrison, M.E.S. (1959). Evidence and interpretation of 'Landnam' in the North-East of Ireland. Botaniska Notiser, 112, pp.185-204.

Morrison, M.E.S. (1966). Low-latitude vegetation history with special reference to Africa. In World Climate from 8000 to 0 B.C. Royal Met. Soc., London, pp.142-8.

Morrison, M.E.S. (1968). Vegetation and climate in the uplands of South-Western Uganda during the Late Pleistocene Period. I. Muchoya Swamp, Kigezi District. J. Ecol., 56, pp.363-84.

Mosimann, J.E. (1965). Statistical methods for the pollen analyst : multinomial and negative multinomial techniques. In B. Kummel and D. Raup, ed., Handbook of Palaeontological Techniques. Freeman, San Francisco, pp.636-73.

Nichols, H. (1967). Central Canadian palynology and its relevance to Northwestern Europe in the Late Quaternary period. Rev. Palaeobot. Palynol., 2, pp.231-43.

Nilles, J. (1942-45). Digging sticks, spades, hoes, axes, and adzes of the Kuman people in the Bismarck Mountains of East-Central New Guinea. Anthropos, 37-40, pp.205-12.

Noakes, J.C. (1939). Geological report on the Chimbu-Hagen area, Territory of New Guinea. Unpubl.

Oba, T. and C.S. Chard (1963). New Dates for early Pottery in Japan. Asian Perspect., 6, pp.75-6.

Oldfield, F. (1963). Pollen-analysis and Man's role in the ecological history of the South-East Lake District. Geogr. Ann., 45, pp.23-40.

Orloci, L. (1966). Geometric models in Ecology I. The theory and application of some ordination methods. J. Ecol., 54, pp.193-215.

Orloci, L. (1967). An agglomerative method for classification of plant communities. J. Ecol., 55, pp.193-205.

Parsons, J.J. and W.M. Denevan (1967). Pre-Columbian ridged fields. Scient. Amer., 217, pp.93-100.

Pechance, J.F. and G. Stewart (1940). Sage-brush-grass range sampling studies : size and structure of sampling unit. Amer. Soc. Agron. Journ., 32, pp.669-82.

Pelzer, K.J. (1945). Pioneer settlement in the Asiatic tropics. Amer. Geogr. Soc. Spec. Publ. No.29 New York.

Pelzer, K.J. (1958). Land utilization in the humid tropics : agriculture. Proc. 9th Pac. Sci. Cong., 20, pp.124-43.

Pennington, W. (1964). Pollen analyses from the deposits of six upland tarns in the Lake District. Phil. Trans. Roy. Soc. London, B., 248, pp.205-44.

Pennington, W. (1965). The interpretation of some Post-Glacial vegetation diversities at different Lake District sites. Proc. Roy. Soc. B., 161, pp.310-23.

Pielou, E.C. (1959). The use of point-to-plant distances in the study of the pattern of plant populations. J. Ecol., 47, pp.607-13.

Pielou, E.C. (1960). A single mechanism to account for regular, random and aggregated populations. J. Ecol., 48, pp.575-84.

Poore, M.E.D. (1955a). The use of phytosociological methods in ecological investigations. I. The Braun-Blanquet system. J. Ecol., 43, pp.226-44.

Poore, M.E.D. (1955b). The use of phytosociological methods in ecological investigations. II. Practical issues involved in an attempt to apply the Braun-Blanquet system. J. Ecol., 43, pp.245-69.

Poore, M.E.D. (1955c). The use of phytosociological methods in ecological investigations. III, Practical applications. J. Ecol., 43, pp.606-51.

Poore, M.E.D. (1956). The use of phytosociological methods in ecological investigations. IV. General discussion of phytosociological problems. J. Ecol., 44, pp.28-50.

Poore, M.E.D. (1962). The method of successive approximation in descriptive ecology. Adv. in Ecol. Res., 1, 35-68.

Poore, M.E.D. (1964). Integration in the plant community. J. Ecol., 52 (Suppl.), pp.213-26.

Poore, M.E.D. (1968). Studies in Malaysian rain forest : The forest on Triassic sediments in Jengka Forest Reserve. J. Ecol., 56, pp.143-96.

Popenoe, H. (1959). The influence of shifting cultivation cycle on soil properties in Central America. Proc. 9th Pac. Sci. Cong., 7, pp.72-7.

Potter, L.D. and J. Rowley (1960). Pollen rain and vegetation, San Augustin Plains, New Mexico. Bot. Gaz. 122, pp.1-25.

Potzger, J.E., A. Courtemanche, B.M. Sylvio and F.M. Heuber (1957). Pollen from moss polsters on the mat of Lac Shaw Bog, Quebec, correlated with a forest survey. Canad. J. Bot., 13, pp.24-35.

Procter, M.C.F. and C. Lambert (1961). Pollen spectra from recent Helianthemum communities. New Phytol., 60, pp.21-6.

Ranson, J.F. and E.B. Leopold (1962). The standard rain gauge as an efficient sampler of air-borne pollen and spores. Pollen et Spores, 4, p.373.

Read, K.E. (1954). Cultures of the Central Highlands, New Guinea. Southwest. J. Anthrop., 10, pp.1-43.

Reay, M. (1959). The Kuma. Freedom and Conformity in the New Guinea Highlands. Melbourne Univ. Press.

Reiner, R. (1960). The glaciation of Mt Wilhelm, Australian New Guinea. Geogr. Rev., 50, pp.491-503.

Richards, P.W. (1952). The Tropical Rainforest. An Ecological Study. Cambridge Univ. Press.

Richards, P.W. (1958). The concept of the climax as applied to tropical vegetation. In UNESCO Symposium on the Study of Tropical Vegetation, Ceylon, 1956, pp.207-8.

Richards, P.W. (1963). What the tropics can contribute to ecology. J. Ecol., 51, pp.231-41.

Richardson, W.D. (1963). Observations on the vegetation and ecology of the Aripo savannas, Trinidad. J. Ecol., 51, pp.295-313.

Rickwood, F.K. (1955). The geology of the Western Highlands of New Guinea. J. Geol. Soc. Aust., 2, pp.63-82.

Ritchie, J.C. and S. Lichti-Federovich (1963). Contemporary pollen spectra in Central Canada. I. Atmospheric samples at Winnipeg, Manitoba. Pollen et Spores, 5, pp.95-114.

Ritchie, J.C. and S. Lichti-Federovich (1967). Pollen dispersal phenomena in Artic-Subarctic Canada. Rev. Palaeobot. Palynol. 3, pp.255-66.

Robbins, R.G. (1958). Part IV. Vegetation. In Lands of the Goroka-Mount Hagen area, New Guinea. Unpubl. CSIRO, Divs. of Land Research and Regional Survey. Report No. 58/1.

Robbins, R.G. (1960). Montane formations in the Central Highlands of New Guinea. In UNESCO Symposium on Humid Tropics Vegetation, Tjiawi, 1958, pp.176-95.

Robbins, R.G. (1963a). The anthropogenic grasslands of Papua and New Guinea. In UNESCO Symposium on the Impact of Man on the Humid Tropics Vegetation, Goroka, 1960, pp.313-29.

Robbins, R.G. (1963b). Correlations of plant patterns and population migration into the Australian New Guinea Highlands. In J. Barrau, ed. Plants and the Migrations of Pacific Peoples. Bishop Museum Press, pp.45-59.

Robbins, R.G. (1968). Vegetation of the Wewak-Lower Sepik Area. In Lands of the Wewak-Lower Sepik Area, Territory of Papua and New Guinea. CSIRO, Land Research Series No.22, Part IV, pp.109-24.

Robbins, R.G. (In press). Part VII. Vegetation. In Lands of the Goroka-Mount Hagen area, Territory of Papua and New Guinea. CSIRO, Land Research Series.

Robbins, R.G. and R. Pullen (1965). Vegetation of the Wabag - Tari area. In Lands of the Wabag-Tari area, Papua - New Guinea. CSIRO, Land Research Series No.15, Part VII, pp.100-15.

Ross, R. (1954). Ecological studies on the rain forest of Southern Nigeria. III. Secondary succession in the Shasha Forest Reserve. J. Ecol., 42, pp.259-82.

Ross, W. (1936). Ethnological notes on the Mount Hagen Tribes (Mandated Territory of New Guinea). Anthropos, 31, pp.341-63.

Rowley, J.R. and J. Rowley (1956). Vertical migration of spherical and aspherical pollen in a Sphagnum bog. Proceed. Minn. Acad. Sci., 24, pp.28-30.

Rutherford, G.K. and R.A. Perry (1965). Land use capability of the Wabag-Tari area. Part X. In Lands of the Wabag-Tari area, Papua-New Guinea. CSIRO, Land Research Series No.15.

Sangster, A.G. and H.M. Dale (1961). A preliminary study of differential pollen grain preservation. Canad. J. Bot., 39, pp.35-43.

Sangster, A.G. and H.M. Dale (1964). Pollen grain preservation : underrepresented species in fossil spectra. Canad. J. Bot., 42, pp.437-49.

Saunders, J.C. (1965). Forest resources of the Wabag-Tari area. In Lands of the Wabag-Tari area, Papua-New Guinea. CSIRO, Land Research Series No.15, Part VIII, pp.116-24.

Saunders, J.C. (In press). Forest resources of the Goroka - Mount Hagen area. In Lands of the Goroka - Mount Hagen area, Territory of Papua and New Guinea. CSIRO, Land Research Series, Part VIII.

Schulz, J.P. (1960). Ecological Studies on Rain Forest in Northern Suriname. Verhandelingen der Koninklijke Nederlandse Akademie van Wetenschappen, Afd. Natuurkunde. Tweede Reeks, Deel LIII. No.1.

Serpenti, L.M. (1965). Cultivators in the Swamps. Assen, Van Gorcum.

Shanks, R.E. (1954). Plotless sampling trials in Appalachian forest types. Ecology, 35, pp.237-44.

Simmonds, N.W. (1962). The Evolution of the Bananas. Longmans, London.

Smith, A.G. (1970). The influence of Mesolithic and Neolithic man on British vegetation : a discussion. In D. Walker and R.G. West, ed., Studies in the Vegetational History of the British Isles. Cambridge Univ. Press, pp.81-96.

Spencer, J.E. (1966). Shifting cultivation in Southeastern Asia. Univ. California Publ. in Geog. Vol.19. Berkeley.

Spinks, K.L. (1936). The Wahgi river valley of Central New Guinea. Geogr. Journ., 87, pp.222-5.

Stamp, L.D. (1964). Africa : a Study in Tropical Development. Wiley, New York.

Stewart, O.C. (1956). Fire as the first great force employed by Man. In W.L. Thomas, ed., Man's Role in Changing the Face of the Earth, Univ. of Chicago Press, pp.115-133.

Strathern, M. (1969). Why is the Pueraria a Sweet Potato? Ethnology, 8, pp.189-98.

Tauber, H. (1965). Differential pollen dispersion and the interpretation of pollen diagrams. Danm. Geol. Unders. 2, 89, 69pp.

Tauber, H. (1967a). Investigations of the mode of pollen transfer in forested areas. Rev. Palaeobot. Palynol., 3, pp.277-86.

Tauber, H. (1967b). Differential pollen dispersion and filtration. In E.J. Cushing and H.E. Wright, ed. Quaternary Paleoecology. Yale Univ. Press, New Haven, pp.132-41.

Taylor, B.W. (1957). Plant succession on recent volcanoes in Papua. J. Ecol., 45, pp.233-43.

Taylor, B.W. (1964a). Vegetation of the Buna-Kokoda area. In General Report on Lands of the Buna-Kokoda Area, Territory of Papua and New Guinea. CSIRO, Land Research Series. No.10, Part VIII, pp.89-98.

Taylor, B.W. (1964b). Vegetation of the Wanigela - Cape Vogel area. In General Report on Lands of the Wanigela - Cape Vogel Area, Territory of Papua and New Guinea. CSIRO, Land Research Series. No.12. Part VII, pp.69-83.

Terasmae, J. and R.J. Mott (1964). Pollen deposition in lakes and bogs near Ottawa, Canada. Canad. J. Bot., 42, pp.1355-63.

Terasmae, J. and R.J. Mott (1965). Modern pollen deposition in the Nichicun Lake area, Quebec. Canad. J. Bot., 43, pp.393-404.

Thomas, K.W. (1964). A new design for a peat sampler. New Phytol., 63, pp.422-5.

Thompson, J.E. (1967). A geological history of Eastern New Guinea. Aust. Petrol. Explor. Assoc. Journ., 7, pp.83-93.

Thompson J.E. and N.H. Fisher (1965). Mineral deposits of New Guinea and Papua, and their tectonic setting. Unpubl. Bur. Min. Resour., Geol & Geophys, Records. 1965/10.

Troels - Smith, J. (1955). Characterization of Unconsolidated Sediments. Geol. Surv. Danm. IV, 3, No.10.

Troels - Smith, J. (1960). Ivy, mistletoe and elm. Climatic indicators - fodder plants. Danm. Geol Unders. 4, pp.1-32.

Tsukada, M. (1958). Untersuchungen uber das verhaltnis zwishen dem Pollengehalt der Oberflachenproben und der Vegetation des Hochlandes Shiga. Osaka City Univ. Inst. Polytechn. Journ., 9, pp.217-34.

Tsukada, M. (1966a). Late Pleistocene vegetation and climate in Taiwan (Formosa). Proc. Nat. Acad. Sci., 55, pp.543-48.

Tsukada, M. (1966b). Late Postglacial absolute pollen diagram in Lake Nojiri. The Bot. Mag., 79, pp.179-84. Tokyo.

Tsukada, M. (1967). Vegetation in subtropical Formosa during the Pleistocene glaciations and the Holocene. Palaeo-Geog, -Clim., -Ecol., 3, pp.49-64.

Tsukada, M. and E.S. Deevey (1967). Pollen analyses from four Lakes in the Southern Maya area of Guatemala and El Salvador. In E.J. Cushing and H.E. Wright, ed., Quaternary Paleoecology. Yale Univ. Press, New Haven, pp.303-31.

Tsukada, M. and M. Stuiver (1966). Man's influence on vegetation in Central Japan. Pollen et Spores, 8, pp.309-13.

Turner, J. (1964). Surface sample analysis from Ayrshire, Scotland. Pollen et Spores, 6, pp.583-92.

Turner, J. (1965). A contribution to the history of forest clearance. Proc. Roy. Soc. B., 161, pp.343-54.

Turner, J. (1970). Post-Neolithic disturbance of British vegetation. In D. Walker and R.G. West, eds, Studies in the Vegetational History of the British Isles. Cambridge University Press, pp.97-116.

United States Department of Agriculture (1951). Soil Survey Manual. U.S.D.A. Agric. Handbook No.18.

Vallentyne, J.R. (1955). A modification of the Livingstone piston sampler for lake deposits. Ecology, 36, pp.139-41.

Van der Hammen, T. (1961). The Quaternary climatic changes of Northern South America. New York Acad. Sci., 95, pp.676-83.

Van der Hammen, T. and E. Gonzalez (1960a). Upper Pleistocene and Holocene climate and vegetation of the 'Sabana de Bogota' (Columbia, S. America). Leidse Geol. Meded., 25, pp.261-315.

Van der Hammen, T. and E. Gonzalez (1960b). Holocene and late-glacial climate and vegetation of Paramo de Palacio (eastern Cordillera, Columbia, S. America). Geol. en Mijnb., 39, pp.737-87.

Van Steenis, C.G.G.J. (1958). Basic principles of rain forest sociology. In UNESCO Symposium on the Study of Tropical Vegetation, Ceylon, 1956, pp.159-63.

Van Zeist, W. (1967). Late Quaternary vegetation history of Western Iran. Rev. Palaeobot. Palynol., 2, pp.301-11.

Van Zeist, W. and H.E. Wright (1963). Preliminary pollen studies at Lake Zeribar, Zagros Mountains, Southwestern Iran. Science, 140, pp.65-7.

Van Zinderen Bakker, E.M. (1962a). Botanical evidence for Quaternary climates in Africa. Ann. Cape Prov. Mus. II. South Africa.

Van Zinderen Bakker, E.M. (1962b). A late -glacial and post-glacial climatic correlation between East Africa and Europe. Nature, 194, pp.201-3.

Van Zinderen Bakker, E.M. (1963). Palaeobotanical studies. S. African Journ. Sci. 59, pp.332-40.

Van Zinderen Bakker, E.M. (1966). The pluvial theory - an evaluation in the light of new evidence, especially for Africa. Palaeobot., 15, pp.128-34.

Van Zinderen Bakker, E.M. (1967). Upper Pleistocene and Holocene stratigraphy and ecology on the basis of vegetation changes in sub-saharan Africa. In W.W. Bishop and J.D. Clark, eds, Background to Evolution in Africa. Univ. of Chicago Press.

Van Zinderen Bakker, E.M. and J.D. Clark (1962). Pleistocene climates and cultures in North-Eastern Angola. Nature, 196, 639-42.

Vicedom, G.F. and H. Tischner (1943-48). Die Mbowamb. Die kultur der Hagenberg-stamme im Ostlichen Zentral-Neuguinea. Monographien zur Volkerkunde NR.1. Cram, de Gruyter, Hamburg.

Von Post, L. (1946). The prospect for pollen analysis in the study of the Earth's climatic history. New Phytol., 45, pp.193-217.

Waddell, E.W. (1968). The dynamics of a New Guinea highlands agricultural system. Unpubl. Ph.D. Thesis, ANU, Canberra.

Wade, L.K. (1968). The alpine and subalpine vegetation of Mt Wilhelm, New Guinea. Unpubl. Ph.D. Thesis, ANU, Canberra.

Walker, D. (1964). A modified Vallentyne mud sampler. Ecology, 45, pp.642-4.

Walker, D. (1966a). Vegetation of the Lake Ipea region, New Guinea Highlands. I. Forest, grassland, and garden. J. Ecol., 54, pp.503-33.

Walker, D. (1966b). The Late Quaternary history of the Cumberland Lowland. Phil. Trans. Roy. Soc. London, Ser. B. 251, pp.1-210.

Walker, D. (1968). A reconnaissance of the non-arboreal vegetation of the Pindaunde Catchment, Mount Wilhelm, New Guinea. J. Ecol., 56, pp.445-66.

Walker, D., P. Milne, J. Guppy and J. Williams (1968). The computer assisted storage and retrieval of pollen morphological data. Pollen et Spores, 10, pp.251-62.

Warner, J.N. (1962). Sugar cane : An indigenous Papuan cultigen. Ethnology, 1, pp.405-11.

Watson, J.B. (1964). A previously unreported root crop from the New Guinea Highlands. Ethnology, 3, pp.1-5.

Watson, J.B. (1965a). From hunting to horticulture in the New Guinea Highlands. Ethnology, 4, pp.295-309.

Watson, J.B. (1965b). The significance of a recent ecological change in the Central Highlands of New Guinea. Journ. Polynes. Soc., 74, pp.438-50.

Watson, J.B. (1968). Pueraria : Names and traditions of a lesser crop of the central Highlands, New Guinea. Ethnology, 7, pp.268-79.

Watters, R.F. (1960). The nature of shifting cultivation : a review of recent research. Pacific Viewpoint, 1, pp.59-99.

Webb, L.J., J.G. Tracey, W.T. Williams, and G.N. Lance (1967a). Studies in the numerical analysis of complex rain-forest communities. I. A comparison of methods applicable to site/species data. J. Ecol., 55, pp.171-91.

Webb, L.J., J.G. Tracey, W.T. Williams and G.N. Lance (1967b). Studies in the numerical analysis of complex rain-forest communities. II. The problem of species-sampling. J. Ecol., 55, pp.525-38.

White, C. (1967). Plateau and Plain: prehistoric investigations in Arnhem Land, Northern Territory. Unpubl. Ph.D. Thesis, ANU, Canberra.

White, J.P. (1967). Taim bilong bipo : Investigations towards a prehistory of the Papua-New Guinea Highlands. Unpubl. Ph.D. Thesis, ANU, Canberra.

Whittaker, R.H. (1962). Classification of natural communities. Bot. Rev., 28, pp.1-239.

Whittaker, R.H. (1967). Gradient analysis of vegetation. Biol. Rev., 42, pp.207-64.

Williams, F.E. (1937). The natives of Mount Hagen, Papua : further notes. Man, 37, pp.90-6.

Williams, W.T. (1963). Computers as botanists. Nature, 197, pp.1047-9.

Williams, W.T. and J.M. Lambert (1959). Multivariate methods in plant ecology. I. Association analysis in plant communities. J. Ecol., 47, pp.83-101.

Williams, W.T. and J.M. Lambert (1960). Multivariate analysis in plant ecology. II. The use of an electronic digital computer for association analysis. J. Ecol., 48, pp.689-710.

Williams, W.T. and J.M. Lambert (1961). Multivariate methods in plant ecology. III. Inverse association analysis. J. Ecol., 49, pp.717-29.

Williams, W.T., J.M. Lambert and G.N. Lance (1966). Multivariate methods in plant ecology. V. Similarity analyses and Information analysis. J. Ecol., 54, pp.427-445.

Wodehouse, R.P. (1935). Pollen grains. McGraw-Hill, London.

Womersley, J.S. and J.B. McAdam (1957). The forests and forest conditions in the Territories of Papua and New Guinea. Govt. Printer, Port Moresby.

Woodin, H.E. and A.A. Lindsey (1954). Juniper-Pinyon east of the Continental Divide, as analysed by the line-strip method. Ecology, 35, pp.473-89.

Wright, H.E. (1967). The use of surface samples in Quaternary pollen analysis. Rev. Palaeobot. Palynol., 2, pp.321-30.

Wright, H.E. and H.L. Patten (1963). The pollen sum. Pollen et Spores, 5, pp.445-50.

Wright, H.E., J.H. McAndrews and W. van Zeist (1967). Modern pollen rain in Western Iran and its relation to plant geography and Quaternary vegetational history. J. Ecol., 55, pp.415-43.

Wurm, S.A. (1964). Australian New Guinea Highlands languages and the distribution of their typological features. Amer. Anthrop. 66, 2, pp.77-97.

Wurm, S.A. (1966). Language and agriculture in New Guinea. New Scient., 31, pp.216-8.

Yen, D.E. (1963). Sweet potato variation and its relation to human migration in the Pacific. In J. Barrau, ed., Plants and the Migrations of Pacific Peoples. Bishop Museum Press.

APPENDIX 1

THE FIELD ECOLOGICAL DATA

The following tables give the field ecological data in the order:

ANU No.	Family	Genus/Species	Mt Hagen Mixed Forest 3345m No. Individuals per plot 21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Mt Hagen Mixed Forest 3040m No. Individuals per plot 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6262	Aquifoliaceae	Ilex sp.3	22	8	11	20	11	4	15	11	8	9	8	4	8	6	5	7	13	5	8	13																				
6320	Aquifoliaceae	Ilex sp.1																																								
6351	Asteraceae	Olearia sp.3																					1	1		8																
6327	Antherospermaceae	Dryadodaphne sp.																																								
6325	Clusiaceae	Garcinia sp.3																																								
6248	Cunoniaceae	Schizomeria serrata																					1	2	4	5	4	3	12	15	7	23	20	20	15	6	12	25	8	12	9	15
6283	Cunoniaceae	Spiraeopsis brassii																																							2	
6278	Cunoniaceae	Weinmannia sp.																																								
6410	Elaeocarpaceae	Elaeocarpus crenulatus	6	9	9	6	12	8	6	15	9	3	6	5	12	9	8	11	7	11	10	14	5		3		5	5	5			1	2		6		6	7	6	8		16
6425	Elaeocarpaceae	Elaeocarpus ?sayeri																					16	14	10	11	10	4	10		7	20	20	14	13	11	8	7	12	13	1	14
6247	Elaeocarpaceae	Elaeocarpus sp.1																						1	1		5	1	15	14	3	12	32	2	2	6	14		11	10	7	7
6431	Elaeocarpaceae	Sericolea sp.	4	2	4	8	5	9	10	2	[illegible]	1	7	6	2	3	10	13	11	3		8		3	9	4		9	9	6	11	18	14	8	8	8	16	12	10	5	8	12
6317	Elaeocarpaceae	Sloanea sp.2+sp.3																																								
6356	Ericaceae	Vaccinium apiculatum	1	1		8		4	1	5	4	4	2	5		4					2		8	5	1	5	3	8	19	4	16	19	20	12	18	10	14	19	17	19	9	12
6255	Escalloniaceae	Polyosma sp.	24	3	17	35	10	14	12	17	14	7	12	23	17	19	14	23	9	16	17	17					22		7	13	10	14	41	16	13	3	13	10	18	13	11	12
6360	Escalloniaceae	Quintinia sp.	5	7	15	8	5	9	8	12	7	12	13	8		7	10	6	6	11	8	22	9	3	11	9		4	21	16	14	17	19	9	14	12	5	6	14	8	12	12
6439	Euphorbiaceae	Macaranga ?womersleyi																																								
6334	Euphorbiaceae	Omalanthus nervosus																																								
6251	Euphorbiaceae	Omalanthus sp.1																						1		2	3		2	1	1					1	1					
6294	Fagaceae	Nothofagus sp.2																																								
6311	Flacourtiaceae	Casearia sp.																																								
6426	Lauraceae	Cryptocarya sp.1																					10	4	4	1	7	1	32	85	13	34	40	24	42	54	12	22	14	30	20	30
6333	Lauraceae	Endiandra sp.2																																								
6246	Lauraceae																								2	6			2		1							4	2			
6244	Melastomataceae	Astronia sp.1																						4	17			5	19	2	14	24	3	2								2
6421	Monimiaceae	Kibara sp.3																					3	22	17	8	5	12	14	5	15	15	29	8	2	3	10	13	18	7	3	11
6440	Moraceae	Ficus endochaete																																								
6441	Myrsinaceae	?Ardisia sp.		13	25	4	25	13	9	7	29	17	26	15	9	18	18	24	27	20	12	14																				
6265	Myrsinaceae	Rapanea sp.2			17		14						8	6	5	3	9	10	8	15	6	5																				
6354	Myrsinaceae	Rapanea sp.3	30	10	6	25	13	7	9	11	14	23	14	16	1	7	12	19	27	20	12	9														1		3		4	7	
6254	Myrtaceae	Syzygium adelphicum	56	18	7	11	7	6	7	12	8	15	8	12	9	9	6	12	14	12	17	12	1	2	3	5	2		17	8	19	19	31	14	14	14	10	15	13	10	14	16
6285	Myrtaceae	Syzygium sp.2	48	18	7	3	2	3	2	10	8	9	1	1	1	7			3			3																				
6314	Myrtaceae	Syzygium sp.5																																								
6380	Ochnaceae	Schuurmansia henningsii									1												11	6	8	5	6	4	16	18	15	16	11	17	14	7	32	23	23	13	10	12
6397	Pittosporaceae	Pittosporum pullifolium	12	5	6	1		2	5	3	7	4	3	1				4		2	2										4	10	2								1	5
6284	Rosaceae	Prunus costata																																								
6272	Rosaceae	Prunus pullei							1							1		4	5	7	4																					
6249	Rubiaceae	Timonius belensis	4		2		1	1			1	2	1			1							12	1	6	5	6		9	1	14	11	7	8	18	8	1	5	9	6	16	3
6430	Rutaceae	Acronychia sp.2																					5	2	2	6	4		6	15	14	7	33	7	4	6	3	5	8	8	14	7
6486	Rutaceae	Evodia sp.1																																								
6381	Saurauiaceae	Saurauia sp.1	4	8	7	12	2	7	6	22	8	7	7	17	23	10	6	4	2	3	1	2						2		8	11		2			5	2	4		6		1
6277	Staphyleaceae	Turpinia pentandra																																								
6420	Symplocaceae	Symplocos sp.3	46	4	19	13	10	20	15	6	5	6	4	15	16	7	10	10	13	14	12	6	3	5	26	10	6	29	11	22	9	5	26	14	12		10	8	23	12	9	10
6414	Theaceae	Eurya oxysepala	25	7	6	4	11	5	10	9	13	15	6	8	4	7	4	3	2	8	14	11									5				5		1	4	3	4		

			Mt Hagen Mixed Forest 3345m No. Individuals per plot																				Mt Hagen Mixed Forest 3040m No. Individuals per plot																			
ANU No.	Family	Genus/Species	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6374	Winteraceae	Drimys sp.3	21	16	26	34	16	10	14	12	11	12	11	13	11	10	15	12	13	14	11	11	2		1	6	2	7	9		1	8	5	2	5	8	7	2	8	9	11	4
6392	Winteraceae	Drimys sp.4	10	6	5	7	12	2	15	12	5	7	4	2	7	7	7	8	14	14	3	3				9				9	1	15	8	6	7	4	4	8	10	6	3	6
	Pandanaceae	"1/m"																																								
6259	Podocarpaceae	Podocarpus neriifolius	3	6	2	5	1	2	1	10	10	2	2	2		6	9	3		3	10	4										4				1		1			1	
6438	Apocynaceae	Alstonia sp.																																								
6280	Aquifoliaceae	Sphenostemon papuanum																																								
6370	Araliaceae	Harmsiopanax sp.			2	1	2		1	3				2	2	12	4	2	2							5		2	10	4	2	5					1					
6339	Araliaceae	Polyscias sp.																																								
6352	Araliaceae	Schefflera sp.1	19	7	20	6	18	20	11	18	26	28	18	8	8	14	5	15	10	4	7	6	1		4	4		1	4	2	3	4	4	3	1	12	11	12	1	5	16	7
6419	Asteraceae	Olearia sp.1	4	31			17	3	4	4		8	1					7	3																							
6357	Asteraceae	?Senecio sp.					2			1			7									1				1				1												
6281	Chloranthaceae	Ascarina philippinensis																																								
6348	Elaeocarpaceae	Elaeocarpus poculiferus																																								
6332	Elaeocarpaceae	Elaeocarpus sp.2																																								
6267	Epacridaceae	Trochocarpa papuana			4	10		16	12		6	3																														
6424	Escalloniaceae	Polyosma sp.1	1		2	7	3	3	6	8	10	10	3	6	4	13	5	6	8	3	1	2	1	3	1	6	4	2	6	1	20	5	17	10	14	11	14	10	7	9	12	8
6429	Euphorbiaceae	Claoxylon nubicola																					1		4				4		10	8			11	4	2	2				
6322	Euphorbiaceae	Glochidion sp.4																																								
6171	Euphorbiaceae	Macaranga pleiostemona																																								
5530	Euphorbiaceae	Macaranga ?warburgiana																												2		1										
6282	Euphorbiaceae	Phyllanthus nervosus																																								
6335	Euphorbiaceae																																									
6253	Gesneriaceae	Cyrtandra sp.1																									16	17			21		15					8				
6337	Himantandraceae	Galbulimima belgraveana																																								
6279	Lauraceae	Cinnamomum sp.2																																								
6326	Loganiaceae	Geniostema sp.																																								
6245	Monimiaceae	Kibara sp.2																							2					13												
5737	Moraceae	Ficus dammaropsis																																								
6342	Moraceae	Ficus tonsa																																								
6427	Moraceae	Streblus urophyllus																					14	12	1	9	5		10	13	7	11	12	8	14	12	10	10	12	8	6	14
6293	Myrsinaceae	Maesa sp.																																								
6319	Myrsinaceae	Discocalyx sp.																																								
6345	Myrtaceae	Xanthomyrtus sp.																																								
6415	Piperaceae	Piper sp.5							2	2		2																														
6315	Piperaceae	Piper sp.9																																								
6269	Proteaceae	Finschia sp.																																								
6434	Rhamnaceae	Alphitonia incana																																								
6428	Rubiaceae	Amaracarpus sp.1																					25	87	68	70	•	•	•	10	•	•	•	16	23			•	30	•	13	24
6377	Rubiaceae	Amaracarpus sp.3			11	•	34	72	34	23	17		•	43	•	•	•	•	•	•	62	•	62		33	34	22	22	67	23	18	52	52	18	42	25	26	23	27	29	34	27
6365	Rubiaceae	Coprosma papuensis									12	62	10	15	23	19	10	27	5	22	8	32																				
6436	Rubiaceae	Timonius sp.1																																								
6432	Rutaceae	Evodia sp.2																						2		33												2				
6258	Rutaceae	Evodia sp.5		2	2		4		2	4	1	3		5	6	6	4	6	6	2	9	7		2	1		4			4	3	10	8	1	2	2	6	6	10	4	6	6
6435	Rutaceae	Evodiella sp.																																								

Mt Hagen
Mixed Forest
3345m
No. Individuals Per Plot

ANU No.	Family	Genus & Species	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
3433	Thymelaeaceae	Phaleria ?nogeronsis																				
6270	Winteraceae	Drimys sp. 2	18	6	20	17	12	12	41	38	19	20	24	32	2	23	12	25	32	22	24	32
6376	Ericaceae	Dimorphanthera denticulifera	1	17	12	6	17	22	20	13	30	•	22	4	5	22	7	15	9	8	15	10
6268	Ericaceae	Diplycosia sp.	2		24	4	2	5	•	4	29	4	•	4						5	10	20
6264	Loranthaceae	4	1				3		1		1	7	2		1					5	7	5
6271	Monimiaceae	Palmeria sp. 3																				
6408	Piperaceae	Piper sp. 1	18	39	32	16	30	40	31	62	24	14	25	32	24	56	37	29	17	30	27	27
5573	Rosaceae	Rubus moluccanus	10	14	10	4	13	35	15	34	11	12	17	32	32	42	24	27	21	20	24	39
6261	Poaceae	Nastus productus																				
6082	Asteraceae	Blumea arnakidophora					2						7									1
6393	Rosaceae	Potentilla sp. 1	10	2		2	22	8	10				2	4	32	2	1	7		4	4	30
6366	Scrophulariaceae	Hebe ?albiflora	15	2	•	9	•	•	10	20	14	•	14	12	13	4		10	8	15	10	20
6422	Urticaceae	Cypholophus sp.																				
6375	Urticaceae	Elatostema sp. 1			-	4	4	20	6	•	19	10			10	24	•	12	•	•	•	•
6423	Urticaceae	Elatostema sp. 3			•	•	12	20	10	15	5	•			10							
6394	Poaceae	Deyeuxia brassii		•	3	1	19	2	9	6	•	•			1	1	19	7	6	5	22	34
6368	Zingiberaceae	Alpinia sp. 3	14	25	20	16	24	24	22	23		7	3	12		2			5	18	6	12
-	Zingiberaceae	3 'Kuga'	30	12	63	17	23	27	30	•	5	7	15	17	42	46	28	27	52	•	52	•
6022	Cyatheaceae	1	10			3		1		11	3	2	6	6	10		10	7		3		1
-	Cyatheaceae	2			4	9	8	12	16	25	17	7	5	23	23	13	21	16	14	12	5	11
-	Cyatheaceae	3																				
-	Cyatheaceae	4																				
6020	Gleicheniaceae	Dicranopteris linearis	25	2	•	•	•	•	•	21	•	14	23	•		3	22			•	12	16
6029	Gleicheniaceae	Gleichenia hooglandii						17		9	13	12	18		8	•	1	4	2	10	11	35
	Lycopodiaceae	Lycopodium spp.	5	•	20	12	7		20	19	9	•	•	•		20					16	•

Mt Hagen
Mixed Forest
3040m
No. Individuals Per Plot

ANU No.	Family	Genus & Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
3433	Thymelaeaceae	Phaleria ?nogeronsis		2		4	4	6		6	14	10	15	2	9	4	4	1	3	4	5	9
6270	Winteraceae	Drimys sp. 2		2					12	16	13	14	19	1	8	5	13	7	10	13	7	5
6376	Ericaceae	Dimorphanthera denticulifera	2	6	2	3	1	2	9	10	2	12	2	6	4	12	9	1	10	10	4	13
6268	Ericaceae	Diplycosia sp.																				
6264	Loranthaceae	4																				
6271	Monimiaceae	Palmeria sp. 3		35	13	4	35	30	4	7	16	4	9	13	28	6	33	19	15	12	7	6
6408	Piperaceae	Piper sp. 1	39		4	9	11	18	19	8	4	5	3	10	14	3	9	5	11	7	3	5
5573	Rosaceae	Rubus moluccanus	1	8	4	25		6	19	23	19	16	11	6	18	6	13	16	14	6	3	15
6261	Poaceae	Nastus productus		2	8	20	20	3	37	28	41	•	•	•	52	•	•	23	23	60	12	25
6082	Asteraceae	Blumea arnakidophora																				
6393	Rosaceae	Potentilla sp. 1						18			30	18	9	19	15		11	10	25	14		24
6366	Scrophulariaceae	Hebe ?albiflora																				
6422	Urticaceae	Cypholophus sp.	82	•	•	•	•	•	•	•	•	•	•	•	22	10	30	24	•	37	18	44
6375	Urticaceae	Elatostema sp. 1	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
6423	Urticaceae	Elatostema sp. 3	•	•	•	•	30	•	20	30	•	•	•	•	•	20	•	•	•	•	•	•
6394	Poaceae	Deyeuxia brassii																				
6368	Zingiberaceae	Alpinia sp. 3	43	•	18	70	32	•	23	14	38	•	•	•	•	•	•	•	17	14	30	20
-	Zingiberaceae	3 'Kuga'	14	42	•	24	24	•	15	10	29	5	7	12	•	6	16	20	24	14	4	12
6022	Cyatheaceae	1	1		2	2			10	10	4	9	5	10	9		5	13	11	12	7	9
-	Cyatheaceae	2	13	24	39	17	14	32	22	26	14	16	19	32	23	12	36	15	34	17	12	17
-	Cyatheaceae	3		15	16	19		6	12	6	1	17	19	11	24	27	32	19	6	27	16	10
-	Cyatheaceae	4	1		2	5	1	7	1	1			3	2								
6020	Gleicheniaceae	Dicranopteris linearis																				
6029	Gleicheniaceae	Gleichenia hooglandii																				
	Lycopodiaceae	Lycopodium spp.	38			•				4	16	•	•	•	•	•	42	10		•	3	•

ANU No.	Family	Genus/Species	Mt Hagen Mixed Forest 2890m 2740m No. Individuals per plot																				Mt Hagen Degraded Mixed Forest 2705m No. Individuals per plot										Mt Hagen Beech Forest 2740m No. Individuals per plot																			
			41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
6248	Cunoniaceae	Schizomeria serrata	1	2	8		6	16			4	8	8		9	7	3	3	6	4	12	8	6	9	2					2	7	6																			7	
6283	Cunoniaceae	Spiraeopsis brassii					1								2		1		5	5	6	1																		3												
6278	Cunoniaceae	Weinmannia sp.							5	2		1				6				4	1										4	10			4	7	18	8		6		2		24	9	6	4	6		1	1	
6410	Elaeocarpaceae	Elaeocarpus crenulatus	1	3	2	5	4	10	7	6	7			8	6	8	13	2	3	10	13	14	8	1							4							4	6	5	1	6	4	8	3	2	2	4	5	5	5	5
6425	Elaeocarpaceae	Elaeocarpus ?sayeri	16	17	10	9	14	17	4	8	10	18	6	8	18	7	10	25	3	13	14	16	13	14	8						1		70	37	20	22	40	28	30	20	14	42	22	25	20	24	29	20	16	32	23	36
6247	Elaeocarpaceae	Elaeocarpus sp.1	3	4	3		2	1		1		4	2	4		2	10	1		6	6							6			8	3																				
6431	Elaeocarpaceae	Sericolea sp.	6	2	13	4	2	3		6		2	5	1		13	5	5	6	6	12	12		2	8			5			1		7	2	10		6	12	7	20		12	1	10	5	4	2	3	3	4		2
6317	Elaeocarpaceae	Sloanea sp.2+sp.3																																																		
6356	Ericaceae	Vaccinium apiculatum																																																		
6255	Escalloniaceae	Polyosma sp.																																																		
6360	Escalloniaceae	Quintinia sp.	14	17	14	13	9	12	4	1		7	5	2	10	1	10	12	8	8	9	10										7	7	12	3		8	7	12			10				4		4				1
6439	Euphorbiaceae	Macaranga ?womersleyi																																																		
6334	Euphorbiaceae	Omalanthus nervosus			3		2	6																			4			2																						
6251	Euphorbiaceae	Omalanthus sp.1																															18		7	2		2	2		2						1		8	1		2
6294	Fagaceae	Nothofagus sp.2																						2	1								38	18	2	9	16	21	8	10	5	8	1	9	8	2	12	7	14	9	8	8
6311	Flacourtiaceae	Casearia sp.	4		2		4	2	7		4	8	8		3			8	6	4	12	2	3		2								11	12		9	4	8	8	5	7	4		6			10	3	14	7	4	7
6426	Lauraceae	Cryptocarya sp.1	11	7	18	17	24	20	19	14	6	12	14	13	19	25	19	21	25	19	14	19	16	14	13			9		1	4	2	12	15	24	17	27	20	18	15	4	13	14	14	9	16	14	12	18	17	16	15
6333	Lauraceae	Endiandra sp.2								7			5		7	6	11	6		11	8	7	2	3			6				4																					
6246	Lauraceae						2	7											2	4			4		2				6	5	7	3																				4
6244	Melastomataceae	Astronia sp.1							4	10	8		6	20	11	12	7	10		10	8	13	8	11	6		6	5					17	22	8	2				20	4	11								9	10	
6421	Monimiaceae	Kibara sp.3	1	7	6	12	13	10	3	7	10	10	15	7	14	14	9	9	14	9	10	10	18	12							6	2	12	14	12	10	8	8	5	12	4	8	4	13	11	5	6	14	12	14	14	14
6440	Moraceae	Ficus endochaete																																																		
6441	Myrsinaceae	?Ardisia sp.																					13	8							2		22	24	14	11	18	21	12	8	7	11	7	14	16	8	12	18	14	15	16	11
6265	Myrsinaceae	Rapanea sp.2																																																		
6354	Myrsinaceae	Rapanea sp.3																6		8	9	1		3	8	8					10	10																				
6254	Myrtaceae	Syzygium adelphicum	7	4	9	6	3	7	4	5		9	5					15	4		8												13	3	10	2	11	11	2	8	2		2		6	5	3	3	10	5	6	4
6285	Myrtaceae	Syzygium sp.2	14	11	8	11	7	30	2	17	24	12	9	22	14	13	14	15	13	16	12	20	7	2									14	12	8	9	15	12	2	7	9	12	12	9	22	11	9	8	12	13	13	3
6314	Myrtaceae	Syzygium sp.5																																																		
6380	Ochnaceae	Schuurmansia henningsii	13	6	11	2	8	6	5	6	8	6	10	7	7		9	12	11	10	11	6	8	6								5		10		5	3	6	4	6	5	6		2			2	7	2			
6397	Pittosporaceae	Pittosporum pullifolium	2		2																												2																			
6284	Rosaceae	Prunus costata								4	6	7	8		6	3	2	8	8	3		4		4	2	1						4	10	8	10	7	15	4	12	5	3	8	9	12	11	6	17	7	15	7	4	11
6272	Rosaceae	Prunus pullei			8	4	3	4	6	15	5	8	5	6	6	8	11	10	20	18	14	14			1						2	4	28	27	21	12	30		13	19	2	24	16	28	18	15	24	14	18	16	13	26
6249	Rubiaceae	Timonius belensis	10	10	12	5	4	4	9	10	8	6	9	10	10	8	10	12	17	11	12	12	7	19	4	4					5	4	10	9	5	9	7	14	13	19	1	2	7	12	7	16	6	11	10	5	2	5
6430	Rutaceae	Acronychia sp.2	4	2	3	8	10	10	4	9	9	13	4	3	13	4	14	4	8	8	9	6	10										29	16	19	11	32	21	16	16	1	16	12	14	19	10	17	15	7	9	15	16
6486	Rutaceae	Evodia sp.1																																																		
6381	Saurauiaceae	Saurauia sp.1		4	1										3					1			8	1	7	8					1	3							2		1								2			
6277	Staphyleaceae	Turpinia pentandra							6	5	4		1	7	12	13	3	5	6	8	8	7	10	3	5		7	5	12		8	7																				
6420	Symplocaceae	Symplocos sp.3							2	3		14	10	6	5		6	4			9	9	3								10	1	4			3		2	2	8			10				2					
6414	Theaceae	Eurya oxysepala										3		6		2	3	3	4	2			8	1	4										8	6	5	2	4	3	6	12	4	4	1	2	2	5	5			

Mt Hagen Mixed Forest, 2890m – 2740m. No. Individuals per plot

ANU No.	Family	Genus/Species	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
6374	Winteraceae	Drimys sp.3	4		15	12	12	14	7	2	8	2	6	6	22	13	8	3	4	9	14	5
6392	Winteraceae	Drimys sp.4												6		4	4	6	2	2	2	6
	Pandanaceae	"Um"			1	3		3														
6259	Podocarpaceae	Podocarpus neriifolius							2			2						1				
6438	Apocynaceae	Alstonia sp.																				
6280	Aquifoliaceae	Sphenostemon papuanum							6	8	10	16	6	9	10	12	7	14	8	8	6	12
6370	Araliaceae	Harmsiopanax sp.				1	2	1														
6339	Araliaceae	Polyscias sp.																				
6352	Araliaceae	Schefflera sp.1	1	1	8	4			1	7		4		1			4	2	2			
6419	Asteraceae	Olearia sp.1				2	9	8										1				
6357	Asteraceae	?Senecio sp.																				
6281	Chloranthaceae	Ascarina philippinensis													1	2	2		2			6
6348	Elaeocarpaceae	Elaeocarpus poculiferus																				
6332	Elaeocarpaceae	Elaeocarpus sp.2																				
6267	Epacridaceae	Trochocarpa papuana																				
6424	Escalloniaceae	Polyosma sp.1	22	16	23	30	32	29	9	6	10	20	11	13	15	22	16	10	12	11	14	8
6429	Euphorbiaceae	Claoxylon rubicola																				
6322	Euphorbiaceae	Glochidion sp.4																				
6171	Euphorbiaceae	Macaranga pleiostemona																				
5530	Euphorbiaceae	Macaranga ?warburgiana	7	2	4																1	1
6282	Euphorbiaceae	Phyllanthus nervosus	1	11	5	17	22	10	15	28	16	27	11	13	22	22	20	12	13	22	10	18
6335	Euphorbiaceae																					
6253	Gesneriaceae	Cyrtandra sp.1	2		4	21	12	13	22	42	44	16	30	20	17	7	2	13	7	14	7	
6337	Himantandraceae	Galbulimima belgraveana																				
6279	Lauraceae	Cinnamomum sp.2							2			7		4	6		3		1	9	6	3
6326	Loganiaceae	Geniostoma sp.																				
6245	Monimiaceae	Kibara sp.2																				
5757	Moraceae	Ficus dammaropsis																				
6342	Moraceae	Ficus tonsa																				
6427	Moraceae	Streblus urophyllus	14	6	9	15	14	13	9	7	7	7	12	7	12	16	23	12	14	20	12	15
6293	Myrsinaceae	Maesa sp.																				
6319	Myrsinaceae	Discocalyx sp.																				
6345	Myrtaceae	Xanthomyrtus sp.																				
6415	Piperaceae	Piper sp.5																				
6315	Piperaceae	Piper sp.9																				
6289	Proteaceae	Finschia sp.																				
6434	Rhamnaceae	Alphitonia incana																				
6428	Rubiaceae	Amaracarpus sp.1	4	•	14	28	28	•		27	24	21	29	29	24	17	5	7	3	10	9	14
6377	Rubiaceae	Amaracarpus sp.3	•	34	26	30	•	38	50	•	40	•	22	22	35	•	10	24	30	30	32	24
6365	Rubiaceae	Coprosma papuensis																				
6436	Rubiaceae	Timonius sp.1																				
6432	Rutaceae	Evodia sp.2																				
6258	Rutaceae	Evodia sp.5	1		2	3	7	2	4	2		4	10	9	6	3	7	3	3	6	2	4
6435	Rutaceae	Evodiella sp.																				

Mt Hagen Degraded Mixed Forest, 2705m. No. Individuals per plot

ANU No.	Family	Genus/Species	61	62	63	64	65	66	67	68	69	70
6374	Winteraceae	Drimys sp.3										
6392	Winteraceae	Drimys sp.4										
	Pandanaceae	"Um"	7	1								
6259	Podocarpaceae	Podocarpus neriifolius										
6438	Apocynaceae	Alstonia sp.										
6280	Aquifoliaceae	Sphenostemon papuanum	2	7							6	6
6370	Araliaceae	Harmsiopanax sp.		7	7	5	8			2		
6339	Araliaceae	Polyscias sp.										
6352	Araliaceae	Schefflera sp.1	1	·						1	10	8
6419	Asteraceae	Olearia sp.1		4	4	10	5	7	5	3		
6357	Asteraceae	?Senecio sp.										
6281	Chloranthaceae	Ascarina philippinensis	1			1						
6348	Elaeocarpaceae	Elaeocarpus poculiferus										
6332	Elaeocarpaceae	Elaeocarpus sp.2										
6267	Epacridaceae	Trochocarpa papuana										
6424	Escalloniaceae	Polyosma sp.1						4				
6429	Euphorbiaceae	Claoxylon rubicola										
6322	Euphorbiaceae	Glochidion sp.4										
6171	Euphorbiaceae	Macaranga pleiostemona										
5530	Euphorbiaceae	Macaranga ?warburgiana	2				6					
6282	Euphorbiaceae	Phyllanthus nervosus										
6335	Euphorbiaceae											
6253	Gesneriaceae	Cyrtandra sp.1	34	12		20	30	22	30	30	30	30
6337	Himantandraceae	Galbulimima belgraveana										
6279	Lauraceae	Cinnamomum sp.2										
6326	Loganiaceae	Geniostoma sp.										
6245	Monimiaceae	Kibara sp.2	3	10	8	1	8	6	14	8		9
5757	Moraceae	Ficus dammaropsis										
6342	Moraceae	Ficus tonsa										
6427	Moraceae	Streblus urophyllus	2	5	4		1	3			2	
6293	Myrsinaceae	Maesa sp.										
6319	Myrsinaceae	Discocalyx sp.										
6345	Myrtaceae	Xanthomyrtus sp.										
6415	Piperaceae	Piper sp.5										
6315	Piperaceae	Piper sp.9										
6289	Proteaceae	Finschia sp.										
6434	Rhamnaceae	Alphitonia incana										
6428	Rubiaceae	Amaracarpus sp.1	40	7	2	10	13	8			8	15
6377	Rubiaceae	Amaracarpus sp.3	42	13	23	•	•	•	33	•	22	
6365	Rubiaceae	Coprosma papuensis										
6436	Rubiaceae	Timonius sp.1										
6432	Rutaceae	Evodia sp.2										
6258	Rutaceae	Evodia sp.5	1	6	4	2	4	2				10
6435	Rutaceae	Evodiella sp.										

Mt Hagen Beech Forest, 2740m. No. Individuals per plot

ANU No.	Family	Genus/Species	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
6374	Winteraceae	Drimys sp.3		12	10	4	15	30	10	7		12	7	10	20	10	9	11	8	8	7	6
6392	Winteraceae	Drimys sp.4	19	12	8	9	9	8	7	6	4	6	5		9	3	7	8	8	4	8	4
	Pandanaceae	"Um"	1	2		5	5	3	2	4	1	2	5		1	1	2	6	1		4	2
6259	Podocarpaceae	Podocarpus neriifolius				2			6					1			1			2	1	
6438	Apocynaceae	Alstonia sp.																				
6280	Aquifoliaceae	Sphenostemon papuanum		2	7	8		4	2	3		4		2								
6370	Araliaceae	Harmsiopanax sp.																				
6339	Araliaceae	Polyscias sp.																				
6352	Araliaceae	Schefflera sp.1	6	3		11	5	2		3	1		1	10	2	1			2	4	2	3
6419	Asteraceae	Olearia sp.1							1													
6357	Asteraceae	?Senecio sp.																				
6281	Chloranthaceae	Ascarina philippinensis																				
6348	Elaeocarpaceae	Elaeocarpus poculiferus																				
6332	Elaeocarpaceae	Elaeocarpus sp.2																				
6267	Epacridaceae	Trochocarpa papuana																				
6424	Escalloniaceae	Polyosma sp.1	19	10	13	7	6	5	2	6	2	9	2	10	10	8	5	8	13	12	16	8
6429	Euphorbiaceae	Claoxylon rubicola																				
6322	Euphorbiaceae	Glochidion sp.4																				
6171	Euphorbiaceae	Macaranga pleiostemona																				
5530	Euphorbiaceae	Macaranga ?warburgiana							3	1	4											
6282	Euphorbiaceae	Phyllanthus nervosus	15	7	6	2	2													2		
6335	Euphorbiaceae																					
6253	Gesneriaceae	Cyrtandra sp.1						4	4	2	9			1								
6337	Himantandraceae	Galbulimima belgraveana																				
6279	Lauraceae	Cinnamomum sp.2																				
6326	Loganiaceae	Geniostoma sp.																				
6245	Monimiaceae	Kibara sp.2	16	14	10	10	22	7	12	7	4	4	1	6	5	3	5	5	1	4	4	10
5757	Moraceae	Ficus dammaropsis																				
6342	Moraceae	Ficus tonsa																				
6427	Moraceae	Streblus urophyllus	28	18	16	10	20	7	16	16 1	7	12	13	12	14	17	13	12	10	12	14	1[illegible]
6293	Myrsinaceae	Maesa sp.																				
6319	Myrsinaceae	Discocalyx sp.																				
6345	Myrtaceae	Xanthomyrtus sp.	27 1	21	7	6	17	2		6	1 1	8		3	28	13	12 2	4	7 6	6	4	2
6415	Piperaceae	Piper sp.5																				
6315	Piperaceae	Piper sp.9																				
6289	Proteaceae	Finschia sp.																				
6434	Rhamnaceae	Alphitonia incana																				
6428	Rubiaceae	Amaracarpus sp.1	12		2	3		6		5	8				3		4					
6377	Rubiaceae	Amaracarpus sp.3	37	26	22	•	12	12	32	8	20	34	20	18	39	17	15	22	23	32	26	•
6365	Rubiaceae	Coprosma papuensis																				
6436	Rubiaceae	Timonius sp.1																				
6432	Rutaceae	Evodia sp.2																				
6258	Rutaceae	Evodia sp.5	5	9	3	3	3	7	10	4	4	6	4	12	12	5	10	14	5	3	6	6
6435	Rutaceae	Evodiella sp.																				

Mt Hagen Mixed Forest
2890m 2740m
No. Individuals Per Plot

ANU No.	Family	Genus & Species	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
0349	Sapindaceae																					
0256	Saurauiaceae	Saurauia sp. 4																				
0433	Thymelaeaceae	Phaleria ?nogerensis				10	6	10	1	2	2	5	1			3						1
0372	Urticaceae	Debregeasia sp. 1																				
0270	Winteraceae	Drimys sp. 2	17	11	6	16	14	28	2	6	8	4	3	6	14	10	5	5	14	1	6	10
-	Liliaceae	Cordyline fruticosa																				
0299	Saurauiaceae	Saurauia sp. 3+ sp. 7							2													
-	Cucurbitaceae																					
0353	Ericaceae	Dimorphanthera alpina																				
0376	Ericaceae	Dimorphanthera denticulifera	11	3	32	13	24	7	12	28	13	8	23	11	21	18	24	29	22	22	40	17
0271	Monimiaceae	Palmeria sp. 3	•	•	21	41	•	32	10	10	12	14	7	10	18	15	20	14	14	17	24	31
0408	Piperaceae	Piper sp. 1	12	7	4	7	25	18	24	20	26	28	30	28	32	20	26	20	19	27	26	22
5173	Rosaceae	Rubus moluccanus	3	•	22	22	•	•		8	8	14	10	15	11	6	7	8	8	9	35	16
0287	Rubiaceae	Psychotria sp.																				
0291	Solanaceae	Solanum ?belense							4	10	10	4	10	14	18	22	13	16	27	22	12	14
0340	Vitaceae	Tetrastigma sp.	4	2	3				9	15	12	10	8	15	14	12	10	17	19	15	15	12
-	?Vitaceae	'Tropena'							7	7		2	14	7	3	4	8	10	9	10	4	4
-	Pandanaceae	Freycinetia sp.							10	20	16	8	38	44	42	19	27	29	25	48	42	26
0201	Poaceae	Nastus productus	•	•	•	16	17	•	25	19	31	34	30	32	38	34	40	34	•	•	40	34
0209	Gesneriaceae	Cyrtandra sp. 3		2	2	7	25	12				15	5	10	19		12		3	12		10
0379	Haloragaceae	Gunnera macrophylla			4																	
0393	Rosaceae	Potentilla sp. 1	10	6	8																	
5746	Rosaceae	Rubus rosifolius																		2		
0422	Urticaceae	Cypholophus sp.	•	•	•	•	15	16	•	•	17	•	•		4	10	•	13	•	30	•	13
0375	Urticaceae	Elatostema sp. 1	•	•		•	•	7	•	•	•	•	•	20	•	•	•	•	25	•	•	•
6312	Urticaceae	Elatostema sp. 2							•	•	•	•	•	30	20	3	13					
6423	Urticaceae	Elatostema sp. 3	•	•	•	•	•	•			•	•	•	•		2		•		13	17	20
0290	Urticaceae	Pilea sp. 1	•	•	•	•	•	•														
-	Cyperaceae	Carex spp.		6	12																	
6368	Zingiberaceae	Alpinia sp. 3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
5975	Zingiberaceae	1 'Pugarr'	30	•	8	15	25	7	10	8	2	12	15	16	17	8	26	12	13	8	14	15
6144	Zingiberaceae	2 'Muga'	20	•	•	9	4	8		3	4	7		4	3	3	5		5			
-	Zingiberaceae	3 'Kuga'							4	1	4	22	8	2	4	6	2	12	6	4	10	2
0022	Cyatheaceae	1							5	2	15	5	14	2		12	2		3	6		5
-	Cyatheaceae	2	9	16	4	9	20	7		12	12	15	8	10	10	12	14	7	12	8	10	10
-	Cyatheaceae	3		4	7	12	28	25	23	11	23	24	24	8	24	12	29	32	16	24	16	24
-	Cyatheaceae	4																				
6320	Gleicheniaceae	Dicranopteris linearis	•	30	•	14	•	•							32	7	32	2	5	19	30	29
6086	Marattiaceae						1		4	8	2	4	1	4	4	2	7	2	4	4	8	7
-	Lycopodiaceae	Lycopodium spp.	25	•	4	1		2											19	3		

Mt Hagen Degraded Mixed Forest
2705m
No. Individuals Per Plot

ANU No.	Family	Genus & Species	61	62	63	64	65	66	67	68	69	70
0349	Sapindaceae											
0256	Saurauiaceae	Saurauia sp. 4				6	6			6	4	6
0433	Thymelaeaceae	Phaleria ?nogerensis	1	4	2							
0372	Urticaceae	Debregeasia sp. 1				6						
0270	Winteraceae	Drimys sp. 2	12	15	7		8			2	10	10
-	Liliaceae	Cordyline fruticosa										
0299	Saurauiaceae	Saurauia sp. 3+ sp. 7	9	3	2	10	23	11	19	9		
-	Cucurbitaceae										•	3
0353	Ericaceae	Dimorphanthera alpina										
0376	Ericaceae	Dimorphanthera denticulifera	6	16	9	16	6	16	5	15	20	15
0271	Monimiaceae	Palmeria sp. 3	9	13	•	•	•	10	18	•	21	24
0408	Piperaceae	Piper sp. 1	27	19	•	•	•	•	•	•	•	•
5173	Rosaceae	Rubus moluccanus	12	•	•	•	•	22	•	•	7	15
0287	Rubiaceae	Psychotria sp.								•		
0291	Solanaceae	Solanum ?belense					•	•	23	•	42	•
0340	Vitaceae	Tetrastigma sp.	14	15	23	•	20	16	23	30	16	25
-	?Vitaceae	'Tropena'					15	10	14	10	6	16
-	Pandanaceae	Freycinetia sp.		10								
0201	Poaceae	Nastus productus	•	•	•	2	•					
0209	Gesneriaceae	Cyrtandra sp. 3	20	17	14	•	16	•	22	20	18	36
0379	Haloragaceae	Gunnera macrophylla										
0393	Rosaceae	Potentilla sp. 1										
5746	Rosaceae	Rubus rosifolius										
0422	Urticaceae	Cypholophus sp.			•	•		•	22	•	•	•
0375	Urticaceae	Elatostema sp. 1	•	•	•	•	•	•	•	•	•	•
6312	Urticaceae	Elatostema sp. 2						•	•	•	•	•
6423	Urticaceae	Elatostema sp. 3	2	12	•	•	•	•	•	•	•	•
0290	Urticaceae	Pilea sp. 1										
-	Cyperaceae	Carex spp.										
6368	Zingiberaceae	Alpinia sp. 3	•				10	10	6	15	50	30
5975	Zingiberaceae	1 'Pugarr'	5	3		1		2	1	8	6	19
6144	Zingiberaceae	2 'Muga'	5		12	11	1	6	10		7	7
-	Zingiberaceae	3 'Kuga'	3	4	2	5	3	2	2	6	8	20
0022	Cyatheaceae	1										
-	Cyatheaceae	2	20	9	6	7	7	3			7	5
-	Cyatheaceae	3	12	17	5	6		1	12		5	1
-	Cyatheaceae	4								8	10	1
6320	Gleicheniaceae	Dicranopteris linearis	•	•	•	•	18			12		
6086	Marattiaceae		6	8	5	3	3		3	7		4
-	Lycopodiaceae	Lycopodium spp.										

Mt Hagen Beech Forest
2740m
No. Individuals Per Plot

ANU No.	Family	Genus & Species	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
0349	Sapindaceae			6		2	3	1							8	2	4	4		2	2	
0256	Saurauiaceae	Saurauia sp. 4					2				3											
0433	Thymelaeaceae	Phaleria ?nogerensis	10	12	2	1	2		17	2	3	10		6	5	2	8	5	15	7	6	8
0372	Urticaceae	Debregeasia sp. 1																				
0270	Winteraceae	Drimys sp. 2	19	16	14	15	12	12	12	15	4	6	5	6	13	11	8	6	10	12	7	2
-	Liliaceae	Cordyline fruticosa										2	2									
0299	Saurauiaceae	Saurauia sp. 3+ sp. 7																				
-	Cucurbitaceae																					
0353	Ericaceae	Dimorphanthera alpina				15	7	10	4	3		6		6				4			13	
0376	Ericaceae	Dimorphanthera denticulifera	15	18	10	2	12	•	18	18	6	7	3	20	12	14	26	8	22	3	11	1
0271	Monimiaceae	Palmeria sp. 3	•	•	25	17	19	14	23	12	6	21	14	12	20	18	26	18	22	•	14	22
0408	Piperaceae	Piper sp. 1	10	20	7	18	12	16	14	14	6	7	2	2	4	1	11	3	3		6	2
5173	Rosaceae	Rubus moluccanus	25	14	10	18	13	7	22	13	1	3	2	2	2		4	4		8	5	2
0287	Rubiaceae	Psychotria sp.	11		15	15	8	5	14	3	4	6	4		2	2	12	20	17	17	5	7
0291	Solanaceae	Solanum ?belense																				
0340	Vitaceae	Tetrastigma sp.	9	15	9	25	23	16	16	13	8	12	13	10	13	14	15	18	21	23	16	20
-	?Vitaceae	'Tropena'	6	20	4	5	1		2	2		3		1	2		7	3	8	5	2	7
-	Pandanaceae	Freycinetia sp.	13	7		12	12	7	26	•	5	2			13		12	3	•	•		•
0201	Poaceae	Nastus productus	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
0209	Gesneriaceae	Cyrtandra sp. 3										3	2				12	2	2			
0379	Haloragaceae	Gunnera macrophylla																				
0393	Rosaceae	Potentilla sp. 1	7		3														14		•	•
5746	Rosaceae	Rubus rosifolius																				
0422	Urticaceae	Cypholophus sp.				•	3	•			3	13	3		4						2	
0375	Urticaceae	Elatostema sp. 1	•	•	•		•	•	•	•	•	•	•	10	12	38	40	•	•	17	•	•
6312	Urticaceae	Elatostema sp. 2																				
6423	Urticaceae	Elatostema sp. 3	5	15		7	5	4	2	10	8	6	9	10	10	8	20	4	12	22	14	3
0290	Urticaceae	Pilea sp. 1																				
-	Cyperaceae	Carex spp.																				
6368	Zingiberaceae	Alpinia sp. 3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
5975	Zingiberaceae	1 'Pugarr'	1	2		10	19	25	50	14	16	10	8	•	23	32	14	9	12	7	10	7
6144	Zingiberaceae	2 'Muga'				1																
-	Zingiberaceae	3 'Kuga'	8			20	2	10	4		6	19	5					1				
0022	Cyatheaceae	1																				
-	Cyatheaceae	2	15	14	8	16	18	19	18	25	11	14	19	24	20	17	23	18	14	16	12	10
-	Cyatheaceae	3	10	16	28	18	22	14	17	10	16	20	22	17	7	15	14	20	10	9	6	10
-	Cyatheaceae	4									2											
6320	Gleicheniaceae	Dicranopteris linearis	17	8	5		20	6	13	6	7				2	5		4	24	•		
6086	Marattiaceae																					
-	Lycopodiaceae	Lycopodium spp.																				

Mt. Hagen Beech Forest 2585m — NO. INDIVIDUALS PER PLOT (plots 91–100)

Mt. Hagen Degraded Beech Forest + Regrowth 2400m — NO. INDIVIDUALS PER PLOT (plots 101–120)

ANU No.	Family	Genus/Species	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
6262	Aquifoliaceae	*Ilex* sp.3																														
6320	Aquifoliaceae	*Ilex* sp.1											4	8	12		2	7	8	12	9	4	5	12	11	3	8	7	7			10
6351	Asteraceae	*Olearia* sp.3																														
6327	Antherospermaceae	*Dryadodaphne* sp.											4	14	6	1	3	7	8				6	8	5	2	4	5	8			6
6325	Clusiaceae	*Garcinia* sp.3												1	20	5	8	20	15	17	26	17		2	12	9	14	29	40	20	40	6
6248	Cunoniaceae	*Schizomeria serrata*	3	6		1	1		6	6	8	5	4	10	13			8	8			6		3	11	3		4	11	9	13	4
6283	Cunoniaceae	*Spiraeopsis brassii*											5	4				2	1		2										8	20
6278	Cunoniaceae	*Weinmannia* sp.			4	7	18	4	6	1	3																			7		
6410	Elaeocarpaceae	*Elaeocarpus crenulatus*	7	9	5	5	4	8	8	7	13	3	2	8	4		1		2					1	5			2	2	2	3	1
6425	Elaeocarpaceae	*Elaeocarpus ?sayeri*	23	24	16	18	12	10	10	23	16	12	15	12	11	2		7	11	2	7	8	9	6	7	6	2	1	4	10	7	13
6247	Elaeocarpaceae	*Elaeocarpus* sp.1	4	5						2							7	2	6			6			4	1		2	7		1	1
6431	Elaeocarpaceae	*Sericolea* sp.	2	8	5	6	8	2	10	5	6	7					1	10		6	1	2						5	2		3	
6317	Elaeocarpaceae	*Sloanea* sp.2+sp.3												1		5	5	8	4			4	1	4				5			6	17
6356	Ericaceae	*Vaccinium apiculatum*																														
6255	Escalloniaceae	*Polyosma* sp.																														
6360	Escalloniaceae	*Quintinia* sp.															3	6		1	2			1	4			5			2	2
6439	Euphorbiaceae	*Macaranga ?womersleyi*																														
6334	Euphorbiaceae	*Omalanthus nervosus*											42	27	28	10	1	4					27	48	42	3	1				4	18
6251	Euphorbiaceae	*Omalanthus* sp.1					2			2																						
6294	Fagaceae	*Nothofagus* sp.2	12	14	2		7	1	7	7	9	7	23	1	8	7	7	10	7	6	6	7	7		12	10	11	10	12	4	4	7
6311	Flacourtiaceae	*Casearia* sp.		4	8	8	8	9	10	8	8	10		2	7	5		7	2		4	1	1	4	4		2	8		1	2	6
6426	Lauraceae	*Cryptocarya* sp.1	12	9	7	13		4	7	4	9	12	9	12	14		8	7	5	6	3		3	1	7	4	5			4	4	4
6333	Lauraceae	*Endiandra* sp.2											6	10	12	4	2	5	6	2	2	10	11	5	8	10	6	7	6	8	6	18
6246	Lauraceae						1																									
6244	Melastomataceae	*Astronia* sp.1		5	2	8	6	7	8						7	1	8		3	6	4	1				4	10	2	7	7	8	2
6421	Monimiaceae	*Kibara* sp.3	7	12		16	10	20	10	12	8	12	10	8	9	6	6	10	6	9	4	7	5		8	4	8	9	12	4	3	10
6440	Moraceae	*Ficus endochaete*																														
6441	Myrsinaceae	*?Ardisia* sp.	12	10	6	6	4	6	13	14	12	19	4	12	9	3	6	8	14	4	7	2	5		14	10	10	9	4	12	7	14
6265	Myrsinaceae	*Rapanea* sp.2																														
6354	Myrsinaceae	*Rapanea* sp.3																	12	6	5	8			1		5	10	13	7	2	
6254	Myrtaceae	*Syzygium adelphicum*	2																													
6285	Myrtaceae	*Syzygium* sp.2	8	7	3	5		14	10	6	14	13	3	12	5	3		1	8		8	8		4	5		9	11	7		6	9
6314	Myrtaceae	*Syzygium* sp.5													8	1	2	4			4	3	12	1	3	7	9	6	1		2	4
6380	Ochnaceae	*Schuurmansia henningsii*	4	11			1								2			7	7	8	8		3	1	10			10	5	3	5	
6397	Pittosporaceae	*Pittosporum pullifolium*		14				4																				2				
6284	Rosaceae	*Prunus costata*	3	15	7	8	4	3	5	12	6	12	4	4	10	1		3	12	2	1	4	1	8	7	3		2	6	5	5	7
6272	Rosaceae	*Prunus pullei*	20	7	11	3			2	7	24	11	1	5	8			7	13	14	3	11	5	8	12	8	12	9	12	9	12	11
6249	Rubiaceae	*Timonius belensis*	7	10	12	4	10	7	6	4	14	6	5	10	6	1		7	8		3	7			2	3	2	7			9	6
6430	Rutaceae	*Acronychia* sp.2	13	19	7		2	4	5	8	8	8																				
6486	Rutaceae	*Evodia* sp.1													6				4	3	2	1	5	8	7		1				5	8
6381	Saurauiaceae	*Saurauia* sp.1											5	10	1	3	1			2			7	11	4	1			2			4
6277	Staphyleaceae	*Turpinia pentandra*		6	6	6	8	5	15	2	9			2		2									1		1					
6420	Symplocaceae	*Symplocos* sp.3											7	8	11			6	6	5		8	6	10	10		5	2	5		7	12

Mt Hagen
Beech Forest
2585 m
NO. INDIVIDUALS PER PLOT

Mt Hagen
Degraded Beech Forest Regrowth
2400 m
NO. INDIVIDUALS PER PLOT

ANU No.	Family	Genus & Species	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
6416	Theaceae	Eurya oxysepala	4		4	4	6	4	2	8	10	8	8	8	9	4	1	8	1	4	4	6	6	8	9			2	5	5		12
6374	Winteraceae	Drimys sp. 3	4	9	4				1	2	4	3																		2	1	4
6392	Winteraceae	Drimys sp. 4	6	14	2	6		1	2	8	1	1	1	1	1			2			1	6		8	6	5	8	2	6	3	4	4
	Pandanaceae	'Um'	5	4	2	4	2	9	3	6	4	5																				
6259	Podocarpaceae	Podocarpus neriifolius	1									4			2	2		7	7	4	2		1		5	1			6		1	
6280	Aquifoliaceae	Sphenostemon papuanum	10	12	10	2	5	7	11	15	1	12		1	1			3	6	7	1								5			5
6370	Araliaceae	Harmsiopanax sp.					4		2		1																					
6339	Araliaceae	Polyscias sp.											2		1	4			3	1		1		3	3	3			3			2
6352	Araliaceae	Schefflera sp. 1		4	4			3	3	6	4	4															1		3		2	
6419	Asteraceae	Olearia sp. 1								1		7					12	10						1			1	2				1
6332	Elaeocarpaceae	Elaeocarpus sp. 2												3	12	3								1	2							
6424	Escalloniaceae	Polyosma sp. 1	10	8	9	8	10	8	16	12	8	8																				
6322	Euphorbiaceae	Glochidion sp. 4											4	11	5	2	7	4	4	6		4	3	8	2	3	5	5	5		10	11
5530	Euphorbiaceae	Macaranga ?warburgiana											2	5	8	1		1					4	5	6						5	14
6282	Euphorbiaceae	Phyllanthus nervosus				2	7	9	15	2	10		24	5	6	13	12	24	26	18	15	35	5	1	12	26	39	16	30	38	36	34
6335	Euphorbiaceae																					4		5	5	8	1	12	12		4	4
6253	Gesneriaceae	Cyrtandra sp. 1			15	10	16	20	12			1		1	3											3			10	4		
6337	Himantandraceae	Galbulimima belgraveana															9	1	8				4	1	2		4		4			
6279	Lauraceae	Cinnamomum sp. 2	2		2			10					4	6	5	5	5	9	4	3	10	9	2	8	17	4	3	4	6	12	7	12
6326	Loganiaceae	Geniostoma sp.													2								2		7							1
6245	Monimiaceae	Kibara sp. 2	8	4	3	4	6	5	5	9	9	11																				
6342	Moraceae	Ficus tonsa																					2									
6427	Moraceae	Streblus urophyllus	14	19	10	6	11	7	14	12	17	7	12	6	10	2	4	10	6	8	10	16	5	6	16	2	10	12	14	6	12	6
6293	Myrsinaceae	Maesa sp.											1	2																		
6319	Myrsinaceae	Discocalyx sp.																4	1								2	10	4			2
6345	Myrtaceae	Xanthomyrtus sp.		6	3		14			7	10	2		3	4			7	2	2	7			2	4		2	13	15		4	4
6415	Piperaceae	Piper sp. 5	2	2		2	2	5	5	2	5	6	4	11	9	5	6	12	8	10	5	6	3	8	9	4	6	7	12	8	10	10
6315	Piperaceae	Piper sp. 9											12	16	6	5			2				16	18	7				1		5	15
6289	Proteaceae	Finschia sp.					4	2			7																					
6434	Rhamnaceae	Alphitonia incana											2	8	2									3	1							
6428	Rubiaceae	Amaracarpus sp. 1		19	18	6	6	25	23	14		4																				
6377	Rubiaceae	Amaracarpus sp. 3	10	19	*	*	*	*	27	15	8	8						10	12	10	20	20	6		4	3	20	20	20	15	15	10
6258	Rutaceae	Evodia sp. 5	3	13	9	12	17	7	12	9	10	8	10	12	14	6	6	5		4	6	2	20	22	13	3		1		4	10	13
6435	Rutaceae	Evodiella sp.																														2

Mt Hagen Beech Forest 2385m — No. Individuals Per Plot

ANU No.	Family	Genus & Species	91	92	93	94	95	96	97	98	99	100
6347	Sapindaceae	Guioa sp.										
6331	Sapindaceae	Mischocarpus sp.										
6349	Sapindaceae										4	2
6329	Sapotaceae	Planchonella macropoda										
6256	Saurauiaceae	Saurauia sp.4					4		2			1
6324	Saurauiaceae	Saurauia sp.5										
6343	Symplocaceae	Symplocos sp.2										
6298	Theaceae	Eurya meizophylla										
6338	Theaceae	Eurya tigang										
6433	Thymelaeaceae	Phaleria ?sogerensis	3	2	8	2	1		2	2	1	
6481	Trimeniaceae	Trimenia papuana										
6372	Urticaceae	Debregeasia sp.1										
6270	Winteraceae	Drimys sp.2	22	9	12	6	13	12	12	10	10	4
-	Liliaceae	Cordyline fruticosa										
6323	Podocarpaceae	Podocarpus imbricatus										
6299	Saurauiaceae	Saurauia sp.3+ sp.7					10	42	8	1		
-	Cucurbitaceae											
6353	Ericaceae	Dimorphanthera alpina		5	13			•	2	17	3	3
6376	Ericaceae	Dimorphanthera denticulifera	5	10	3	5	4	8		•	10	•
6268	Ericaceae	Diplycosia sp.										
6384	Ericaceae	Rhododendron womersleyi										
6264	Loranthaceae	4										
6271	Monimiaceae	Palmeria sp.3	17	27	24	18	24	37	•	20	23	23
6408	Piperaceae	Piper sp.1	3	2	16	34	24	•	8	5	17	5
5573	Rosaceae	Rubus moluccanus	2	12	18	21	18	14	17	14	12	9
6287	Rubiaceae	Psychotria sp.	5		14	5		10	1			
6291	Solanaceae	Solanum ?belense										
6326	Vitaceae	Cayratia sp.					12		7	•	•	10
6346	Vitaceae	Tetrastigma sp.	28	24	12	13	13	17	14	10	17	22
-	?Vitaceae	"Tropena"	4	8	7	4	6	13	6	9	7	8
-	Pandanaceae	Freycinetia sp.	32	33	34	16	•	10	43	•	•	•
6261	Poaceae	Nastus productus	•	•	•	•	•	•	•	•	•	•
-	Poaceae	Bambusa sp.										
-	-	"Toowang"										
6082	Asteraceae	Blumea arnakidophora										
5724	Asteraceae	Crassocephalum crepidioides										
6269	Gesneriaceae	Cyrtandra sp.3		2	6	5	25	30	3	2	2	10
6379	Haloragaceae	Gunnera macrophylla										
6032	Lamiaceae	Plectranthus sp.1				2	10	10				
6393	Rosaceae	Potentilla sp.1										
5746	Rosaceae	Rubus rosifolius		8	12	2	5	12		10		
6366	Scrophulariaceae	Hebe ?albiflora										
6422	Urticaceae	Cypholophus sp.		3		•	•	•	14			2

Mt Hagen Degraded Beech Forest and Regrowth 2400m — No. Individuals Per Plot

ANU No.	Family	Genus & Species	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
6347	Sapindaceae	Guioa sp.	1	8	7	3	1		5	2	6	7		3				5	4	4	5	3
6331	Sapindaceae	Mischocarpus sp.		1	5				1			2		3				5				3
6349	Sapindaceae																		4		4	7
6329	Sapotaceae	Planchonella macropoda		1	4			5	6				1	4	2			4	2		4	2
6256	Saurauiaceae	Saurauia sp.4	7	14	8	8	5	4		2			9	8	8			1	4	2	4	15
6324	Saurauiaceae	Saurauia sp.5		5	1			1						2							2	
6343	Symplocaceae	Symplocos sp.2	2	2	3		1	8	7	5	7	9	1	8	7	3		2	2		6	10
6298	Theaceae	Eurya meizophylla																				
6338	Theaceae	Eurya tigang	2	5	6	1					2											
6433	Thymelaeaceae	Phaleria ?sogerensis																				
6481	Trimeniaceae	Trimenia papuana																				
6372	Urticaceae	Debregeasia sp.1	4		4								2	1							3	
6270	Winteraceae	Drimys sp.2			3	2			2					1								2
-	Liliaceae	Cordyline fruticosa	12	12		12		4	2	3	3	3	2	8	1	1	3	3	10	7	4	5
6323	Podocarpaceae	Podocarpus imbricatus	2	1	8	2	4	4	6			6			2			4	4	3		
6299	Saurauiaceae	Saurauia sp.3+ sp.7	1	10	4	4	10	2		4				6								3
-	Cucurbitaceae																					
6353	Ericaceae	Dimorphanthera alpina						9	•	4	3						4	4	14	4	6	1
6376	Ericaceae	Dimorphanthera denticulifera					4		3					1		3	2	7	5			2
6268	Ericaceae	Diplycosia sp.																				
6384	Ericaceae	Rhododendron womersleyi					4	5	5		6							2		1		
6264	Loranthaceae	4																				
6271	Monimiaceae	Palmeria sp.3	20	12	24	15	12	18	30	14	22	24	25	26	31	20	15	20	28	25	30	15
6408	Piperaceae	Piper sp.1			3		10	4	10	4	10	10			12		4	10	15	2	6	•
5573	Rosaceae	Rubus moluccanus	15	15	•	12	5	4	7	2	2	4	34	23	15	12	9	8	3	3	21	26
6287	Rubiaceae	Psychotria sp.																				
6291	Solanaceae	Solanum ?belense																				
6326	Vitaceae	Cayratia sp.	•	15	12	5	4		7	6	5	7	15		20	15	4	5	10	3	5	13
6346	Vitaceae	Tetrastigma sp.	10	7	14	9	9	12	20	10	14	16	2	14	20	7	6	16	12	12	12	9
-	?Vitaceae	"Tropena"	9	12	7	4	6	13	12	4	8	8	4	9	9	4	15	13	15	12	7	12
-	Pandanaceae	Freycinetia sp.	26	22	•	•	•	•	•	•	•	•	12	7	•	•	•	•	•	•	•	•
6261	Poaceae	Nastus productus	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
-	Poaceae	Bambusa sp.	2	1	8																	
-	-	"Toowang"		6	6	6	12	10	15	10	13	2	5	8	20	10	11	10	10	6	20	18
6082	Asteraceae	Blumea arnakidophora		9											2							
5724	Asteraceae	Crassocephalum crepidioides																				
6269	Gesneriaceae	Cyrtandra sp.3	6	5	4				3		1		1									
6379	Haloragaceae	Gunnera macrophylla																				
6032	Lamiaceae	Plectranthus sp.1	4			1	1	15	4												7	8
6393	Rosaceae	Potentilla sp.1				1																
5746	Rosaceae	Rubus rosifolius																				
6366	Scrophulariaceae	Hebe ?albiflora																				
6422	Urticaceae	Cypholophus sp.			7			5														

Beech Forest 2385 m

ANU No.	Family	Genus & Species	91	92	93	94	95	96	97	98	99	100
6375	Urticaceae	Elatostema sp. 1	-						•	•	•	12
6312	Urticaceae	Elatostema sp. 2										
0423	Urticaceae	Elatostema sp. 3	4	8	6	24	12	12	18	17	12	3
6340	Orchidaceae	Glomera sp. 2										
6341	Orchidaceae	Glomera sp. 3										
0066	Poaceae	Miscanthus floridulus										
6368	Zingiberaceae	Alpinia sp. 3	•	•	•	•	•	•	•	•	•	•
5975	Zingiberaceae	1 'Pugarr' •	14	25	24	4	12	4	5	12	10	17
0144	Zingiberaceae	2 'Muga' •										2
-	Zingiberaceae	3 'Kuga'	2	2	2	10	26	11		10	8	6
-	Orchidaceae											
5022	Cyatheaceae	Cyathea sp.										
-	Cyatheaceae	2	17	17	14	10	12	16	4	14	18	16
-	Cyatheaceae	3	21	21	5	9	10	14	10	8	13	11
-	Cyatheaceae	4		1		1	7	6	6	1		
0026	Gleicheniaceae	Dicranopteris linearis			-	•	12	4	2	15	•	•
0029	Gleicheniaceae	Gleichenia hooglandii										
6086	Marattiaceae			2	3	3	4	4	6		2	

Degraded Beech Forest and Regrowth 2400 m

ANU No.	Family	Genus & Species	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
6375	Urticaceae	Elatostema sp. 1	2		7		6	15	15	4			15		20	4	4	4	6	2	2	2
6312	Urticaceae	Elatostema sp. 2		21	•										14							20
0423	Urticaceae	Elatostema sp. 3																				
6340	Orchidaceae	Glomera sp. 2					4	•	•				3				•	2				
6341	Orchidaceae	Glomera sp. 3					8	2	4				6				10	1				
0066	Poaceae	Miscanthus floridulus	•	•	•	•	10							•	•	•	4					•
6368	Zingiberaceae	Alpinia sp. 3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
5975	Zingiberaceae	1 'Pugarr' •	10	13	26	12	12	12	•	10	16	15	18	10	17	18	•	10	16	15	22	20
0144	Zingiberaceae	2 'Muga' •																				
-	Zingiberaceae	3 'Kuga'	4		2	2	10	14	9	3	2	4	2	8	6	17		7	15	3	2	
-	Orchidaceae		8	•	18	13	•	•	17	12	2	10	2		10	10	13	6	5	10	1	8
5022	Cyatheaceae	Cyathea sp.	12	22	4	3							14	13	3						8	9
-	Cyatheaceae	2	3	2	10	7	11	13	20	9	15	11	10	13	12	15	16	11	10	11	34	10
-	Cyatheaceae	3	2	3	9	2	10	5	8	10	4	5		22	2		6	8	8	3	3	12
-	Cyatheaceae	4	2	8		1		5				3	6	1	3							
0026	Gleicheniaceae	Dicranopteris linearis		6	2																	
0029	Gleicheniaceae	Gleichenia hooglandii	•	•	6	10							•	•	•						5	•
6086	Marattiaceae			2				4	2	2	2*	2		8	1	3			10			1

Degraded Beech Forest and Regrowth 2280 m

ANU No.	Family	Genus & Species	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
6422	Urticaceae	Cypholophus sp.		2					2	2	4	12	12				1		3	4	16	
6375	Urticaceae	Elatostema sp. 1	7	2	8		2	7	4	2	8	12	3	25	5	6	10	1	15		4	4
6312	Urticaceae	Elatostema sp. 2									•	•	•	5					25	2		
6066	Poaceae	Miscanthus floridulus	•	•	•	•	•	•	•	•	•	14	•		3	5		•	•	•	•	•
6368	Zingiberaceae	Alpinia sp. 3	•	4	•	•		•	26	•	•	•	•	•	•	•	16	15	•	15	•	•
5975	Zingiberaceae	1 'Pugarr'	20	25	20	3	10	17	19	9	20	16	24	20	21	32	27	8	20	14	18	18
0144	Zingiberaceae	2 'Muga'												4								
-	Zingiberaceae	3 'Kuga'																7				
-	Orchidaceae				2		2	8	2	5		1		20		22	7	10	2	6		
6022	Cyatheaceae	Cyathea sp.	2			4	6	8	1	10	3		2							3	1	9
-	Cyatheaceae	2						1	2		3			5	5	4	6	4			2	
-	Cyatheaceae	3														2		1				
-	Cyatheaceae	4	6	5		8	3	1	7	5	5	4	3	4			2		4	2	1	
0026	Gleicheniaceae	Dicranopteris linearis	•	•	•	•	•	•	•	•	•	•	•	•			•	•	•	•	•	•
0029	Gleicheniaceae	Gleichenia hooglandii	•	•	•	•	5	•	•	•	•	•	•	•		2	•	•	•	3	•	•
6086	Marattiaceae		6	4	5	3	4	1	1	4	12	15	11	11	10	6	14	4	2	3	8	4

Mt. Hagen
Degraded Beech Forest + Regrowth
2700m
NO. INDIVIDUALS PER PLOT

ANU No.	Family	Genus/Species	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
6262	Aquifoliaceae	Ilex sp.3																				
6320	Aquifoliaceae	Ilex sp.1				2	2				5		7	6		6			2	3	7	2
6351	Asteraceae	Olearia sp.3																				
6327	Antherospermaceae	Dryadodaphne sp.												7								
6325	Clusiaceae	Garcinia sp.3	1				2	4		2	4	1	5	14	7	8		2			3	1
6248	Cunoniaceae	Schizomeria serrata					1						8			9	12	10		1	7	
6283	Cunoniaceae	Spiraeopsis brassii	10	6	6	3	16	10	20	21	3	1	10	14	8	10	14	13		12	7	8
6278	Cunoniaceae	Weinmannia sp.																				
6410	Elaeocarpaceae	Elaeocarpus crenulatus														4	3					
6425	Elaeocarpaceae	Elaeocarpus ?sayeri																				
6247	Elaeocarpaceae	Elaeocarpus sp.1						3						5					6			
6431	Elaeocarpaceae	Sericolea sp.			4			3							3						6	
6317	Elaeocarpaceae	Sloanea sp.2+sp.3	9	3	6	2		6	1		1	4	9	6	5		1	6				9
6356	Ericaceae	Vaccinium apiculatum																				
6255	Escalloniaceae	Polyosma sp.																				
6360	Escalloniaceae	Quintinia sp.																				
6439	Euphorbiaceae	Macaranga ?womersleyi	1	6	1	3	28	16	13	15	10	4	5	8	14	6	4	10	10		7	13
6334	Euphorbiaceae	Omalanthus nervosus	4	10	7	10	2	4	5	7	6	6	15	11	4		17	8			8	
6251	Euphorbiaceae	Omalanthus sp.1																				
6294	Fagaceae	Nothofagus sp.2	5			4	13	6	2					6	7	9	7	8	8		1	2
6311	Flacourtiaceae	Casearia sp.			3		2	5				3	5	5	3	7	1			12		
6426	Lauraceae	Cryptocarya sp.1	2				4	4		1				9	13	9	6	5		4	4	1
6333	Lauraceae	Endiandra sp.2	3		2	1				3			10	12	8	8	11	6	4	1	5	
6246	Lauraceae																					
6244	Melastomataceae	Astronia sp.1	6	4	7	1	3	1			4	13	10	9	5	4	20	2	11	14	13	7
6421	Monimiaceae	Kibara sp.3	2		4	4	5	5	10	6	9	5	10	15	10	6	13	6	6		10	4
6440	Moraceae	Ficus endochaete			4						2	4	7			3	12	5			3	1
6441	Myrsinaceae	?Ardisia sp.	6	4	7	6	6	3	7		8	6	8	8	9	12	13	10	10	9	9	1
6265	Myrsinaceae	Rapanea sp.2																				
6354	Myrsinaceae	Rapanea sp.3												6	3	1						
6254	Myrtaceae	Syzgium adelphicum																				
6285	Myrtaceae	Syzygium sp.2												1	10	4						
6314	Myrtaceae	Syzygium sp.5												10	9	5	2				1	
6380	Ochnaceae	Schuurmansia henningsii			2						5								3			
6397	Pittosporaceae	Pittosporum pullifolium	1		8		1	9					1		8	3		5			4	
6284	Rosaceae	Prunus costata													4	1						
6272	Rosaceae	Prunus pullei	4		6		5		1	3	4	3	2	6	6	10	4	5	2	3	10	2
6249	Rubiaceae	Timonius belensis	7	9	10	6	8	8	14	3	8	7	16	4	8	20	10	17	15	15	22	5
6430	Rutaceae	Acronychia sp.2																				
6486	Rutaceae	Evodia sp.1	4	4	4	1	7	6	6	1	4		1	5	9	8	6		5	3	3	4
6381	Saurauiaceae	Saurauia sp.1					1		2	2												
6277	Staphyleaceae	Turpinia pentandra																				
6420	Symplocaceae	Symplocos sp.3			1		4		1	2						4					2	
6414	Theaceae	Eurya oxysepala	4	5	12	4	10	4	8	12	7	5	9	9	10	12	15	11	14	8	13	5

Mt Hagen
Degraded Beech Forest + Regrowth
2280m
No. Individuals per plot

ANU NO.	Family	Genus/species	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
6374	Winteraceae	Drimys sp. 3					4	1							5							1
6392	Winteraceae	Drimys sp. 4			4				1	4				4	2	9		1	1			
	Pandanaceae	'Um'																				
6259	Podocarpaceae	Podocarpus neriifolius							2						3							
6438	Apocynaceae	Alstonia sp.			7		1				5	4			2			1		4	1	
6280	Aquifoliaceae	Sphenostemon papuanum								2	1					10	6			1	3	
6370	Araliaceae	Harmsiopanax sp.								4	6											
6339	Araliaceae	Polyscias sp.		2	8		4	2				1		2	5	6	4	4				
6352	Araliaceae	Schefflera sp.1	6		6			2	5	5	3		11	5	5	6	4	10	8		17	11
6419	Asteraceae	Olearia sp.1					3															
6357	Asteraceae	?Senecio sp.																				
6281	Chloranthaceae	Ascarina philippinensis	4					1	6							1					1	
6348	Elaeocarpaceae	Elaeocarpus poculiferus																				
6332	Elaeocarpaceae	Elaeocarpus sp.2																				
6267	Epacridaceae	Trochocarpa papuana																				
6424	Escalloniaceae	Polyosma sp.1											1		1		4		2			
6429	Euphorbiaceae	Claoxylon nubicola																				
6322	Euphorbiaceae	Glochidion sp.4			4	2									5		4			10		
6171	Euphorbiaceae	Macaranga pleiostemona						3		1	2											
5530	Euphorbiaceae	Macaranga ?warburgiana	3	1		1	1	7	10	12	8	4		3	6	2	10	5	8	8	5	2
6282	Euphorbiaceae	Phyllanthus nervosus	10	2	6	11	12	13	10	9	20	19	12	5	10	12	11	22	17	7	17	10
6335	Euphorbiaceae				4		2	6	2	4		8	5	8	8	10	4				10	7
6253	Gesneriaceae	Cyrtandra sp.1		5	4	4	7	4	6	3	60	19	16	22	3	5	4	22		12		1
6337	Himantandraceae	Galbulimima belgraveana													2							
6279	Lauraceae	Cinnamomum sp.2	4	2	5	4	4	7	6	5	5	6	7	9	12	4	10				2	
6326	Loganiaceae	Geniostoma sp.			8	3	7	4	4	12	7	11	10	4	1	7		8	2	7	6	9
6245	Monimiaceae	Kibara sp.2																				
5757	Moraceae	Ficus dammaropsis						2	2	8								1	2	1	3	3
6342	Moraceae	Ficus tonsa						3	12	1	4	8	7	6	8	3	10	5	5	4	9	4
6427	Moraceae	Streblus urophyllus	5		6	2	6	2		6	3	5	5	8	14	9	6	7	3		2	
6293	Myrsinaceae	Maesa sp.			2	1		1	6	3	2	2	7				1	8	4	1	1	
6319	Myrsinaceae	Discocalyx sp.																				
6345	Myrtaceae	Xanthomyrtus sp.															1					
6415	Piperaceae	Piper sp.5		7	2				4	4	6	3		3	2	2		2	3		5	
6315	Piperaceae	Piper sp.9	12	4	8	7	2	10	14	7	5	2	14	7	4	5	6		8	8	8	6
6289	Proteaceae	Finschia sp.																				
6434	Rhamnaceae	Alphitonia incana			2		1		5	14					1				4			
6428	Rubiaceae	Amaracarpus sp.1																				
6377	Rubiaceae	Amaracarpus sp.3	10		10	15	15	15	11	15	20	26	4	25	16	22	20	20	20	13	19	9
6365	Rubiaceae	Coprosma papuensis																				
6436	Rubiaceae	Timonius sp.1	13	6	20	2	10	9	8	8	15	11	2	8	4	6	12	14	9	13	18	3
6432	Rutaceae	Evodia sp.2																				
6258	Rutaceae	Evodia sp.5					2			2			2	3	4	7	7	3	7		6	5
6435	Rutaceae	Evodiella sp.			2	5	3	5	6	7		5	7	4	7	5	9	7	8	8	2	

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Degraded Beech Forest and Regrowth
2280m
No. Individuals Per Plot

ANU No.	Family	Genus & Species	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
6347	Sapindaceae	Guioa sp.													6	8	4		4			
6331	Sapindaceae	Mischocarpus sp.																				
6349	Sapindaceae		5		9	3	5	7	1	2	7	1	7	10	10	8	8	6	10		10	4
6329	Sapotaceae	Planchonella macropoda												12	9	5	1					
6236	Saurauiaceae	Saurauia sp.4						7	12	4	1		4	1	5	3	5	4		6	5	1
6324	Saurauiaceae	Saurauia sp.5								4												
6343?	Symplocaceae	Symplocos sp.2				2				2	4	1		10	14	5	6		1	1	5	
6298	Theaceae	Eurya meizophylla						1								2			2			
6338	Theaceae	Eurya tigang			8	2	7	5	12		3	1	3	6	4	2	8	7	1		6	2
6433	Thymelaeaceae	Phaleria ?sogerensis		2																		
6481	Trimeniaceae	Trimenia papuana																				
6372	Urticaceae	Debregeasia sp.1	3	4	1				1	8	4		2	3			3	6			5	
6270	Winteraceae	Drimys sp.2																				
-	Liliaceae	Cordyline fruticosa	13	9			2	3		2			14	2	4		2	5	23	4	3	7
6325	Podocarpaceae	Podocarpus imbricatus														1						
6299	Saurauiaceae	Saurauia sp.3+ sp.7			5	10	1	4	4	4	5	6	12					7	2	10	8	2
-	Cucurbitaceae																					
6353	Ericaceae	Dimorphanthera alpina	4	4	15		6	7	2	3	7	17	9	20	1	16	3	8	1	12	14	4
6376	Ericaceae	Dimorphanthera denticulifera	8		2		3	5	1	2	1		14	9	3	10	2	4		6	5	
6268	Ericaceae	Diplycosia sp.																				
6384	Ericaceae	Rhododendron womersleyi																				
6264	Loranthaceae	4																				
6271	Monimiaceae	Palmeria sp.3			3	7	2	5	14	7	8	15	15	14	17	10	11	2	12		2	1
6408	Piperaceae	Piper sp.1	18	22	5	10	3	10	14	10	28	15	•	28	22	18	27	14		2	12	5
3573	Rosaceae	Rubus moluccanus	2		5	5		5	6	15	10	8	25	6	3	5	7	12	1	2	10	8
6287	Rubiaceae	Psychotria sp.																				
6291	Solanaceae	Solanum ?belense																				
6328	Vitaceae	Cayratia sp.																4				
6346	Vitaceae	Tetrastigma sp.	10	4	10	2	7	7	6	12	3	12	12	12	16	8	12	10	12	18	10	7
-	?Vitaceae	"Tropena"	4	4	7	10	4	12	20	14	13	16	11	21	10		12	12	12	7	9	5
-	Pandanaceae	Freycinetia sp.		2	29		3	6	20	15	12	40	11	30	30	35	28	12	12	4	10	12
6261	Poaceae	Nastus productus	8	•	10		25	•	•	20	•	•	•	•	•	•	•	•	•	6	3	•
-	Poaceae	Bambusa sp.		1	8	7		2	4		10	17	20								7	
-	-	"Toowang"	12	6	4	12	6		9	8	6	10	10	7	4	7	12	12	10	12	10	5
6082	Asteraceae	Blumea arnakidophora	1	1	10	1	6	4	6	8	16	9	14	2		6	9	10	4	1	8	7
5724	Asteraceae	Crassocephalum crepidioides																				
6269	Gesneriaceae	Cyrtandra sp.3	3																			
6379	Haloragaceae	Gunnera macrophylla																				
6032	Lamiaceae	Plectranthus sp.1							7	15	10	15		3		4	11	8	8	10	12	
6393	Rosaceae	Potentilla sp.1												8								
5746	Rosaceae	Rubus rosifolius																				
6366	Scrophulariaceae	Hebe ?albiflora																				

ANU No.	Family	Genus & Species	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218
6489	Anacardiaceae	Rhus taitensis						6	4	21	34			5							3
6438	Apocynaceae	Alstonia sp.						2	1							4				3	2
6320	Aquifoliaceae	Ilex sp.1	6	7																	
6479	" "	Sphenostemon papuanum	3	1	7	6	10														
6370	Araliaceae	Harmsiopanax sp.								6	4										
6471	" "	Mackinlaya sp.	4		5	4	7											5	3		
6339	" "	Polyscias sp.	4	2												4	5	2	6	5	7
6352	" "	Schefflera sp.	4			3	4	3	6			3		4	2	11		4	3	3	2
6281	Chloranthaceae	Ascarina philippinensis											4								
6417	Cunoniaceae	Spiraeopsis brassii	6			7				6		1		4		3				2	3
6278	" "	Weinmannia sp.							1			2	3		6	4					
6248	" "	Schizomeria serrata	13	8	1	6	6								5		5	6	2		4
6348	Elaeocarpaceae	Elaeocarpus poculiferus							1						3					1	
6247	" "	Elaeocarpus sp.																	3		
6431	" "	Sericolea sp.	4	1																	
6317	" "	Sloanea sp.2/3	5	2								2			5					1	
6488	Escalloniaceae	Carpodetus sp.					5		10	4	5	3	7	2	2	5	3	6	3	1	6
6476	" "	Polyosma sp.										3		2	3						
6075	Euphorbiaceae	Acalypha sp.1							1	9	12			30	14	4					
6081	" "	Glochidion sp.1				4	8	4	12	11	8	7	11	4	9	6	5	6	9	5	9
5530	" "	Macaranga ?warburgiana			4			8					4	3	2	4					
6439	" "	Macaranga ?womersleyi	6	10		5	6		4	4	3		7			4				7	6
5581	" "	Omalanthus ?nervosus								6	4		2	4							
6282	" "	Phyllanthus nervosus	13	4	3	6	12					8	9	5	13	14	11	9	15	10	10
6311	" "	gen.1.			3																
6335	" "	gen. 2.	6	2	4		2					2	6		3		4	8	6	7	4
6457	Fagaceae	Castanopsis acuminatissima	15	12	8	10	16		5			7	7	9	6		8	10	15	11	7
6485	"	Nothofagus sp.1	12	8	6	5	9					3			4	4		2	4	6	
6337	Himantandraceae	Galbulimima belgraveana										4	2		2						
6270	Lauraceae	Cinnamomum sp.2										4			5		2	3	4	4	
6321	"	Cryptocarya sp.1	5			4		13	6	5	2	5	15	4	6		2	6		5	
6459	"	Cryptocarya sp.4			3	4	6	5	3	2	1	5	7	3	5	3	3	6	8	6	6
6333	"	Endiandra sp.2	12	7		5						4		4	4		3			4	
6502	"	?Litsea sp.															4	6	9	6	6
	Liliaceae	Cordyline sp.				4				4	3				2	4			2		2
6482	Loganiaceae	Geniostema arfakense										4	7			3					
6244	Melastomataceae	Astronia sp.1	5				13		4			2								2	
6487	Moraceae	Artocarpus vrieseanus						1	7		3		2								
5757	"	Ficus dammaropsis														2					
6440	"	Ficus endochaete						7	4		3	3				2					
6466	"	Ficus gul			6	2		3	9	10	14	3	8		3	6					
6342	"	Ficus tonsa						6	6	9	14	4	10	3	8	4	2	5	4	3	3
6421	Monimiaceae	Kibara sp.3		6	6	8						6		7	6		13	12	6	9	7
6427	Moraceae	Streblus urophyllus	4	7								2					3				
6441	Myrsinaceae	?Ardisia sp.		7				4	6	1	1	6			5		5	7		8	
6319	" "	Discocalyx sp.					4						5								
6293	" "	Maesa sp.										3			5						
6285	Myrtaceae	Syzygium sp.2						3	3				8	2	4	4	5	9	9	9	3
6469	"	Syzygium sp.3						2							3						
6314	"	Syzygium sp.5															3				
6345	"		4	5																	
6380	Ochnaceae	Schuurmansia henningsii					5					4	4	4	9	18				5	6
	Palmae	'Yaga'	2	3	4		5					2			12	4					3
	Pandanaceae	Pandanus sp.1			6	3							1								

ANU No.	Family	Genus & Species	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218
	Pandanaceae	Pandanus sp.2			1	6						4			8	4				4	
6259	Podocarpaceae	Podocarpus neriifolius							2											1	
6289	Proteaceae	Finschia sp.			1													1			
6434	Rhamnaceae	Alphitonia incana	4	9	5	5															
6473	Rhizophoraceae	Gynotroches axillaris	5	6	7	4	9					1	10		4	4			3	3	3
6284	Rosaceae	Prunus costata					6					5	3	4	3			2	6	8	6
6344	"	Prunus pullei	8	9	5	2	3		4			4						6	3	7	5
6249	Rubiaceae	Timonius belensis					1														5
6436	"	Timonius sp.	8	4		7						3	5		8	4	12	9	8	3	5
6218	"	Wendlandia sp.						8	3	7	11			12		9				2	
6430	Rutaceae	Acronychia sp.2	9	4	9		5					4	10	4		3	8	3			
6486	"	Evodia sp.1						2				7				4	5	11	3		
6432	"	Evodia sp.2						1				4									
6458	"	Evodia sp.6	4	2	7	5				5	3	3			3						
6435	"	Evodiella sp.	10	4	2	9			4	4	2	3	8	3	4	10			2	9	6
6347	Sapindaceae	Guioa sp.			2	5	2					4	10	7	7		4	5	5	5	2
6331	"	Mischocarpus sp.						7		6	4				4	1	1				
6349	"	gen. 1.	4	7	4	5	10	4	3			3		7	5		5	4	4	4	5
6329	Sapotaceae	Planchonella macropoda			4	4															
6462	Saurauiaceae	Saurauia sp.3	15	4	1	4	1									1				2	
6467	"	Saurauia sp.11															2		4		
6277	Staphyleaceae	Turpinia pentandra												4	6	3					
6343	Symplocaceae	Symplocos sp.	10	4			14							2	4	2			3	4	4
6298	Theaceae	Eurya meizophylla	10	8			6									3	1	5	7		
6414	"	Eurya oxysepala	10	6		5			4			6		4	4	4					
6481	Trimeniaceae	Trimenia papuana	14	3			8			3						4					

Wurup - Mt Oga

Oak forest

No. Individuals per plot

ANU No.	Family	Genus & Species	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218
6353	Ericaceae	Dimorphanthera alpina																x	x		
6376	"	Dimorphanthera denticulifera					x														
6271	Monimiaceae	Palmeria sp. 3	x	x	x		x								x				x		
	Pandanaceae	Freycinetia sp.	x	x	x		x					x	x	x	x	x				x	x
6202	Philesciaceae	Geitonoplesium cymosum																x			
6408	Piperaceae	Piper sp. 1													x	x	x		x		
6415	"	Piper sp. 5	x	x				x	x	x	x	x		x		x					
	Poaceae	Bambusa sp.	x	x	x	x	x							x						x	x
6261	"	Nastus productus	x	x	x	x	x					x	x	x	x	x	x	x	x	x	x
5573	Rosaceae	Rubus moluccanus	x				x		x				x	x	x	x					
6328	Vitaceae	Cayratia sp.	x	x	x		x							x	x						
6346	"	Tetrastigma sp.					x														
6470	Acanthaceae	Dicliptera sp.												x	x	x					
	Araceae									x											
6082	Asteraceae	Blumea arnakidophora							x	x	x										
6003	Cyperaceae	Carex ?beccans							x	x	x	x	x	x		x					
5575	Fabaceae	Desmodium repandum								x	x			x							
6269	Gesneriaceae	Cyrtandra sp. 3				x															
6032	Lamiaceae	Plectranthus sp. 1												x		x					
6216	Melastomataceae	Poikilogyne sp.							x					x		x					
6102	Orchidaceae	?Eria sp.															x				
6066	Poaceae	Miscanthus floridulus							x					x					x		
6428	Rubiaceae	Amaracarpus sp.1															x	x	x	x	
6477	"	Amaracarpus sp. 2			x	x	x														
6377	"	Amaracarpus sp. 3					x	x		x	x			x			x	x	x		
6422	Urticaceae	Cypholophus						x		x	x					x					
6375	"	Elatostema sp. 1			x	x	x	x	x	x	x					x	x	x	x	x	x
6312	"	Elatostema sp. 2			x	x		x	x	x	x				x						
6423	"	Elatostema sp. 3			x	x									x	x	x	x	x	x	
6368	Zingiberaceae	Alpinia sp. 3		x			x			x	x						x	x	x		
6144	"	Gen. 2	x				x		x							x	x	x			
	"							x						x		x					
6022	Cyatheaceae	Gen. 2								x											
	"					x															x
	"				x			x	x	x	x	x	x		x	x			x	x	x
6029	Gleicheniaceae	Gleichenia hooglandii							x				x	x	x	x			x		
6086	Marattiaceae				x																
	Pteridaceae	'Pint'								x	x										

ANU No.	Family	Genus/Species	Mt Hagen Mixed Forest 3345m — Height Classes (m) 0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	Diameter Classes (cm) 0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-	Mt Hagen Mixed Forest 3040m — Height Classes (m) 0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	Diameter Classes (cm) 0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-
6262	Aquifoliaceae	Ilex sp.3	133	2	4	13	6	1			129	11	11	4	3			1																		
6320	Aquifoliaceae	Ilex sp.1	30								30																									
6351	Asteraceae	Olearia sp.3	59	1							60									4	3	1						6	2							
6327	Antherospermaceae	Dryadodaphne sp.																																		
6325	Clusiaceae	Garcinia sp.3																																		
6248	Cunoniaceae	Schizomeria serrata																		197	2	1	2	4	4	11		199	4	1	2	2	2	2	4	5
6283	Cunoniaceae	Spiraeopsis brassii																																		
6278	Cunoniaceae	Weinmannia sp.																																		
6410	Elaeocarpaceae	Elaeocarpus crenulatus	133	2	7	13	13	8			131	16	11	6	3	1	4	5	1	64	3	3		4	3	4		67	3	2	2	1	3			3
6425	Elaeocarpaceae	Elaeocarpus ?saveri																		198	6	9	3					208	6	2						
6247	Elaeocarpaceae	Elaeocarpus sp.1																		135		2	2		3	1		135	3	1	1	1		1	1	
6431	Elaeocarpaceae	Sericolea sp.	100	5	6	1	4				103	7	4	2						162	4	4	1		2	1		169	1	1	1		1	1		
6317	Elaeocarpaceae	Sloanea sp.2+sp.3																																		
6356	Ericaceae	Vaccinium apiculatum	50	1		3	4	6			50	1	3	1	1	3	1	2	3	225	4	1	4	1	2	5		230	3	2	1			1	1	4
6255	Escalloniaceae	Polyosma sp.	210	26	43	33	7				236	48	17	8	6	2	2			205	5	2	2		1			209	3	1		1			1	
6360	Escalloniaceae	Quintinia sp.	137	4	4	12	22	7			149	3	9	3	8	6	6	2		189	2	2	3	5	5	7		191	6	1	1	5	4	1	2	2
6439	Euphorbiaceae	Macaranga ?womersleyi																																		
6334	Euphorbiaceae	Omalanthus nervosus																																		
6251	Euphorbiaceae	Omalanthus sp.1																		6		2		3	1			6	1	1	2	2				
6294	Fagaceae	Nothofagus sp.2																																		
6311	Flacourtiaceae	Casearia sp.																																		
6426	Lauraceae	Cryptocarya sp.1																		467	1	1	4	4	2	2		470		5		3		1	2	
6333	Lauraceae	Endiandra sp.2																																		
6246	Lauraceae																			9	1	3	3	1				10	5	1		1				
6244	Melastomataceae	Astronia sp.1																		80	1	4	5	2				80	4	5	1	2				
6421	Monimiaceae	Kibara sp.3																		203	3	5	7	2				205	7	3	4	1				
6440	Moraceae	Ficus endochaete																																		
6441	Myrsinaceae	?Ardisia sp.	248	20	36	9	2				254	46	11	5		1																				
6265	Myrsinaceae	Rapanea sp.2	123	3	4	4	7				128	3	5	3	2																					
6354	Myrsinaceae	Rapanea sp.3	213	17	10	14	2				230	21	5				1																			
6254	Myrtaceae	Syzygium adelphicum	240	2	5	6	4	2			241	4		5	2	4	3			224				1	1	1		224		1			1			1
6285	Myrtaceae	Syzygium sp.2	122		2		3				123	1			1	2																				
6314	Myrtaceae	Syzygium sp.5																																		
6380	Ochnaceae	Schuurmansia henningsii	1								1									239	9	9	5	4	1	2		240	17	4	2	2	4			

Mt Hagen Mixed Forest 3345m

ANU No.	Family	Genus/Species	Height Classes (m) 0-3	3-6	6-9	9-12	12-15	15-18	Diameter Classes (cm) 0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-
6397	Pittosporaceae	Pittosporum pullifolium	45	2	7	2	1		48	4	5						
6284	Rosaceae	Prunus costata															
6272	Rosaceae	Prunus pullei	19			1			19		1			1			
6249	Rubiaceae	Timonius belensis	13			1			13	1							
6430	Rutaceae	Acronychia sp.2															
6486	Rutaceae	Evodia sp.1															
6381	Saurauiaceae	Saurauia sp.1	135	4	9	12			138	9	10	2		1			
6277	Staphyleaceae	Turpinia pentandra															
6420	Symplocaceae	Symplocos sp.3	214	1					215								
6414	Theaceae	Eurya oxysepala	117	4	30	17	5		125	26	15	5	1	1			
6374	Winteraceae	Drimys sp.3	228	24	30	12	2		238	33	11	3		1			
6392	Winteraceae	Drimys sp.4	177	4	3	2	3		164	9	2		2				
	Pandanaceae	"Um"															
6259	Podocarpaceae	Podocarpus neriifolius	67	6	3		1	4	73	3	1			1	1		2
6280	Aquifoliaceae	Sphenostemon papuanum	58						58								
6370	Araliaceae	Harmsiopanax sp.	29						29								
6352	Araliaceae	Schefflera sp.1	215	23	25	5			239	19	6	3			1		
6424	Escalloniaceae	Polyosma sp.1	92	4	2	1			96	3							
5530	Euphorbiaceae	Macaranga ?warburgiana															
6282	Euphorbiaceae	Phyllanthus nervosus															
6253	Gesneriaceae	Cyrtandra sp.1															
6279	Lauraceae	Cinnamomum sp.2															
6245	Monimiaceae	Kibara sp.2															
6427	Moraceae	Steblus urophyllus															
6415	Piperaceae	Piper sp.5	4		2				5	1							
6289	Proteaceae	Finschia sp.															
6434	Rhamnaceae	Alphitonia incana															
6258	Rutaceae	Evodia sp.5	55	2	4	3			59	3	2						
6349	Sapindaceae																
6256	Saurauiaceae	Saurauia sp.4															
6433	Thymelaeaceae	Phaleria ?aogerensis															
6270	Winteraceae	Drimys sp.2	347	26	16				372	15	2						

Mt Hagen Mixed Forest 3040m

ANU No.	Family	Genus/Species	Height Classes (m) 0-3	3-6	6-9	9-12	12-15	15-18	18-21	Diameter Classes (cm) 0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-
6397	Pittosporaceae	Pittosporum pullifolium	20							20								
6284	Rosaceae	Prunus costata																
6272	Rosaceae	Prunus pullei																
6249	Rubiaceae	Timonius belensis	143	2			1			144	1				1			
6430	Rutaceae	Acronychia sp.2	143	3	5	6	2			148	4	4	1	1	1			
6486	Rutaceae	Evodia sp.1																
6381	Saurauiaceae	Saurauia sp.1	41							41								
6277	Staphyleaceae	Turpinia pentandra																
6420	Symplocaceae	Symplocos sp.3	206	9	9	6	11	2	2	212	9	6	4	6	4	3		1
6414	Theaceae	Eurya oxysepala	17							17								
6374	Winteraceae	Drimys sp.3	77		2	3	5	2		77	2	4	3			3		
6392	Winteraceae	Drimys sp.4	92	1				2	1	93					1			2
	Pandanaceae	"Um"																
6259	Podocarpaceae	Podocarpus neriifolius	6			1				7								
6280	Aquifoliaceae	Sphenostemon papuanum																
6370	Araliaceae	Harmsiopanax sp.	26	2						27	1							
6352	Araliaceae	Schefflera sp.1	94	1						95								
6424	Escalloniaceae	Polyosma sp.1	142	13	5	1	2			152	7	4						
5530	Euphorbiaceae	Macaranga ?warburgiana	2		1					3								
6282	Euphorbiaceae	Phyllanthus nervosus																
6253	Gesneriaceae	Cyrtandra sp.1	53							53								
6279	Lauraceae	Cinnamomum sp.2																
6245	Monimiaceae	Kibara sp.2	13							13								
6427	Moraceae	Steblus urophyllus	155	20	13	2				179	11							
6415	Piperaceae	Piper sp.5																
6289	Proteaceae	Finschia sp.																
6434	Rhamnaceae	Alphitonia incana																
6258	Rutaceae	Evodia sp.5	66		3	1	5	1		67	6	1	2					
6349	Sapindaceae																	
6256	Saurauiaceae	Saurauia sp.4																
6433	Thymelaeaceae	Phaleria ?aogerensis	102							102								
6270	Winteraceae	Drimys sp.2	139	3	1					143								

ANU No.	Family	Genus/Species	Mt Hagen Mixed Forest 2890m – Height Classes (m)								Mt Hagen Mixed Forest 2890m – Diameter Classes (cm)									Mt Hagen Mixed Forest 2740m – Height Classes (m)								Mt Hagen Mixed Forest 2740m – Diameter Classes (cm)								
			0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-
6262	Aquifoliaceae	Ilex sp.3																																		
6320	Aquifoliaceae	Ilex sp.1																																		
6351	Asteraceae	Olearia sp.3	15		2	2					18	1								1			1					1	1							
6327	Antherospermaceae	Dryadodaphne sp.																																		
6325	Clusiaceae	Garcinia sp.3																																		
6248	Cunoniaceae	Schizomeria serrata	30	1	2						33									63	1	2		2		5		64		3	1	1	2	1		1
6283	Cunoniaceae	Spiraeopsis brassii																		18			1					18			1					
6278	Cunoniaceae	Weinmannia sp.																		16	2							18								
6410	Elaeocarpaceae	Elaeocarpus crenulatus	20			1	2		2		20	2				1		1	1	80	1	2		2	1	1		82	1		2	1	1			
6425	Elaeocarpaceae	Elaeocarpus ?sayeri	81					2			81		2							134	8	10	9	3				147	14		3					
6247	Elaeocarpaceae	Elaeocarpus sp.1	12	1							13									34		1			1			35					1			
6431	Elaeocarpaceae	Sericolea sp.	21	1		2	3		3		22	3	1	1	3					62	2	4	2	1		2		65	3		1	2	1	1		
6317	Elaeocarpaceae	Sloanea sp.2+sp.3																																		
6356	Ericaceae	Vaccinium apiculatum																																		
6255	Escalloniaceae	Polyosma sp.	70	11	2						81	2																								
6360	Escalloniaceae	Quintinia sp.	64	7	2	2	3		1		72	3	1	1	1	1				80		1	2		4	1		80	3				1	1	1	2
6439	Euphorbiaceae	Macaranga ?womersleyi																																		
6334	Euphorbiaceae	Omalanthus nervosus																																		
6251	Euphorbiaceae	Omalanthus sp.1	11								11																									
6294	Fagaceae	Nothofagus sp.2																																		
6311	Flacourtiaceae	Casearia sp.	12								12									60			1			1		60		2						
6426	Lauraceae	Cryptocarya sp.1	88	5	1	2			1		93	2		1				1		232	1		2	2	2		1	233	3	1	2					
6333	Lauraceae	Endiandra sp.2																		69	1						3	70				1	1	1		
6246	Lauraceae		6		1						7																									
6244	Melastomataceae	Astronia sp.1																		100	4	7	6	3	1			107	8	3	3					
6421	Monimiaceae	Kibara sp.3	49								49									139		2						139	2							
6440	Moraceae	Ficus endochaete																																		
6441	Myrsinaceae	?Ardisia sp.																																		
6265	Myrsinaceae	Rapanea sp.2																																		
6354	Myrsinaceae	Rapanea sp.3																		21	2							23								
6254	Myrtaceae	Syzygium adelphicum	36								36									46					2	2		46					2	1		1
6285	Myrtaceae	Syzygium sp.2	71	8				1	1		78	1			1		1			199		1	1			2		200	1	1		1				
6314	Myrtaceae	Syzygium sp.5																																		
6380	Ochnaceae	Schuurmansia henningsii	35	1		2	6	2			36	1	4	4		1				104	3	1	2	3	2	4		108	2	2	3	1	2	1		

AHU No.	Family	Genus/Species	Mt Hagen Mixed Forest 2890m: Height Classes (m) 0-3	3-6	6-9	9-12	12-15	15-18	18-21	Mt Hagen Mixed Forest 2890m: Diameter Classes (cm) 0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	Mt Hagen Mixed Forest 2740m: Height Classes (m) 0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	Mt Hagen Mixed Forest 2740m: Diameter Classes (cm) 0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-
6397	Pittosporaceae	Pittosporum pullifolium	3							3								41	1	1		1		1		43	1			1				
6284	Rosaceae	Prunus costata																160		2						161	1							
6272	Rosaceae	Prunus pullei	18	1						19								130				2		2	3	129		1	1	1	1	3	1	3
6249	Rubiaceae	Timonius belensis	34	3	2	2	2		2	36	4		2	1	1		1	102	3	1	2					106		1	1					
6430	Rutaceae	Acronychia sp.2	25	7	1		1			32	2																							
6486	Rutaceae	Evodia sp.1																4								4								
6381	Saurauiaceae	Saurauia sp.1	1				1			2								83	7	6	1	2	3	2		88	4	3	4	1				
6277	Staphyleaceae	Turpinia pentandra																62		3	3		1			63	3	2		1				
6420	Symplocaceae	Symplocos sp.3																18		1	1	1				19		2						
6414	Theaceae	Eurya oxysepala																81	9	7	9	2				90	14	2	2					
6374	Winteraceae	Drimys sp.3	35	11	8	3	1			52	4	1	1					67		3	1	1				69	3							
6392	Winteraceae	Drimys sp.4																																
	Pandanaceae	"Um"	4	4						4		2	1	1				5								5								
6259	Podocarpaceae	Podocarpus neriifolius																115	2	7	6	2				122	6	4						
6280	Aquifoliaceae	Sphenostemon papuanum																																
6370	Araliaceae	Harmsiopanax sp.	1							1								21								21								
6352	Araliaceae	Schefflera sp.1	13			1				13	1							84	31	43	3	1				127	42	2	1					
6424	Escalloniaceae	Polyosma sp.1	48	15	3					62	4							1		1						2								
5530	Euphorbiaceae	Macaranga ?warburgiana	10	3						13								176	18	24	17	7	2	3		200	24	19	4					
6282	Euphorbiaceae	Phyllanthus nervosus	58	1	4	3				59	5	1	1					255								255								
6253	Gesneriaceae	Cyrtandra sp.1	37							37								36	1	2	1	1				38	3							
6279	Lauraceae	Cinnamomum sp.2																																
6245	Monimiaceae	Kibara sp.2																156	11	7						167	7							
6427	Moraceae	Steblus urophyllus	63	5	3					69	2																							
6415	Piperaceae	Piper sp.5																6	1	3		1				8	3							
6289	Proteaceae	Finschia sp.																																
6434	Rhamnaceae	Alphitonia incana																60	3							62	1							
6258	Rutaceae	Evodia sp.5	13		1	1				13	1	1																						
6349	Sapindaceae																																	
6256	Saurauiaceae	Saurauia sp.4																14					1			14		1						
6433	Thymelaeaceae	Phaleria ?sogerensis	25	1						26								58	4		1					62	1							
6270	Winteraceae	Drimys sp.2	78	5	9					81	11																							

			Mt Hagen Degraded Mixed Forest 2705m																	Mt Hagen Beech Forest 2740m																
			Height Classes (m)								Diameter Classes (cm)									Height Classes (m)								Diameter Classes (cm)								
ANU No.	Family	Genus/Species	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-
6262	Aquifoliaceae	Ilex sp.3																																		
6320	Aquifoliaceae	Ilex sp.1																																		
6351	Asteraceae	Olearia sp.3	27		7	5					27	5	4	2	1							1							1							
6327	Antherospermaceae	Dryadodaphne sp.																																		
6325	Clusiaceae	Garcinia sp.3																																		
6248	Cunoniaceae	Schizomeria serrata	23	1	2			1	1	3	23	1		2		1			4	6		1						7								
6283	Cunoniaceae	Spiraeopsis brassii																		2		1						2	1							
6278	Cunoniaceae	Weinmannia sp.	14								14									90	3	1		1		1		93	1			1				1
6410	Elaeocarpaceae	Elaeocarpus cremulatus	12		1						12	1								43	3	4	4	1		1		47	3	5				1		
6425	Elaeocarpaceae	Elaeocarpus ?nayeri	35					1			35			1						448	27	50	20	8	3			513	24	12	5	1	1			
6247	Elaeocarpaceae	Elaeocarpus sp.1	16						1		16								1																	
6431	Elaeocarpaceae	Sericolea sp.	13		2	1					13	2	1							91	1	7	5	3	3			95	6	6	3					
6317	Elaeocarpaceae	Sloanea sp.2+sp.3																																		
6356	Ericaceae	Vaccinium apiculatum																																		
6255	Escalloniaceae	Polyosma sp.																																		
6360	Escalloniaceae	Quintinia sp.	7								7									65	4				1	1		68	1		1		1			
6439	Euphorbiaceae	Macaranga ?womersleyi																																		
6334	Euphorbiaceae	Omalanthus nervosus	4		1	1	1				4	1		1		1				24		4						25	3							
6251	Euphorbiaceae	Omalanthus sp.1																		19		3						22								
6294	Fagaceae	Nothofagus sp.2	1							1	1								1	160	6	10	1	3	2	16	18	171	4	1	2	3	1	7	9	18
6311	Flacourtiaceae	Casearia sp.	3				2				3		1		1					116		1	1	1				117		2						
6426	Lauraceae	Cryptocarya sp.1	58		2	1	1				55	3	1	2				1		319	1	4	1	1				313	6	1	4	1	1			
6333	Lauraceae	Endiandra sp.2	8			2		1		1	11								1																	
6246	Lauraceae		21	2		3			1		22	2	1	1					1	4								4								
6244	Melastomataceae	Astronia sp.1	29	3		4					30		3	1	1		1			95	1	7						99	4							
6421	Monimiaceae	Kibara sp.3	37	1							38									181	3	3	3	1	1			184	5	1	2					
6440	Moraceae	Ficus endochaete																																		
6441	Myrsinaceae	?Ardisia sp.	19		1	1					20		1							196	16	15	13	1				216	13	1		1				
6265	Myrsinaceae	Rapanea sp.2																																		
6354	Myrsinaceae	Rapanea sp.3	45	4		2					49	2																								
6254	Myrtaceae	Syzygium adelphicum																		98		5	1	1		1		102		3					1	
6285	Myrtaceae	Syzygium sp.2	9								9									193	1	2	1	2	2	3		194	4	2			2	1		1
6314	Myrtaceae	Syzygium sp.5																																		
6380	Ochnaceae	Schuurmansia henningsii	18				1	1			18				2					55		1		2				56		2						

			Mt Hagen Degraded Mixed Forest 2705m															Mt Hagen Beech Forest 2740m													
			Height Classes (m)							Diameter Classes (cm)								Height Classes (m)							Diameter Classes (cm)						
ANU No.	Family	Genus/Species	0-3	3-6	6-9	9-12	12-15	15-18	18-21	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	0-3	3-6	6-9	9-12	12-15	15-18	18-21	0-6	6-12	12-18	18-24	24-30	30-36	36-42
6397	Pittosporaceae	Pittosporum pullifolium																2							2						
6284	Rosaceae	Prunus costata	11							11								176	2	2	3	2	2		180	3	2	1			1
6272	Rosaceae	Prunus pullei	7							7								359	8	11	1				375	3		1			
6249	Rubiaceae	Timonius belensis	40	2		1				41	1	1						165	1	4	2				168	2	2				
6430	Rutaceae	Acronychia sp.2																322	17	16	2				347	10					
6486	Rutaceae	Evodia sp.1																													
6381	Saurauiaceae	Saurauia sp.1	3							3								3				1			3					1	
6277	Staphyleaceae	Turpinia pentandra	46		1	4	2	3	1	46	1	2	2	4			2														
6420	Symplocaceae	Symplocos sp.3	12			1		1		12		1			1			21							21						
6414	Theaceae	Eurya oxysepala	4		1					4		1						66				1			66			1			
6374	Winteraceae	Drimys sp.3	55	6	6	8	2			62	6	6		2	1			155	11	21	8				183	12					
6392	Winteraceae	Drimys sp.4																134	1	2	1			1	136	2			1		
	Pandanaceae	"Um"	7			1				7					1			37	4	1	1	2			34	1	5	2	1	1	1
6259	Podocarpaceae	Podocarpus neriifolius																13							13						
6280	Aquifoliaceae	Sphenostemon papuanum	19		1		1			19	2							30	1		1				31		1				
6370	Araliaceae	Harmsiopanax sp.	26		3					26	3																				
6352	Araliaceae	Schefflera sp.1	24							24								56							56						
6424	Escalloniaceae	Polyosma sp.1	41	4	2					44	2							150	9	18	2				168	10	1				
5530	Euphorbiaceae	Macaranga ?warburgiana	8							8								2		1	1				2	2					
6282	Euphorbiaceae	Phyllanthus nervosus																32		2					34						
6253	Gesneriaceae	Cyrtandra sp.1	142	5	1					151	2							4							4						
6279	Lauraceae	Cinnamomum sp.2																													
6245	Monimiaceae	Kibara sp.2																117	2	11					128	2					
6427	Moraceae	Steblus urophyllus	16	1	1					17	1							260	8	20	6	2			286	8		2			
6415	Piperaceae	Piper sp.5																10							10						
6289	Proteaceae	Finschia sp.																													
6434	Rhamnaceae	Alphitonia incana																													
6258	Rutaceae	Evodia sp.5	25		2	1	1	1		25	2		3					117	4	8	1				128	2					
6349	Sapindaceae																	31		1	2				32	2					
6256	Saurauiaceae	Saurauia sp.4	40	1	3					40	4							5							5						
6433	Thymelaeaceae	Phaleria ?sogerensis	7							7								123							123						
6270	Winteraceae	Drimys sp.2	53	2	9					59	5							193	2	9					199	5					

ANU No.	Family	Genus/Species	Mt Hagen Beech Forest 2585m — Height Classes (m)								Diameter Classes (cm)									Mt Hagen Degraded Beech Forest + Regrowth 2400m — Height Classes (m)								Diameter Classes (cm)								
			0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-
6262	Aquifoliaceae	Ilex sp.3																																		
6320	Aquifoliaceae	Ilex sp.1																		121	1	3	3		1			123	3	1	1		1			
6351	Asteraceae	Olearia sp.3	8								8									23	4							24	3							
6327	Antherospermaceae	Dryadodaphne sp.																		80	4	1			1	1	1	80	6				1			1
6325	Clusiaceae	Garcinia sp.3																		258	1							257			1		1			
6248	Cunoniaceae	Schizomeria serrata	32		2	1					32	1	1		1					142	1	3						143	2			1				
6283	Cunoniaceae	Spiraeopsis brassii																		38	1	3						42								
6278	Cunoniaceae	Weinmannia sp.	42						1		42				1					5		2						7								
6410	Elaeocarpaceae	Elaeocarpus crenulatus	63	2	1	1	1		1		66	1			1			1		28	1	4						32	3							
6425	Elaeocarpaceae	Elaeocarpus ?sayeri	127	3	20	7	5	2	1		145	14	1	2	1			1		129	3	6	1	1				133	6		1					
6247	Elaeocarpaceae	Elaeocarpus sp.1	10					1			10					1				37								37								
6431	Elaeocarpaceae	Sericolea sp.	15	1		2					16	2								27	2		1					29	1							
6317	Elaeocarpaceae	Sloanea sp.2+sp.3																		59	1							60								
6356	Ericaceae	Vaccinium apiculatum																																		
6255	Escalloniaceae	Polyosma sp.																																		
6360	Escalloniaceae	Quintinia sp.																		24						2		24					1		1	
6439	Euphorbiaceae	Macaranga ?womersleyi																																		
6334	Euphorbiaceae	Omalanthus nervosus	1	1							2																									
6251	Euphorbiaceae	Omalanthus sp.1																																		
6294	Fagaceae	Nothofagus sp.2	50		4	8	3	1	2	2	55	5	4			1			5	140	5	16		2			6	155	4			2				7
6311	Flacourtiaceae	Casearia sp.	67		4	1	1				70	3								55		2						55	2							
6426	Lauraceae	Cryptocarya sp.1	72	4		3	1				76	1	1	1	1					91	1	2						93	1							
6333	Lauraceae	Endiandra sp.2																		135	5			1				139	1		1					
6246	Lauraceae					1						1																								
6244	Melastomataceae	Astronia sp.1	36								36									69	1							70								
6421	Monimiaceae	Kibara sp.3	103		3	1					103	3	1							136	1		2			1		137	1	1					1	
6440	Moraceae	Ficus endochaete																																		
6441	Myrsinaceae	?Ardisia sp.	67	5	21	6	2				89	9	2	1						147	5			1				146	5	1	1					
6265	Myrsinaceae	Rapanea sp.2																																		
6354	Myrsinaceae	Rapanea sp.3																		52	3	2						53	4							
6254	Myrtaceae	Syzygium adelphicum	1			1					2																									
6285	Myrtaceae	Syzygium sp.2	73	1	3	3	1				74	6	1							97		1				1		98								1
6314	Myrtaceae	Syzygium sp.5																		64	1	1				1		65	1						1	
6380	Ochnaceae	Schuurmansia henningsii	14			1		1			14	1				1				68				1				69			1					

Mt Hagen Beech Forest 2585m

ANU No.	Family	Genus/Species	Height Classes (m) 0-3	3-6	6-9	9-12	12-15	15-18	18-21	Diameter Classes (cm) 0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-
6397	Pittosporaceae	Pittosporum pullifolium	18							18								
6284	Rosaceae	Prunus costata	72				1	1	1	72			1	1		1		
6272	Rosaceae	Prunus pullei	78							78								
6249	Rubiaceae	Timonius belensis	76			4				76	3	1						
6430	Rutaceae	Acronychia sp.2	69	3	1	1				72	2							
6486	Rutaceae	Evodia sp.1																
6381	Saurauiaceae	Saurauia sp.1																
6277	Staphyleaceae	Turpinia pentandra	48		2	1	1			50	1		1					
6420	Symplocaceae	Symplocos sp.3																
6414	Theaceae	Eurya oxysepala	48			2				48	1	1						
6374	Winteraceae	Drimys sp.3	24		3	1				26	1	1						
6392	Winteraceae	Drimys sp.4	41							41								
	Pandanaceae	"Um"	34	7		1	1			32	3	4	2	1				1
6259	Podocarpaceae	Podocarpus neriifolius	5							5								
6280	Aquifoliaceae	Sphenostemon papuanum	83		2					84	1							
6370	Araliaceae	Harmsiopanax sp.	6			1				6	1							
6352	Araliaceae	Schefflera sp.1	27		1					28								
6424	Escalloniaceae	Polyosma sp.1	85	2	6	4				92	5							
5530	Euphorbiaceae	Macaranga ?warburgiana	1		1					2								
6282	Euphorbiaceae	Phyllanthus nervosus	45							45								
6253	Gesneriaceae	Crytandra sp.1	75			1				75		1						
6279	Lauraceae	Cinnamomum sp.2	14							14								
6245	Monimiaceae	Kibara sp.2	40		16	7	1			55	8	1						
6427	Moraceae	Steblus urophyllus	121	3	6	1				127	3	1						
6415	Piperaceae	Piper sp.5	31							31								
6289	Proteaceae	Finschia sp.	10		1	1	1			10		2	1					
6434	Rhamnaceae	Alphitonia incana																
6258	Rutaceae	Evodia sp.5	78	2	13	6		1		90	7	2	1					
6349	Sapindaceae		5			1				6								
6256	Saurauiaceae	Saurauia sp.4	6		1					6	1							
6433	Thymelaeaceae	Phaleria ?sogerensis	22							22								
6270	Winteraceae	Drimys sp.2	102		2					103	1							

Mt Hagen Degraded Beech Forest + Regrowth 2400m

ANU No.	Family	Genus/Species	Height Classes (m) 0-3	3-6	6-9	9-12	12-15	15-18	18-21	Diameter Classes (cm) 0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48
6397	Pittosporaceae	Pittosporum pullifolium	2							2							
6284	Rosaceae	Prunus costata	76	2	5					83							
6272	Rosaceae	Prunus pullei	169	3		1				172	1						
6249	Rubiaceae	Timonius belensis	74	1					1	74	1						1
6430	Rutaceae	Acronychia sp.2															
6486	Rutaceae	Evodia sp.1	46		3	1				49	1						
6381	Saurauiaceae	Saurauia sp.1	51							51							
6277	Staphyleaceae	Turpinia pentandra	6							6							
6420	Symplocaceae	Symplocos sp.3	108		2					108	2						
6414	Theaceae	Eurya oxysepala	91	4	4				1	95	3	1		1			
6374	Winteraceae	Drimys sp.3	4	1						5							
6392	Winteraceae	Drimys sp.4	37		1					57	1						
	Pandanaceae	"Um"															
6259	Podocarpaceae	Podocarpus neriifolius	38	1						39							
6280	Aquifoliaceae	Sphenostemon papuanum	29							29							
6370	Araliaceae	Harmsiopanax sp.															
6352	Araliaceae	Schefflera sp.1	4							4							
6424	Escalloniaceae	Polyosma sp.1	40	1						40	1						
5530	Euphorbiaceae	Macaranga ?warburgiana	51							51							
6282	Euphorbiaceae	Phyllanthus nervosus	365	41	6					402	10						
6253	Gesneriaceae	Crytandra sp.1	23		1					23	1						
6279	Lauraceae	Cinnamomum sp.2	132	3						135							
6245	Monimiaceae	Kibara sp.2	1	1						1	1						
6427	Moraceae	Steblus urophyllus	170	1	2	1				171	3						
6415	Piperaceae	Piper sp.5	145	1						146							
6289	Proteaceae	Finschia sp.															
6434	Rhamnaceae	Alphitonia incana	14	2	1	1				17	1						
6258	Rutaceae	Evodia sp.5	129	12	6					144	2	1					
6349	Sapindaceae		15							15							
6256	Saurauiaceae	Saurauia sp.4	84	5	12					100	1						
6433	Thymelaeaceae	Phaleria ?sogerensis															
6270	Winteraceae	Drimys sp.2	10							10							

Mt Hagen
Degraded Beech Forest + Regrowth
2280m

No.	Family	Genus/Species	Height Classes (m) 0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	Diameter Classes (cm) 0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-
6262	Aquifoliaceae	Ilex sp. 3																	
6320	Aquifoliaceae	Ilex sp. 1	40		2						41	1							
6351	Asteraceae	Olearia sp. 3	1		2						1	2							
6327	Antherospermaceae	Dryadodaphne sp.	6				1				6					1			
6325	Clusiaceae	Garcinia sp. 3	54								54								
6248	Cunoniaceae	Schizomeria serrata	56	2					1		57	1							1
6283	Cunoniaceae	Spiraeopsis brassii	114	22	25	27	8				150	27	12	2					
6278	Cunoniaceae	Weinmannia sp.																	
6410	Elaeocarpaceae	Elaeocarpus crenulatus	6			1					6	1							
6425	Elaeocarpaceae	Elaeocarpus ?sayeri																	
6247	Elaeocarpaceae	Elaeocarpus sp. 1	12	3	1						13		1						
6431	Elaeocarpaceae	Sericolea sp.	14		1	1					14	2							
6317	Elaeocarpaceae	Sloanea sp 2+sp. 3	54		3		4	2			56	1	3						
6356	Ericaceae	Vaccinium apiculatum																	
6255	Escalloniaceae	Polyosma sp.																	
6360	Escalloniaceae	Quintinia sp.																	
6439	Euphorbiaceae	Macaranga ?womersleyi	96	25	27	12	5		1		129	27	5	2	2	1			
6334	Euphorbiaceae	Omalanthus nervosus																	
6251	Euphorbiaceae	Omalanthus sp. 1																	
6294	Fagaceae	Nothofagus sp. 2	48	6	15	4	4		1	1	60	9	5	2	1				2
6311	Flacourtiaceae	Casearia sp.	42		3	1					42	2	2						
6426	Lauraceae	Cryptocarya sp. 1	62	3	1	2					65	3							
6333	Lauraceae	Endiandra sp. 2	75	1		1	2				75	2		2					
6246	Lauraceae																		
6244	Melastomataceae	Astronia sp. 1	112	5	14	3					126	6	2						
6421	Monimiaceae	Kibara sp. 3	128	1	1						130								
6440	Moraceae	Ficus endochaete	32	1	1	3	1	1			33	1	2		3				
6441	Myrsinaceae	?Ardisia sp.	128	4	10						139	3							
6265	Myrsinaceae	Rapanea sp. 2																	
6354	Myrsinaceae	Rapanea sp. 3	8	2							10								
6254	Myrtaceae	Syzygium adelphicum																	
6285	Myrtaceae	Syzygium sp. 2	14	2							16								
6314	Myrtaceae	Syzygium sp. 5	27			1					27	1							
6380	Ochnaceae	Schuurmansia henningsii	9		1						9	1							
6397	Pittosporaceae	Pittosporum pullifolium	34		3	3	1				34	3	3	1					
6284	Rosaceae	Prunus costata	3		2	1					4	2							
6272	Rosaceae	Prunus pullei	70	5	1						75	1							
6249	Rubiaceae	Timonius belensis	158	8	32	9	6				188	14	7	4					
6430	Rutaceae	Acronychia sp. 2																	
6486	Rutaceae	Evodia sp. 1	71	3	3	3		1			75	1	3	1		1			
6381	Saurauiaceae	Saurauia sp. 1	5								5								
6277	Staphyleaceae	Turpinia pentandra																	
6420	Symplocaceae	Symplocos sp. 3	16								16								
6414	Theaceae	Eurya oxysepala	149	9	11	7	1				162	10	4						
6374	Winteraceae	Drimys sp. 3	7	2	1	1					9	1	1						
6392	Winteraceae	Drimys sp. 4	25					1			25			1					
	Pandanaceae	'Um'																	
6259	Podocarpaceae	Podocarpus neriifolius	5								5								
6280	Aquifoliaceae	Sphenostemon papuanum	23								23								
6370	Araliaceae	Harmsiopanax sp.	10								10								
6352	Araliaceae	Schefflera sp. 1	84	7	7						89	7	2						
6424	Escalloniaceae	Polyosma sp. 1	43	4	2						45	4							
5530	Euphorbiaceae	Macaranga ?warburgiana	73	9	11	3					85	10	1						
6282	Euphorbiaceae	Phyllanthus nervosus	179	21	23	3					206	17	3						
6253	Gesneriaceae	Cyrtandra sp. 1	42								42								
6279	Lauraceae	Cinnamomum sp. 2	79	3	8	2					84	5	3						
6245	Monimiaceae	Kibara sp. 2																	
6427	Moraceae	Streblus urophyllus	86	1	2						88	1							
6415	Piperaceae	Piper sp. 5	117	17	7						133	8							
6289	Proteaceae	Finschia sp.																	
6434	Rhamnaceae	Alphitonia incana	15	10	1						16	9	1						
6258	Rutaceae	Evodia sp. 5	37	3	7	1					43	4	1						
6349	Sapindaceae		103	2	5	2	1				106	5	1	1					
6256	Saurauiaceae	Saurauia sp. 4	36	1	14	5	2				38	13	6	1					
6433	Thymelaeaceae	Phaleria ?sogerensis	2								2								
6270	Winteraceae	Drimys sp. 2																	

ANU No.	Family	Genus & Species	Mt Oga Oak Forest Height classes (m)								Mt Oga Oak Forest Diameter classes (cm)									Wurup Ridgetop Oak Forest Height classes (m)								Wurup Ridgetop Oak Forest Diameter classes (cm)								
			0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-
6489	Anacardiaceae	Rhus taitensis	2	1							3																									
6438	Apocynaceae	Alstonia sp.	5								5																									
6320	Aquifoliaceae	Ilex sp.																		13								13								
6479	"	Sphenostemon papuanum	16								16									21		1	3	2				21	1	3	1	1				
6370	Araliaceae	Harmsiopanax sp.	1								1																									
6471	"	Mackinlaya sp.																		1								1								
6339	"	Polyscias sp.	22	1	2						24	1								5			1					5	1							
6352	"	Schefflera sp.	15								15									36								36								
6325	Clusiaceae	Garcinia sp.3																		29	2							29	2							
6417	Cunoniaceae	Spiraeopsis brassii	5								5									13								13								
6248	"	Schizomeria serrata	59	1	7	3	2		1		60	7	1	2	3					20	2	4	3	1	3	2		21	6	3	1	3		1		
6348	Elaeocarpaceae	Elaeocarpus poculiferus	1								1																									
6247	"	Elaeocarpus sp.	3								3																									
6431	"	Sericolea sp.																		5								5								
6317	"	Sloanea sp. 2/3			1							1								6				1				6		1						
6488	Escalloniaceae	Carpodetus sp.																		5								5								
	"	Polyosma sp.	16	2			1				18			1						4		1						4	1							
6491	Euphorbiaceae	Croton sp.	3				1				3			1																						
6081	"	Glochidion sp. 1	33						1		33	1								12								12								
5530	"	Macaranga ?warburgiana																		4								4								
6439	"	Macaranga ?womersleyi	12	1							13									20				1				20		1						
6282	"	Phyllanthus nervosus	52		3						53	2								37			1					37	1							
6311	"	Gen. 1																		1		1		1				1	1	1						
6335	"	Gen. 2	29			1					29			1						13			1					13	1							
6457	Fagaceae	Castanopsis acuminatissima	14	10	14	10	4	8	4		19	12	9	3	5	4	9	1	2	40		5		5		5	6	40	5	2	4			1	3	6
6485	"	Nothofagus sp. 1	9	1			2		2		10			2		1			1	35				1	2	1		35		2	1			1		
6337	Himantandraceae	Galbulimima belgraveana																		8								8								
6279	Lauraceae	Cinnamomum sp. 2	12	1							13																									
6321	"	Cryptocarya sp. 1	5	1	1						7									35		2		1		1		35	2	1				1		
6459	"	Cryptocarya sp. 4	23	1			2	1			23	1	1			1	1			13								13								
6333	"	Endiandra sp. 2	24								24									21		1				1		21	1	1						
6502	"	?Litsea sp.	29	1		1					30		1																							
	Liliaceae	Cordyline sp.																		4								4								
6482	Loganiaceae	Geniostoma arfakense																		13		1						13		1						
6244	Melastomataceae	Astronia sp. 1	7								7									17		1						17	1							
6466	Moraceae	Ficus gul																		8								8								
6342	"	Ficus tonsr	16	1							17																									
6421	Monimiaceae	Kibara sp. 3	47								47									20								20								
6427	Moraceae	Streblus urophyllus	3								3									11								11								
6441	Myrsinaceae	?Ardisia sp.	11	1							11	1								8		1						8		1						

			Mt Oga Oak Forest: Height classes (m)								Diameter classes (cm)									Wurup Ridgetop Oak Forest: Height classes (m)								Diameter classes (cm)								
ANU No.	Family	Genus & Species	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-
6319	Myrsinaceae	Discocalyx sp.																		4								4								
6285	Myrtaceae	Syzygium sp. 2																		21				2		1		21		2						1
6314	"	Syzygium sp. 5									7			1																						
6345	"	Gen. 1	14								14									9								9								
6380	Ochnaceae	Schuurmansia henningsii	9	2							10	1								5								5								
	Palmae		3								3									14	1							13	1	1						
	Pandanaceae	Pandanus sp. 2																		9								9								
	"	Pandanus sp. 3	4								4									7								7								
6259	Podocarpaceae	Podocarpus neriifolius				1							1																							
6289	Proteaceae	Finschia sp.	1								1												1						1							
6434	Rhamnaceae	Alphitonia incana																		20		2	1					20	2		1					
6473	Rhizophoraceae	Gynotroches axillaris	8	1							9									26		1	3	1				26	1	4						
6284	Rosaceae	Prunus costata	20	1		1					21	1								6								6								
6344	"	Prunus pullei	17	1	2	1					19	1					1			26	1							26	1							
6249	Rubiaceae	Timonius belensis	5								5									4					1			4				1				
6436	"	Timonius sp.	35	2							35	2								17		2						17	1	1						
6210	"	Wendlandia sp.	2								2																									
6430	Rutaceae	Acronychia sp. 2	18			1					18		1							25								25								
6486	"	Evodia sp. 1	19								19									5								5								
6432	"	Evodia sp. 2	2								2																									
6458	"	Evodia sp. 6			1						1									17			1					17	1							
6215	"	Evodiella sp.	35								35									24			2					24	1							
6347	Sapindaceae	Guioa sp.	21								21									9								9								
6349	"	Gen. 1	22								22									30								30								
6329	Sapotaceae	Planchonella macropoda																		7				1				7			1					
6462	Saurauiaceae	Saurauia sp. 3	2								2									23		1		1				23	2							
6467	"	Saurauia sp. 11	4								4																									
6343	Symplocaceae	Symplocos sp.	8	3							10	1								27		1						27	1							
6298	Theaceae	Eurya meizophylla	9	3			1				10	2	1							23	1							24								
6414	"	Eurya oxysepala																		21								21								
6481	Trimeniaceae	Trimenia papuana																		25								25								
6433	Thymelaeaceae	Phaleria ?nogerensis																		3								3								
6374	Winteraceae	Drimys sp. 3	10								10									46								46								
6392	"	Drimys sp. 4																		7								7								

Wurup Slopes

Degraded and Regrowth Oak forest

ANU No.	Family	Genus/Species	Height classes (m)								Diameter classes (cm)								
			0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48	48-
6489	Anacardiaceae	Rhus taitensis	13	10	5	35	7				18	16	14	11	9	2			
6438	Apocynaceae	Alstonia sp.	6			1					6			1					
6370	Araliaceae	Harmsiopanax sp.	10								10								
6338	Araliaceae	Polyscias sp.	3			2					3	1	1						
6352	Araliaceae	Schefflera sp.	29								29								
6281	Chloranthaceae	Ascarina philippinensis	4								4								
6417	Cunoniaceae	Spiraeopsis brassii	14								14								
6278	Cunoniaceae	Weinmannia sp.	15				1				15			1					
6248	Cunoniaceae	Schizomeria serrata	26	4		3		1			26	2	3	1		1	1		
6348	Elaeocarpaceae	Elaeocarpus poculiferus	6								6								
6476	Escalloniaceae	Polyosma sp.	44	1							45								
6075	Euphorbiaceae	Acalypha sp. 1	50								50								
4691	"	Croton sp.	7	1							8								
6081	"	Glochidion sp. 1	62	5	3	2					65	5		2					
5530	"	Macaranga ?warburgiana	22		2						22	1	1						
6439	"	Macaranga Mwomersleyi	20		1						20	1	1						
5581/6334	"	Omalanthus ?nervosus	15	1							15	1							
6282	"	Phyllanthus nervosus	39								39								
6335	Euphorbiaceae		10			2					10		1	1					
6457	Fagaceae	Castanopsis acuminatiss.	22	5	1	2			4		25	1	1			2		2	3
6485	Fagaceae	Nothofagus sp. 1	4			1	1	1			4				1				2
6279	Lauraceae	Cinnamomum sp. 2	9								9								
6321	Lauraceae	Cryptocarya sp. 1	19								19								
6459	"	Cryptocarya sp. 4	23	1	2	7		1			23	4	5	1	1				
6333	"	Endiandra sp. 2	54	2	3	1					55	4		1					
	Liliaceae	Cordyline sp.	13								13								
6244	Melastomataceae	Astronia sp. 1	6								6								
6487	Moraceae	Artocarpus vrieseanus	13	2		2					15		1				1		
5757	"	Ficus dammaropsis	2								2								
6440	"	*Ficus endochaete*	15	2	2						16	3							
6466	"	Ficus gul	52	3	1						52	1	2	1					
6342	"	Ficus tonsa	59	3	2						62	2							
6421	Monimiaceae	Kibara sp. 3	19								19								
6427	Moraceae	Streblus urophyllus	2								2								
6441	Myrsinaceae	?Ardisia sp.	23								23								
6293	"	Maesa sp.	9								9								
6469	Myrtaceae	Syzygium sp. 3	4			1					4				1				
6345	Myrtaceae		1								1								
6380	Ochnaceae	Schuurmansia henningsii	32	3	3						36	2							
	Palmae		19								19								
	Pandanaceae	Pandanus sp. 2	1								1								
	Pandanaceae	Pandanus sp. 3	16								16								
6259	Podocarpaceae	Podocarpus neriifolius	2								2								
6434	Rhamnaceae	Alphitonia incana					1							1					
6473	Rhizophoraceae	Gynotroches axillaris	17	1				1			17	1	1						
6284	*Rosaceae*	*Prunus costata*	15								15								
6344	Rosaceae	Prunus pullei	8								8								
6436	Rubiaceae	Timonius sp.	18	2							20								
6218	Rubiaceae	Wendlandia sp.	40	5	5						43	6	1						
6430	Rutaceae	Achronychia sp. 2	21	4		1					23	2	1						
6486	Rutaceae	Evodia sp. 1	13								13	1							
6432	Rutaceae	Evodia sp. 2	9								9								
6458	Rutaceae	Evodia sp. 6	14								14								
6215	Rutaceae	Evodiella sp.	36	2							36	2							
6347	Sapindaceae	Guioa sp.	32								32								
6331	Sapindaceae	Mischocarpus sp.	12	3							12	2	1						
6349	Sapindaceae		22								22								
6462	Saurauiaceae	Saurauia sp. 3	1								1								
6467	Saurauiaceae	Saurauia sp. 11	2								2								
6277	Staphyleaceae	Turpinia pentandra	13								13								
6343	Symplocaceae	Symplocos sp.	5	1							6								
6298	Theaceae	Eurya meizophylla	1	2							1	2							
6414	Theaceae	Eurya oxysepala	22								22								
6481	Trimeniaceae	Trimenia papuana	7								7								
6463	Ulmaceae	Trema amboinensis	1								1								

Plot No.			1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13
ANU No.	Family	Genus & Species	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C
5803	Poaceae	Arthraxon hispidus					1																					
6007	"	Arundinella setosa	37	5	51	10	42	5	43	10	48	10	54	10	48	10	43	10	40	10	41	10	70	15	51	15	142	40
6016	"	Capillipedium parviflorum	18		29	5	14		35	5	19		14		23	5	18		29	5	24	5	29	5	43	10	82	20
6024	"	Dimeria dipteros											42	5	24	5	66	10	46	5	93	15	34	5	9		10	
6020	"	Eulalia trispicata					1		19										19		20		17		8			
6013	"	Imperata cylindrica					39	10	56	10	43	10			115	20	29	5	134	25	63	15	146	30	125	25	125	30
6001	"	Ischaemum barbatum	56	10	58	10	28	5	42	10	30	5	34	5	44	5	25	<5	8		12	<5	37	5	23	5	8	
6001	"	Sacciolepis indica	14		11		2		4		5				2		6		2				6		3		14	
6006	"	Themeda australis	*	80	*	80	*	60	*	80	*	70	*	60	*	80	*	80	*	60	*	80	*	50	*	50	*	40
6003	Cyperaceae	Carex ?baccans	40	10	14	<5	22	5	25	5	20	5	8		16		7		16	<5	6				3		29	5
6014	"	Fimbristylis sp.			9		4		2		1								7									
6021	"	Rhynchospora rubra					1		2		16		59	10	40	5	40	5	62	10	94	18	63	10	2			
6010	"	Rhynchospora rugosa	43	5	31	5	33	5	58	10	49	5	36	5	29	5	33	5	28	5	44	5	44	5	12		16	
5724	Asteraceae	Crassocephalum crepidioides			8																				12			
6019	"	Emilia prenanthoidea			1																							
6017	"	Lactuca sp.	4		13	5	4				2		15	5	8		9		10	5	3		5		6		2	
6035	Haloragaceae	Haloragis chinensis																					4					
6004	Apiaceae	Centella asiatica	30	5	3		25	5	6				18	5	9		18		24	5			32	5			16	
6002	Hypericaceae	Hypericum sp. 1.	1										1				1											
6009	Melastomataceae	Osbeckia chinensis	3		6		7		13		1		31		21		20		34		43	5	35		9			
6028	Polygalaceae	Polygala paniculata															1											
6008	"	Polygala sp. 1.	29	<5	22		15		21		7		13		7		9		40		7		45	5	26		17	
6051	Violaceae	Viola arcuata																									8	
5828	"	Viola betonicifolia			3						2		4		8		11		30	5	7		41	5	8		26	
6025	Orchidaceae	Spathoglottis sp. 2.															3											
6027	Ochnaceae	Schuurmansia henningsii															1											
6018	Cyatheaceae	gen. 1.			1				3												1		7	20	11	25	1	5
6022	"	gen. 2.					2		10		1								2	5	1				6	10	9	15
6005	Dicksoniaceae	Culcita villosa	1						1										10	10			12	10			2	
6026	Gleicheniaceae	Dicranopteris linearis															3		43	25					8	5	5	
6029	"	Gleichenia hooglandii																	20	15	4							
6023	Pteridaceae	Sphenomeris chinensis							1				1				1		4		11	5	4		18	10	7	
6015	Lycopodiaceae	Lycopodium cernuum							1		22	5	54	15	29	10	40	10	3		82	20	3		13			

Plot No.			14	14	15	15	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23	23	24	24	25	25	26	26
ANU No.	Family	Genus & Species	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C
5083	Poaceae	Arthraxon hispidus	12		26		98	15	65	10	11						19		54	5	19		28		15		22	
6007	"	Arundinella setosa	92	20	105	20	71	30	132	40	43	20	8		2				6									
6016	"	Capillipedium parviflorum	60	15	102	25	96	20	90	20	13																	
6024	"	Dimeria dipteros									•	40	56	10	•	40							23		17			
6013	"	Imperata cylindrica	152	35	156	35	43	10									44	5	21		40	5			12		8	
6048	"	Isachne globosa	1		17	<5	74	20	143	40	•	60	•	40	•	40	•	60	•	30	•	30	•	60	39	20	67	20
6001	"	Ischaemum barbatum															140	20	325	20	253	25	108	10	•	80	•	80
6041	"	Leersia hexandra																	9		4							
6058	"	Saccharum sp.													73	10	53	7	72	15	86	15	49	5	10		21	
6011	"	Sacciolepis indica	4		17		39	5	25		18		28															
6006	"	Themeda australis	•	50	•	60	•	40	40	10			5				28		55	5	34	5	25		23		26	
6038	Cyperaceae	Cyperus globosus															65	5	128	15	49	5	27		38	5	12	
6056	"	Elaeocharis sp.															•	40	•	60	•	40	•	50	142	25	60	10
6014	"	Fimbristylis sp.							59	5	1		6				29		25		7		14		22		14	
6045	"	Lipocarpha chinensis					128	20	132	24	205	40	•	40	•	60	•	25	62	5	14		39	5	19		45	5
6044	"	Machaerina rubiginosa									34		4		18													
6021	"	Rhynchospora rubra					22		20		18		25		29				3		4		7		9		36	5
6010	"	Rhynchospora rugosa																							17		12	
6039	"	Scirpus mucronatus															23		34	5	13		25		10		25	5
6037	Juncaceae	Juncus cf. prismatocarpus			20	5	95	15	3				63	15	102	15												
6004	Apiaceae	Centella asiatica															19		28		20		15		11		5	
5732	"	Oenanthe javanica			7		9								7		10		4									
6054	Asteraceae	Adenostemma hirsutum			21				25						30		18				2							
5724	"	Crassocephalum crepidioides	6		5		15		18		23		15		48	5	8		2						2			
6019	"	Emilia prenanthoidea	2				1																					
6047	"	Erigeron sumatrensis	7		12	5					4		9		22	10												
6017	"	Lactuca sp.													7													
6077	Boraginaceae	gen. 1.											3		30		23		11		1		14		23		38	
6040	Eriocaulaceae	Eriocaulon hookerianum											5		10													
6033	Fabaceae	Desmodium microphyllum													18													
6035	Haloragaceae	Haloragis chinensis															15		15		10		9		36		28	
6055	Hypericaceae	Hypericum sp. 2.													1		3		5		6		6					
6043	Lamiaceae	Dysophylla verticillata															35	5	28		32	5	8		17		5	
6032	"	Plectranthus sp. 1.													1		3		1									
6053	Lentibulariaceae	Utricularia sp. 1.							5		2				23													
6009	Melastomataceae	Osbeckia chinensis	6		18		20								5													
6008	Polygalaceae	Polygala sp. 1.															44	5	36		30	5	30	5	42	5	27	
6049	Scrophulariaceae	Linnophyla aromatica							42	10			18	5	8		23	5	13		4				11		7	
6051	Violaceae	Viola arcuata			6		19		25		16		10															
5828	"	Viola betonicifolia													4													
6052	Xyridaceae	Xyris sp.									3		3															
6025	Orchidaceae	Spathoglottis sp. 2.	1	5	2	5	1	5																				
6018	Cyatheaceae	gen. 1.	10	40	3	20	5	30	1	5																		
6022	"	gen. 2.			10	10	6	5																				
6005	Dicksoniaceae	Culcita villosa													10	5												
6023	Pteridaceae	Sphenomeris chinensis															4		1									
6015	Lycopodiaceae	Lycopodium cernuum																										

Plot No.			27	27	28	28	29	29	30	30	31	31	32	32	33	33	34	34	35	35	36	36	37	37	38	38
ANU No.	Family	Genus & Species	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C
5803	Poaceae	Arthraxon hispidus	.				11						7		9		36		29		16				4	
6024	"	Dimeria dipteros	6				34	5	14		45	5	18		*	40	*	20	*	20	*	15	*	20	25	5
6048	"	Isachne globosa															9		13						12	
6001	"	Ischaemum barbatum	136	40	87	30	78	20	68	20	37	10	83	20	20		53	5	52	10	61	15	22		11	
6041	"	Leersia hexandra	*	80	*	60	*	60	*	40	*	50	*	50	264	25	250	15	*	20	42	5	253	20	*	15
6058	"	Saccharum sp.															17		20		5				7	
6011	"	Sacciolepis indica	20		9		20		18				10		50	5	66	5	64	5	47	5	10		1	
6038	Cyperaceae	Cyperus globosus	19		32	5	79	10	46	5	43	5	52	5	*	20	*	20	*	20	*	10	*	20	57	5
6059	"	Cyperus haspan					6		12		15		6				3		6							
6056	"	Eleocharis sp.			10		50	5	25		20		133	18			86	10	22		12					
6014	"	Fimbristylis sp.	85	20	48	5	82	20	105	20	30		45													
6045	"	Lipocarpha chinensis	21		35	5	43	5	44	5	78	10	96	15	58	3	20		23		15					
6044	"	Machaerina rubiginosa	42	5	56	8	24		120	20	161	25	98	17	*	50	*	70	*	60	*	50	*	60	*	60
6010	"	Rhynchospora rugosa	42	5	15		7		17		9		11				29		5		5		12		17	
6039	"	Scirpus mucronatus	7		31		14		8		14		48	5											92	10
6037	Juncaceae	Juncus cf prismatocarpus	8		11		32	5	31	5	28	5	32	5	*	15	94	15	30	5	76	10	25	5	20	
6042	Alismataceae	Caldesia parnassifolia													92	20	174	20	150	20	125	20	60	10	22	
5732	Apiaceae	Oenanthe javanica	8		12		9		13																	
5724	Asteraceae	Crassocephalum crepidiodes	4																							
6019	"	Emilia prenanthoidea													5		3		19		3					
6017	"	Lactuca sp.					5										3		10		1		3		3	
6040	Eriocaulaceae	Eriocaulon hookeriana	41	5	16		10		15		16		7		204	10	61	5	46	5	37		6		7	
6055	Hypericaceae	Hypericum sp. 2.	5		28		22		24																	
6043	Lamiaceae	Dysophylla verticillata	3						1						8		9		10		4		4		1	
6032	"	Plectranthus sp. 1.	9		10		2		5		5				3		5		14							
6053	Lentibulariaceae	Utricularia sp. 1.	1				17		12		42		33						7							
6049	Scrophulariaceae	Limnophyla aromatica	30	5	61	10	75	10	77	10	56	5	49	5	78	10	36	5	36	5	38	5	25			
6051	Violaceae	Viola arcuata	11		5		4				4								16		8					
6052	Xyridaceae	Xyris sp.			2		4		6		6												2		1	
6061	Orchidaceae	Thelypteris palustris																	27	5	21	5				
6062	"	gen. 1.																							16	
6015	Lycopodiaceae	Lycopodium cernuum													5						6					

ANU No.	Family	Genus/Species	1 N	1 C	2 N	2 C	3 N	3 C	4 N	4 C	5 N	5 C	6 N	6 C	7 N	7 C	8 N	8 C	9 N	9 C	10 N	10 C	11 N	11 C	12 N	12 C	13 N	13 C	14 N	14 C
6041	Poaceae	Leersia hexandra	•	80	•	60	•	70	•	80	•	60	•	80	•	40	•	90	•	90	•	90	•	90	•	90	•	80	•	80
5782	Poaceae	Phragmites karka	18	5	14		18	5	10	5	9		11	5	14	5	4		53	10	31	9	19	5	41	10	66	20	34	10
6048	Poaceae	Isachne globosus	10		20		26		85	10	80	10	30		85	10	48	5	·25		30		17		3		23		22	
6011	Poaceae	Sacciolepis indica	26		13		15		9		31		40				14		156	10	·72	5	18		6		22		3	
6016	Poaceae	Capillipedium parviflorum			10		•	30	•	40	•	20	•	40	•	60	•	10												
6001	Poaceae	Ischaemum barbatum			27																		28		7				70	15
5803	Poaceae	Anthraxon hispidus									1														2					
5805	Poaceae	Apluda mutica									4																			
6189	Poaceae	Paspalum orbiculare											6																	
6014	Cyperaceae	Fimbristylis sp.	12														6													
6039	Cyperaceae	Scirpus mucronatus	3																											
6045	Cyperaceae	Lipocarpha chinensis																												
6010	Cyperaceae	Rhynchospora rugosa																												
5926	Amaranthaceae	Amaranthus sp.																	15		5		3				6		10	
5732	Apiaceae	Oenanthe javanica	40	5	16		42	5	40	5	40	5	30		92	5	•	10	•	20	•	25	70	5	182	10	160	10	•	40
5841	Asteraceae	Adenostemma hirsutum			3								4		13								4							
6019	Asteraceae	Emilia prenanthoidea	15		20		9		16		41		23		61		13		65	5	80	5	70	5	15		54	5	27	
5797	Asteraceae	Erechthites valerianifolia															1		3		1									
5780	Asteraceae	Erigeron sumatrensis																	4											
6017	Asteraceae	Lactuca sp.																												
6201	Euphorbiaceae	Glochidion sp. 3.	9	5	11	5	15	10	20	5	25	5	18	10	11	5	2													
5836	Fabaceae	Crotalaria ferruginea											18		3															
5893	Fabaceae	Desmodium lasiocarpum																												
6032	Lamiaceae	Plectranthus sp.1.	8		29		8		10		53	5	50	5	78	5	53	<5	7						47					
6200	Lamiaceae	1	8																3											
6205	Malvaceae	Hibiscus sp.																												
6203	Melastomataceae	Melastoma ? affine	•	60	•	80	•	60	•	50	•	40	27	50	13	20	•	25												
6204	Nepenthaceae	Nepenthes sp.																												
6202	Philesiaceae	Geitonoplesium cymosum	3		17		12		6		12																			
5736	Polygonaceae	Polygonum longisetum	4				12		6		7						3		140	5	90	5	13		34	2	64	5	72	5
5798	Urticaeae	Pouzolzia sp.	10	40	•	25	•	20	•	40	•	40	92	10	150	10	•	5	15		91	10	•	60	240	20	•	20	152	10
6051	Violaceae	Viola arcuata	9				4						5		6		13		60	10	7				3		9			
5828	Violaceae	Viola betonicifolia													4															
5501	Dennstaedtiaceae	Dennstaedtia sp.	19	5	8		16		12		20		4		7		42	5	15		7		5		2		2			
6015	Lycopodiaceae	Lycopodium cernum	9		11				2		6		2				4													

ANU No.	Family	Genus/Species	15 N	15 C	16 N	16 C	17 N	17 C	18 N	18 C	19 N	19 C	20 N	20 C	21 N	21 C	22 N	22 C	23 N	23 C	24 N	24 C	25 N	25 C	26 N	26 C	27 N	27 C	28 N	28 C
6041	Poaceae	Leersia hexandra	•	90	•	80	•	80	•	90	•	80	•	80	•	90	•	80	•	90	•	80	•	80	•	80	•	50	•	60
5782	Poaceae	Phragmites karka	60	40	26	10	27	5	19	5	44	15	25	10	4		5		12	5	20	5	9	5	9		14	5	12	5
6048	Poaceae	Isachne globosus	15		30		10		1		1		12		8		142	15	70	5	30		30		30		20		20	
6011	Poaceae	Sacciolepis indica	11		4		24		70	5	110	10	25		•	50	•	20	•	10	80	5	90	5	70	5	24		40	5
6016	Poaceae	Capillipedium parviflorum											•	40	•	5	•	10	•	5	•	60	•	60	•	60	•	80	•	80
6001	Poaceae	Ischaemum barbatum	76	10	69	10	70	10	39	5	68	10	80	15	80	15	130	10	130	15	60	5	74	5	•	10	80	5	65	5
5803	Poaceae	Anthraxon hispidus											235	10	50	5	30		35		5		25		40		20			
5805	Poaceae	Apluda mutica																												
6189	Poaceae	Paspalum orbiculare																	6				8		8				14	
6014	Cyperaceae	Fimbristylis sp.																												
6039	Cyperaceae	Scirpus mucronatus																												
6045	Cyperaceae	Lipocarpha chinensis			22						2				12		65		5		80		90	5	10				15	
6010	Cyperaceae	Rhynchospora rugosa																	5											
5926	Amaranthaceae	Amaranthus sp.	4						4		19						2		5		4						2			
5732	Apiaceae	Oenanthe javanica	•	20	•	10	140	10	•	40	•	20	24		5		15		15		10		15		6		3		2	
5841	Asteraceae	Adenostemma hirsutum	4								1				1															
6019	Asteraceae	Emilia prenanthoidea	80	5	66	5	176	10	110	8	174	10					1				2									
5797	Asteraceae	Erechthites valerianifolia	1										5																	
5780	Asteraceae	*Erigeron sumatrensis*																												
6017	Asteraceae	Lactuca sp.													5															
6201	Euphorbiaceae	Glochidion sp. 3.	2	5	4	5	2	5	1	5																				
5836	Fabaceae	Crotalaria ferruginea																			7									
5693	Fabaceae	Desmodium lusiocarpum											19	30																
6032	Lamiaceae	Plectranthus sp.1.											18		124	10	120	10	•	10	25		52	5	20		30		20	
6200	Lamiaceae	1																												
6205	Malvaceae	Hibiscus sp.									7																			
6203	Melastomataceae	Melastoma ? affine	3		11	20	8	5									1													
6204	Nepenthaceae	Nepenthes sp.																			8		1							
6202	Philesiaceae	Geitonoplesium cymosum																												
5736	Polygonaceae	Polygonum longisetum	31		72	5	90	5	150	10	70	8																		
5798	Urticaeae	Pouzolzia sp.	•	60	•	30	•	60	•	20	•	20					12				6		4							
6051	Violaceae	Viola arcuata											25		15		16		20		6						4			
5828	Violaceae	Viola betonicifolia																												
5501	Dennstaedtiaceae	Dennstaedtia sp.	23		16		7				9																			
6015	Lycopodiaceae	Lycopodium cernum													9		15		20		15		20		20		4		6	

AND No.	Family	Genus/Species	29 N	29 C	30 N	30 C	31 N	31 C	32 N	32 C	33 N	33 C	34 N	34 C	35 N	35 C	36 N	36 C	37 N	37 C	38 N	38 C	39 N	39 C	40 N	40 C
6041	Poaceae	Leersia hexandra	*	80	*	90	*	90	*	80	*	90	*	90	*	95	*	80	*	80	*	80	*	90	*	80
5782	Poaceae	Phragmites karka	34	20	30	20	7	5	42	20	47	20	5		3		8	5	38	25	11	5	8	5	11	10
6048	Poaceae	Isachne globosus	12		7		11		11		22		12				3		10		6		6		40	
6011	Poaceae	Sacciolepis indica			4		6		6		9		27		12		8		6				6		60	
6016	Poaceae	Capillipedium parviflorum															13		44						44	5
6001	Poaceae	Ischaemum barbatum	34	5	16		19		25		5		49	5	22		40	5	18		44		45		62	8
5803	Poaceae	Anthraxon hispidus							15		78	5	5								7					
5805	Poaceae	Apluda mutica																								
6189	Poaceae	Paspalum orbiculare																								
6014	Cyperaceae	Fimbristylis sp.							20		12								5				10			
6039	Cyperaceae	Scirpus mucronatus																								
6045	Cyperaceae	Lipocarpha chinensis																								
6010	Cyperaceae	Rhynchospora rugosa																								
5926	Amaranthaceae	Amaranthus sp.					3		4				4		14										1	
5732	Apiaceae	Oenanthe javanica	170	10	164	10	*	20	*	20	140	10	*	20	*	50	*	20	*	20	*	40	150	10	*	20
5841	Asteraceae	Adenostemma hirsutum					2										1				23		13		3	
6019	Asteraceae	Emilia prenanthoidea	4				6		4		27		43		11		12		44		34		30		9	
5797	Asteraceae	Erechthites valerianifolia									1															
5780	Asteraceae	Erigeron sumatrensis																								
6017	Asteraceae	Lactuca sp.																					4		3	
6201	Euphorbiaceae	Glochidion sp. 3.	1				2		3		1		2	5	2		4		4		2		4	5	1	
5836	Fabaceae	Crotalaria ferruginea																								
5893	Fabaceae	Desmodium lasiocarpum																								
6032	Lamiaceae	Plectranthus sp.1.	86	5	140	10	102	10	*	20	*	20	25	5	4		3		36	5	15		30			
6200	Lamiaceae	1																								
6205	Malvaceae	Hibiscus sp.																								
6203	Melastomataceae	Melastoma ? affine	6	20	12	10	7	10	8	10	12	10	5	10	4	5	14	20	6	10	24	40	25	50	3	5
6204	Nepenthaceae	Nepenthes sp.			3		3				4				4		6									
6202	Philesiaceae	Geitonoplesium cymosum																								
5736	Polygonaceae	Polygonum longisetum	16				8		16		27		125	10	120	15	50	70	20		26		10		24	
5798	Urticaeae	Pouzolzia sp.	*	40	200	20	*	40	*	40	*	30	*	40	*	50	*	80	*	60	150	10	*	40	31	
6051	Violaceae	Viola arcuata																					4			
5828	Violaceae	Viola betonicifolia																								
5501	Dennstaedtiaceae	Dennstaedtia sp.									2		1		3		5		9		12		9		6	
6015	Lycopodiaceae	Lycopodium cernum											10				3									

Plot No.			41	41	42	42	43	43	44	44	45	45	46	46	47	47	48	48	49	49	50	50	51	51
ANU No.	Family	Genus & Species	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C
5803	Poaceae	Arthraxon hispidus							4		4				78	5			51		2		26	
6007	"	Arundinella setosa	*	60	*	50	*	60	*	50	*	50	*	30	*	60	*	20	*	70	*	40	*	80
6016	"	Capillipedium parviflorum	72	5	19		52	5	6		45	5	55	5	70	5	74	5	210	20	240	10	200	20
5848	"	Eragrostis sp.	3		46	5	36		11		23	5	53		96	10								
6013	"	Imperata cylindrica	170	10	68	5					80	5			206	10	42	5	*	20	300	15	360	20
6001	"	Ischaemum barbatum	220	20	270	10	*	20	*	60	*	30	*	50	*	40	*	60						
5743	"	Ischaemum polystachyum																			107	5		
6041	"	Leersia hexandra																			8		23	
5819	"	Ophiuros exaltatus					15		9		8		17		13		7							
5559	"	Paspalum conjugatum	56	5	20		32	5	25	5	13		27		12		7							
6011	"	Sacciolepis indica	6				8		2		3				2				8		9		37	5
6006	"	Themeda australis	*	50	*	50	*	40	*	40	*	50	*	50	*	20	*	20						
6003	Cyperaceae	Carex ?beccans							7		70	5			4		19						36	
6014	"	Fimbristylis sp.	5		29		9		18		24		26		19		16		26		21		34	
6021	"	Rhynchospora rubra	13		10				17				21		15		5							
6010	"	Rhynchospora rugosa	12		15		16		62		23		62	5	13		26		7		83		31	
6004	Apiaceae	Centella asiatica	11		30		105	5	92	5	57		176	5	72	5	16		38		50		200	5
6019	Asteraceae	Emilia prenanthoidea	3		3		2		4		3		6		2		3		2		7		11	
5797	"	Erechthites valerianifolia					2														11			
6047	"	Erigeron sumatrensis											6		4				4		8			
6017	"	Lactuca sp.							18		16		16		4		5				12		12	
5836	Fabaceae	Crotalaria ferruginea																	1		4		7	
6209	"	Desmodium heterocarpon																	1					
6033	"	Desmodium microphyllum	13		16		17		5		9		15		10		28							
6032	Lamiaceae	Plectranthus sp. 1.																			4			
6009	Melastomataceae	Osbeckia chinensis							17				8				6							
6028	Polygalaceae	Polygala paniculata							12															
6108	Rosaceae	Rubus fernandi - muelleri																			4			
6233	Rubiaceae	Hedyotis sp.	43		7		8		33		24		9		5		5		26		24		41	
5828	Violaceae	Viola betonicifolia																	6		16			
6213	Aquifoliaceae	Ilex sp.																					2	
6171	Euphorbiaceae	Macaranga pleiostemona																			2			
6205	Malvaceae	Hibiscus sp.											3		12								3	
6207	Melastomataceae	Melastoma ?polyanthum																	2		3			
6027	Ochnaceae	Schuurmansia henningsii																	6	15	30	20	15	20
6206	Rubiaceae	Wendlandia sp.																	1		10		4	
6172	Sapindaceae	Dodonaea viscosa																			1			
6208	Urticaceae	Maoutia sp.																	1		1	5		
6023	Pteridaceae	Sphenomeris chinensis																	38	5	93	5	39	
	Pteridae	'Maipung'															17		7		18		78	5
6015	Lycopodiaceae	Lycopodium cernuum	9						2		2				4				22		2		33	5

Plot No / ANP No.	Family	Genus & Species	52 S	52 C	53 S	53 C	54 S	54 C	55 S	55 C	56 S	56 C	57 S	57 C	58 S	58 C	59 S	59 C	60 S	60 C	61 S	61 C
5805	Poaceae	Apluda mutica	30		12								11						4		23	
5803	"	Arthraxon hispidus	40	5	32		41		26		120		82				10		23		26	
6002	"	Arundinella setosa	*	80	*	40	*	20	*	20	*	40	*	40	10		6		31		48	5
6010	"	Capillipedium parviflorum	*	30	*	20	*	20	171	10	*	40	203	20	46		135	20	145	10	102	5
6013	"	Imperata cylindrica	145	5	43				140	10	220	20			96	10	46		70	5	138	10
5243	"	Ischaemum polystachyum	60	10	*	40	160	20	*	20	*	20	*	40	*	90	*	70	*	50	*	50
6041	"	Leersia hexandra			5		15		5		10						22					
6056	"	Miscanthus floridulus													8							
5819	"	Ophiuros exaltatus			17																	
5559	"	Paspalum conjugatum																	12		22	
5282	"	Phragmites karka													12		6		24	5	8	
6011	"	Sacciolepis indica	22		40	5	20		37		26		19						10			
6003	Cyperaceae	Carex ?breviculmis	36		31		40				54		40		4						18	
6014	"	Fimbristylis sp.	37		43						13		12		3						12	
6010	"	Rhynchospora rugosa	52		19		42		29		18		31									
6004	Apiaceae	Centella asiatica	34		93	5	70	5	127	5	70	5	33								20	
5841	Asteraceae	Adenostemma hirsutum													2							
6019	"	Emilia prenanthoidea	12		20		3		19		28		15		9		27		16		16	
5797	"	Erechthites valerianifolia	9		5		3		3		5				2							
6047	"	Erigeron sumatrensis	4		8		2		5		6		4									
6017	"	Lactuca sp.	5																			
5687	Begoniaceae	Symbegonia sp.													19							
6211	Convolvulaceae	Ipomoea fimbriosepala	2								5		5									
5915	Euphorbiaceae	?Fiuggia sp.											2	5								
5836	Fabaceae	Crotalaria ferruginea	1		2								16						1			
6209	"	Desmodium heterocarpon	20		25		19						3		26						3	
6033	"	Desmodium microphyllum									6		8									
5575	"	Desmodium repandum													2		5					
6032	Lamiaceae	Plectranthus sp. 1.													76	10	27	5	33	10	24	
6072	Loranthaceae	gen. 1.																			7	10
6009	Melastomataceae	Osbeckia chinensis			2																	
6202	Philesiaceae	Geitonoplesium cymosum																	13	5	24	
6008	Polygalaceae	Polygala sp. 1.			2		2															
6108	Rosaceae	Rubus fernandi - muelleri			120	15	48												2			
5573	"	*Rubus moluccanus*													39	10	2					
6233	Rubiaceae	Hedyotis sp.	28		18		54		62		79		40		30	5	25		10		12	
5798	Urticaceae	Pouzolzia sp.											8									
6051	Violaceae	Viola arcuata																	12		32	
5828	"	Viola betonicifolia	5		7		5		6		12		23									
6025	Orchidaceae	Spathoglottis sp.													17	5						
6081	Euphorbiaceae	Glochidion sp. 1.					1		1						1						2	
6171	"	Macaranga pleiostemona			4		3		5	10	2		1		1	5	1	50	3	10	3	10
5530	"	Macaranga ?warburgiana																	1		1	
5581	"	Omalanthus ?nervosus									2				1						2	
6205	Malvaceae	Hibiscus sp.											3									
6207	Melastomataceae	Melastoma ?polyanthum	13						2				3	5								
6225	Menispermaceae	Stephania montana															5		11	5		
6466	Moraceae	Ficus gul	1										2				4	20	1		2	15
6027	Ochnaceae	Schuurmansia henningsii	21	20	4		10	20	2				46	40							20	50
6206	Rubiaceae	Wendlandia sp.	13		4		3		6	10			3		1	5			2	20	5	
6172	Sapindaceae	Dodonaea viscosa			2		4	10	6	10	3	20	8		2	5			2		4	
5525	Saurauiaceae	Saurauia sp. 10.																			2	30
6219	Sterculiaceae	Commersonia bartramia	2						1													
6173	Theaceae	Eurya meizophylla																	1	50		
6208	Urticaceae	Maoutia sp.					1		2	5	1		2	20								
5590	Verbenaceae	Callicarpa sp.	3		1		4		2		2		2		8	5						
6018	Cyatheaceae	Cyathea sp. 1.					2	10	2	10	1											
6022	"	Cyathea sp. 2.					1															
6005	Dicksoniaceae	Culcita villosa							7													
6023	Pteridaceae	Sphenomeris chinensis	52	5	27		47		94	10	19		4									
	Pteridae	'Punt'											23	5	48	10	2		18	10		
	"	'Pug'									9	5			6	10	30	20	11	5		
	"	'Kandramp'	7						17		14	5										
	"	'Maipung'	55	10	7				104	10	23											
6015	Lycopodiaceae	Lycopodium cernuum	63	5	19		27															

ANU No.	Family	Genus & Species	1		2		3		4		5		6		7		8		9		10		11		12		13		14	
			N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C
	Convolvulaceae	Ipomoea batatas 'Teyga'	29	20									57	15	•	20	46	5	25	10					15	5				
	"	" " 'Pora'	82	30			2		7	5											3									
	"	" " 'Terema'	32	10																										
	"	" " 'Bombumi'	55	20	2	10	17	20	21	40	86	20	128	40			110	30	•	20	75	20	65	20	131	30	112	10		
	"	" " 'Minima'	4	5	13	30	10	30	10	10							10	10			15		5		68	10	75	5		
	"	" " 'Degarn'	4	5	4	15	10	5	14	5	23	5	47	15	•	30	28	5	52	10	69	20	163	40	100	30	4			
	"	" " 'Koepep'	52	10			6	10																	5	5				
	"	" " 'Konimey'	7	5	3	10			12	3	1		9	5	28	10					7		6							
	"	" " 'Kandip'			3	10	5	10																						
	"	" " 'Krapkelua'			14	10	15	10	16	10			4	5					9		6									
	"	" " 'Baralang'			2	5			10	5																				
	"	" " 'Karatsoga'																												
	"	" " 'Krate'											33	10																
5805	Poaceae	Apluda mutica																	•	15							65		62	5
5803	"	Arthraxon hispidus					10		•	20	15		112	5	61		104	5	253	10	5		39		30				360	10
6007	"	Arundinella setosa																									78	5	168	10
6016	"	Capillipedium parviflorum																											146	5
5802	"	Digitaria sp.	69	5	•	10	168	10	•	30	64				72		26		52		86		•	5	288	10	•	20		
6013	"	Imperata cylindrica									•	20															•	40	72	5
6048	"	Isachne globosus			4				15																		165	5		
5743	"	Ischaemum polystachyum									•	50	286	20	•	60	•	20	138	10	•	40	•	40	148	5				
6041	"	Leersia hexandra	43	5	146	10	4				132	10	105	10	48								296	10	220	10				
6066	"	Miscanthus floridulus																											34	
6063	"	Oplismenus compositus																			17		46		27		•	10		
6177	"	Panicum paludosum																												
6011	"	Sacciolepis indica							48		38		17		11		39		74	10	12		10		3		41		13	
5600	"	Setaria palmifolia									9		21	5	14				6		29	5	60	10	27					
6006	"	Themeda australis																									•	15	•	50
6179	Cyperaceae	Bulbostylis densa									•	5			59						10				8		37		•	20
	"	Carex ?beccana																									15		38	5
5882	"	Carex ?neurochlamys																									29		114	5
6038	"	Cyperus globusus													7															
5749	"	Cyperus melanospermus																									28		38	
6014	"	Fimbristylis sp.																	3		3		4				7		12	
6045	"	Lipocarpha chinensis	13		7				9		68		92	5	73		95	5	156	5	59		460	10	13		22		56	
6021	"	Rhynchospora rubra									17		41	5	14		30		8		22								1	
6010	"	Rhynchospora rugosa																												
6004	Apiaceae	Centella asiatica																									80	5	160	5
5310	Asteraceae	Adenostemma hirsutum																												
5726	"	Bidens pilosa	•	10	59	5	112	5	•	20	132	10	95	10	260	10	121	5	135	5	205	10	144	5	•	20	350	10	25	
5724	"	Crassocephalum crepidioides	13		22		25		195	10	78	5	25				22		13		19				55		102	5	86	5
6019	"	Emilia prenanthoidea																												
5797	"	Erechthites valerianifolia																												
5780	"	Erigeron sumatrensis											5						2		3		4		3		8		39	
6017	"	Lactuca sp.																									32		17	
6080	"	Siegesbeckia orientalis																							1		40		12	

ANU No.	Family	Genus & Species	15		19		20		21		22		23		24		25		26		27		28		29		30		31	
			N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C
	Convolvulaceae	Ipomoea batatas 'Teyge'					1		6						52	10														
	"	" " 'Pora'									3	5	4																	
	"	" " 'Terema'																												
	"	" " 'Bombuni'			5		35		23	5			5		34	5	54		2		1						7		3	
	"	" " 'Minima'			23		22	5	5		7	25	11		26	5	17										3		26	
	"	" " 'Dagarn'					1						16		29	5	7								8		10		13	
	"	" " 'Koepep'					4		1								2													
	"	" " 'Konimey'									4	15	24	25	43	10	10						3		5		4			
	"	" " 'Kandip'																												
	"	" " 'Krapkelua'							3																					
	"	" " 'Baralang'							1		2	5					1													
	"	" " 'Karateoga'									8	25	15		23	5														
	"	" " 'Krate'																												
5605	Poaceae	Apluda mutica	43	5																										
5803	"	Arthraxon hispidus	400	20	•	20	10				50		23		42		62	5											19	
6007	"	Arundinella setosa	230	20																										
6016	"	Capillipedium parviflorum	120	10																										
5802	"	Digitaria sp.					220	5	•	20	110	5	110	5	49		120	5			46		2						130	5
6013	"	Imperata cylindrica	145	10	51		6		68	5					305	10	208	20	82	5	460	20	3				300	10	•	60
6048	"	Isachne globosus																			6						37			
5743	"	Ischaemum polystachyum			•	40	•	70	•	60	23		•	10	•	40	•	70	•	80	•	90	•	95	•	90	•	70	•	20
6041	"	Leersia hexandra					42		140	5	230	5	132		45		235	5									14		200	5
6006	"	Miscanthus floridulus	51																2		9									
6003	"	Oplismenus compositus			•	10					37		84	5	30		140	5					4		121	5	250	5	•	10
6177	"	Panicum paludosum																					50	5	360	20	•	50	•	20
6011	"	*Sacciolepis indica*	32		240	10	8		115	5	11		37		3		2		12		25				2		5		93	5
5600	"	Setaria palmifolia			240	10	170	10	50		12		120	10	•	40	62	10	123	20	56	5	24	5	21				•	20
6006	"	Themeda australis	•	70																										
6179	Cyperaceae	Bulbostylis densa	•	5	•	20	54		•	5							55												10	
6003	"	Carex ?beccana			43	5													4		11									
5882	"	Carex ?neurochlamys	25				40		•	10					6															
6038	"	Cyperus globosus																												
5749	"	Cyperus melanospermus	71		300	5	270	5	•	10	6				54		62		340	5	•	5	106	5	•	5	100	5	•	5
6014	"	Fimbristylis sp.	32		19		70		15								4												35	
6045	"	Lipocarpha chinensis	23																											
6021	"	Rhynchospora rubra		14			7								2		2		2						3				43	5
6010	"	Rhynchospora rugosa	20																											
6004	Apiaceae	Centella asiatica	160	5	26				45				12						4										9	
5510	Asteraceae	Adenostemma hirsutum			33				19						2		19		31		8									
5726	"	Bidens pilosa	24		210	5	54		62	5	71	5	220	10	151	5	200	5	41		10		16		20		47		140	5
5724	"	Crassocephalum crepidioides	57		220	5	135	5	250	5	62	5	160	10	•	10	180	5	1		4		1						34	
6019	"	Emilia prenanthoidea															6													
5797	"	Erechthites valerianifolia							2						2						1		1		1					
5780	"	Erigeron sumatrensis	69		5		6		4		4		6				8				3						1		14	
6017	"	Lactuca sp.	18																											
6080	"	Siegesbeckia orientalis	45		41				14		13		14		3		14		7		44									

ANU No.	Family	Genus & Species	1 N	1 C	2 N	2 C	3 N	3 C	4 N	4 C	5 N	5 C	6 N	6 C	7 N	7 C	8 N	8 C	9 N	9 C	10 N	10 C	11 N	11 C	12 N	12 C	13 N	13 C	14 N	14 C
6077	Boraginaceae	Gen. 1																									10			
6073	Campanulaceae	Wahlenbergia sp.							13																					
5754	Caryophyllaceae	Drymaria cordata	14								120	5	23		14		50				5									
5738	Commelinaceae	Commelina sp.	17		8				10		121	5	172	10	271	5	*	10	188	5	218	5	67		17					
5814	Euphorbiaceae	Euphorbia serrulata																											29	
6033	Fabaceae	Desmodium microphyllum																									9		26	
6032	Lamiaceae	Plectranthus sp. 1																									82	5	52	
6009	Melastomataceae	Osbeckia chinensis																											5	
6074	Oxalidaceae	Oxalis corniculata							11																		2			
6028	Polygalaceae	Polygala paniculata																												
6008	"	Polygala sp. 1																									10			
5748	Polygonaceae	Polygonum nepalense	*	20	48		23		85	5	148	10	105	10	183	5	103	5	127	5					65				43	3
5573	Rosaceae	Rubus moluccanus																												
5746	"	Rubus rosifolius									10						7		14		6		7		4		67	5	9	
5730	Solanaceae	Solanum nigrum																												
5828	Violaceae	Viola betonicifolia			10		2		9		18								8		6						22		6	
6025	Orchidaceae	Spathoglottis sp. 2																											15	

ANU No.	Family	Genus & Species	15 N	15 C	19 N	19 C	20 N	20 C	21 N	21 C	22 N	22 C	23 N	23 C	24 N	24 C	25 N	25 C	26 N	26 C	27 N	27 C	28 N	28 C	29 N	29 C	30 N	30 C	31 N	31 C
6077	Boraginaceae	Gen. 1					47	5	8						6															
6073	Campanulaceae	Wahlenbergia sp.			11																				3					
5754	Caryophyllaceae	Drymaria cordata																	8		6		5						7	
5738	Commelinaceae	Commelina sp.			45		8		52		5				21		16		47		83	5	13		60	5	61		98	5
5814	Euphorbiaceae	Euphorbia serrulata	21																											
6033	Fabaceae	Desmodium microphyllum	9																											
6032	Lamiaceae	Plectranthus sp. 1	127	5																	18		8							
6009	Melastomataceae	Osbeckia chinensis	4																											
6074	Oxalidaceae	Oxalis corniculata					5		9		34				3		4		5						2				3	
6028	Polygalaceae	Polygala paniculata																											88	5
6008	"	Polygala sp. 1	9																											
5748	Polygonaceae	Polygonum nepalense	34		*	20	210	5	*	5	32		44		160	5	180	5							6				13	
5573	Rosaceae	Rubus moluccanus	1																											
5746	"	Rubus rosifolius	1														2		11		14		3						86	5
5730	Solanaceae	Solanum nigrum			7																									
5828	Violaceae	Viola betonicifolia	21		48		38		14		15		14		18		15		50		97	5	30		17		7		41	
6025	Orchidaceae	Spathoglottis sp. 2	32																											
5535	Cyatheaceae	Gen. 1																	3	20	1									
5854	"	Gen. 2																	2	20										
6182	Dennstaedtiaceae	Hypolepis sp.																	1	5										
6183	"	Histiopteris incisa																	8	10										
6029	Gleicheniaceae	Gleichenia hooglandii																	4											
6015	Lycopodiaceae	Lycopodium cernuum	1																											

AKU.No.	Family	Genus & Species	32		33		34		35		36		37		38		39		40		41		42		43		44		45		46		47		48	
			N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C
	Araceae	Colocasia esculenta 'Gegwimp'													2		1				2	5							6	10	10	30	10	10	12	15
		'Muglump'					7	5					1		2																					
		'Mepim'	14	5	9	10	3		4	10	5	10	3	5	5	5	5	5	6		15	20	12	10	5	10			6	10	8	15	9	20	6	10
		'Maiquoin'	1		2		3		1		3	5																	1	5						
		'Pul'			1																															
		'Gitua'					5		3		5	5			3		3																			
		'Kralongbillamp'					1		3	10	2																									
		'Kitina'									1																									
		'Barn'																			8	30														
		'Gragrumbil'																											3	5	2	5	2	5	3	5
	Musaceae	Musa spp. 'Dekonta'	1										2	5	1	10							1	20					1	10						
		'Tugumamp'			4	10	4	10			2		1	5	4	15	2	10	9	30											1	5				
		'Kumburg'											1	5																						
		'Mari'																			1	15														
		'Ganinga'																							9	25	4	5								
	Poaceae	Saccharum officinarum 'Po'	4	10	4	5	5	10	6	15	3	10	6	10	6	10	6	10	6	15	5	20	5	40	8	50	9	20	11	20	11	20	10	10	4	5
5740	Acanthaceae	Rungia klossii											5		3		5	5	4		2	5														
5729	Amaranthaceae	Amaranthus tricolor			2		4				2		4		4		1		9		2															
5807	Apiaceae	Hydrocotyle javanica							10		38		17																							
5732	"	Oenanthe javanica			42	20							3		27	10	26	10			31	5	12													
	Brassicaceae	Brassica oleracea			1		4		9																											
	Dioscoreaceae	Dioscorea sp. 'Op'	5		2		1								1																					
	Euphorbiaceae	Ricinus communis	3		6		10		11	10	8	10	20	5	3	5	3		3	5	5		5	10			1				1					
6175	Fabaceae	?Dolichos sp.					2								1						2								8		3		5		13	
5825	",	Psophocarpus tetragonolobus	7		9		4						2								4															
6074	Oxalidaceae	Oxalis corniculata	8		10		15		9		12				14		7				6		4		5				1						10	
	Passifloraceae	Passiflora sp.									5		3		2		1		2																	
5783	Piperaceae	Piper sp.	1																																	
	Poaceae	Saccharum edule 'Tropin'	3		3						2	5					3	5	4	10	1	5	3	10	4	20	6	20								
5737	"	Setaria palmifolia			8	10	6	20	5	25	3	5	15	40	21	40	13	50	13	40	14	50			21								11		10	15
5730	Solanaceae	Solanum nigrum	14		17		15		7		7		16		13		13		9		33		4		7						8					
	"	Solanum tuberosum											1																							
6004	Apiaceae	Centella asiatica	42										21		19		54		27		140	5	13		•	10										
3510	Asteraceae	Adenostemma hirsutum	18		14		7		26		14		49		46		61	5	5		27		48	5	59		7		21		37		58			
5726	"	Bidens pilosa	•	50	•	30	75		•	20	140	5	53	5	92	5	128	5	105	5	70	5	133	5	76	5	47		•	20			•	5	33	5
5724	"	Crassocephalum crepidioides	•	20	•	40	•	40	200	10	260	10	180	10	260	10	140	5	•	20	56	5	61	5	38		72	5	•	40	29		46	5	60	5
5797	"	Erechthites valerianifolia													2		8		1		4															
5780	"	Erigeron sumatrensis	17		15		6		3		10		3		3		3		4		2		20		15		10				8		24		13	
6017	"	Lactuca sp.	5		5				5						4		4		6		5		3													
6080	"	Siegesbeckia orientalis	11		19		28		6		11		14				9		16		18		13		17		15				1					
5918	"	'Nobenavi'											2																							
6077	Boraginaceae	Gen. 1																	10				6		13						4		9		14	
6073	Campanulaceae	Wahlenbergia sp.					3																		7											
5734	Caryophyllaceae	Drymaria cordata	46		165	5	84		43		26		90		130	5	120	5	20		100	5	20		13											
5738	Commelinaceae	Commelina sp.	240	5	293	10	200	5	106	5	172	5	42		44		184	5	146	5	160	5							15		10				18	
6033	Fabaceae	Desmodium microphyllum																	7																	
5575	"	Desmodium repandum													2																					
6065	Lamiaceae	Plectranthus sp.																			4															
6028	Polygalaceae	Polygala paniculata									119	5	10						2		6		190	10	260	10	•	10	7							
5748	Polygonaceae	Polygonum nepalense	•	60	•	25	•	15	57		47				41		96		85		72		15		12											
6184	Primulaceae	Lysimachia japonica							38		26		45		5																					

ANU No.	Family	Genus & Species	32		33		34		35		36		37		38		39		40		41		42		43		44		45		45		47		48	
			N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C	N	C
5746	Rosaceae	Rubus rosifolius			15		12		3				4		3		10		10		11		43		210	10	100	20			3					
6051	Violaceae	Viola arcuata																																	•	5
5828	"	Viola betonicifolia	21		34	5	3		7						11		15		24		18		12		10						10		15		33	
5803	Poaceae	Arthraxon hispidus	12										140						25				8				34		12		•	40	•	20	140	10
5802	"	Digitaria sp.													78	5	86	5	21				62		80	5		75								
6099	"	Eleusine indica																									•	40	5				1			
6013	"	Imperata cylindrica	152	5	8								2		3		15		92	5	24		5		13						22		45	5	86	10
5743	"	Ischaemum polystachyum	50				3		15		6				6		5		25		6		19		44	5	•	50			13				22	
6041	"	Leersia hexandra													8				4												15		3			
6066	"	Miscanthus floridulus	17		24		5						2										10		29						9				67	10
6063	"	Oplismenus compositus							14						105		58	5	34				•	40	•	40	62									
6177	"	Panicum paludosum																															•	20		
5539	"	Paspalum conjugatum	39		•	20	12		'48		129	5	3		4		5		93	5	11		14													
6189	"	Paspalum orbiculare																									32	5								
6011	"	Sacciolepis indica	9		7		9								6		5		2				6		9		26								68	20
5600	"	Setaria palmifolia			16		92	10	129	5	140	10	167	5	74	11			28	8							11		7		2					
6003	Cyperaceae	Carex ?beccans			29		1						8		12		10				25		8		5											
6038	"	Cyperus globosus													9		5		18		37		6													
5749	"	Cyperus melanospermus	45		48		16		4		60		50		44		51		48		140		26		49		56									
6021	"	Rhynchospora rubra			1						3		3						4		5															
	Casuarinaceae	Casuarina spp.									10	40	3	40	1	5											1									
6075	Euphorbiaceae	Acalypha sp. 1	4		27								11		20		3														1				17	5
5639	"	Acalypha sp. 2															2																			
6081	"	Glochidion sp. 1											1	20	7																					
6171	"	Macaranga pleiostemona			5										2						7		2	5	1		3				2					
5581	"	Omalanthus ?nervosus	1				3						2						5		2															
	Liliaceae	Cordyline sp. (3 types)					13	20	•	10			1												1											
5759	Moraceae	Broussonetia papyifera									5	5	2		2		1		10	20	3	5														
5757	"	Ficus dammaropsis	3																								4									
6434	Rhamnaceae	Alphitonia incana																					2	5							5					
6172	Sapindaceae	Dodonaea viscosa	4		21		14	5	16	5	25	10	8		36	5	10	10	23	10			35	40	38	60			2		7		34	10		
6462	Saurauiaceae	Saurauia sp. 3																	1		3	5			1											
5569	Solanaceae	Solanum ?torvum																							2											
6298	Theaceae	Eurya meizophylla																							2		2				7					
5771	Urticaceae	Debregeasia sp. 2	1		2		1				1		5		11		5		4		14															
6018	Cyatheaceae	Gen. 1																							2											
6022	"	Gen. 2																					8													
6023	Pteridaceae	Sphenomeris chinensis																					4								67	50				
6185	Thelypteridaceae	Gen. 1									34										6															
	'Pug'		40		34		20								5		16		68	5	88	5	5		5											
	'Bugamp'				2		7										15		24		38				10											

APPENDIX 2

THE POLLEN ANALYSIS RESULTS

The following tables show the actual pollen and spore counts before expression as percentages.

SURFACE SAMPLES

Sample No. / Pollen Taxa	HS3	HS4	HS9	HS12	HF2	HF15	HF3	HF5	HF7	HF6	HF10	KV203	HO71	HO72	KV2	KV4	VK9	VK8	VK4	VK3	VK7	KV1	VK6	VUR3	VUR4	VUR5	VUR2	VUR6	VUR7	VUR8	DR12	DR13	DR SVII
Acronychia		3																															
Ascarina	1		1	1		1	4	3		1		1							1		1					1							
Castanopsis	1	3	6	2	4	12	3	3	2	3	5	167	113	60	17	43	263	17	7	7	5	11	8	8	5	9	4	6	15	4	11	11	13
Celastraceae						8																											
Claoxylon					2		1																										
Cunoniaceae	1		2		4	11		3	2				1		8					1		20			4		2					1	
Dacrydium																									1			1					
Drimys				4		1		90	15																								
Elaeocarpaceae	1	2	2	13	13	22	6	7	6	3	1	7	3		13	3						1					1	2			1	1	2
Epacridaceae - 30µ		23		4																													
Ericaceae - 40µ	2					4	1	1	1		1																						
Evodia				4	2		1						2	2	1	1						1								1			
Fagraea						5									1																		
Helicia				1								3		1																			
Ilex			2	5	1						1					1																	
Lauraceae		1		3	1	5	4	2	43		18									1													
Myrtaceae	2			1	17	7	1							12	27	1		2				1							1	2		1	
Nothofagus	18	[illegible]	41	17	20	21	41	93	143	192	72	20	57	142	25	92	1	12	13	4	9	8	6	15	15	21	4	14	25	7	54	21	9
?Palmae																												1					
?Pandanus						1								1							1		1		2	2			4	1	2		1
Phyllocladus		1	2																1			1				1		2	1	1			
Podocarpus - 2 vesiculate			1	7			3				1		1	2			1	1	1	1			1	2	1	3	2	1		2		1	
Podocarpus - 3 vesiculate		1			1																												
?Prunus				2																													
Quintinia	3		2	24	16	31	4							1																			
Rapanea				1																													
?Sapindaceae	2	1		1	1		1	1	1																								
Sphenostemon			2	2	1	7	1	3				1																					
Symplocos	3	2		1		1					1																						
Acalypha	10	2	3		3	4	5	5		3	1	3	3	4	9	5	5	11	4	2	3	24		8	3	23	4	2	1	1	8	5	4
Casuarina	2	1	4		4		6	1	2	3	3		2	1		7	13	50	5	1	2	12	4	23	4	8	5	1	1	2	11	4	6
Dodonaea			3		1	2	1	3	1	1	2	1	2	1	1	1		17	2	3		1	1	1	1		1	2				3	1
Euphorbiaceae	1	1			13	1							1																				
Glochidion																												1	1				
Macaranga	9	6	5	2	5	8	8	11	25	4	35	5	2		6	4	4	63	2		1	3		5		1	1	3	1		4	4	1
Melastomataceae																												1					2
Moraceae										1			1		1			4													3		
Omalanthus				1						3																2							
Saurauia		1			11	5	1		1	1	2		1	4		3													1				
Schefflera	18	10	19	1	6	7	15	9	12	6	3	7	5	4	68	4	4	7	1	8	6	11	5	4	4	10	2	1	1		11	21	4
Trema	7	3	2	6	5	21	11	4	28	37	12	25	12	9	19	7	10	25	14	7	10	31	10	8	12	6	7	5	10	25	11	14	9
Urticaceae	2	1	5	2		2			4				2	2		2								3	2	1			1		2		1

SURFACE SAMPLES

Sample No. / Pollen Taxa	HS3	HS4	HS9	HS12	HF2	HF15	HF3	HF5	HF7	HF6	HF10	KW203	HOF1	HOF2	KW2	KW4	KX9	WK8	WK4	WK3	WK7	KW1	WK6	WUR3	WUH4	WUR5	WUR2	WUR6	WUR7	WUR8	DR12	DR13	DRSW 11
Apiaceae	1																							1					2				
Astelia	5	3																															
Asteraceae CP3	6															1		1	2					3	3	1			2				
Asteraceae - fenestrate						1																				1							
Brassicaceae					1		1													1			2				1					2	
?Chenopodiaceae											1														5					1			
Coprosma	3	1	3	2																													
Drymaria											19														2								
Haloragis								1			3			1					3	1			1	1								1	6
Lamiaceae																								1									3
Liliaceae (C3)											1															1							
Plantago aundensis	6	4	1																														
Plantago lanceolata																								1								1	
?Potentilla			1																														
Ranunculus	9	5	1																														
Wahlenbergia						1	1																			1						1	
Potamogeton	1																																
?Utricularia																												1	1		3		
Xyris																															2		
Poaceae	21	25	59	6	8	5	12	6	5	5	11	8	12	11	8	24	20	30	136	149	120	22.	135.	134	107	69	76.	120	59	33	31	68	90
Cyperaceae - unmeasured	4	1	1		1	1	2	1		3	2		2	2	1	4	1	5	8	7	2	3	2	27	18	7	12	20	9	18	24	53	18
Pteridae - indeterminate	12	7	36	6	9	8	3	6	10	3	19	2	18	11	5	19	7	12	24	10	15	39	21	23	29	27	51	8	28	69	14	14	18
Monolete - verr. 24μ	30																																
Monolete - verr. 35μ	4	1		5	5	3	6	2	4	3	1	1	1	6		3	3		10	2	3	1	11	6	2	1	1	12	7	3		2	24
Monolete - papilliate	5	2	6	6			9		10	5	4			2	13	2		16				2		3	3		6			10	1	2	
Monolete - scabrate					6			2	1	1		2	1				1	7															
Trilete - psilate	6	11	7	19	5	26	24	15	13	4		5	5	2	5	8	10	5	12	4	28	11	8	11	16	10	14	13	8	14	11	24	12
Trilete - papilliate	20	7	4	108	36	7	59	4		2		2	4	5	4	8	3	2	7	6		20	2		1	6					3	1	
Trilete - reticulate	3		42				2		1																								
Trilete - echinate																				1			3	2	2			1	5	3		1	1
Pteris sim.																								1						1	1		
Grammitidaceae			1	1		5																											
Lycopodium 'rugulate' lge.																															1		2
Lycopodium cernuum														1	1				2	3	7	1	9	5	1	1	6	4	12	.	30	19	13
Lycopodium 'reticulate'			5		1		7			1					1				1														
Lycopodium 'fossulate'			1				1					1										1										1	

Core No. M 1

Depth (cm) / Pollen Taxa	0-1	9-10	19-20	29-30	36-37	40-41	50-51	59-60	63-64	70-71	79-80	90-91	100-101	111-112	121-122	130-131	145-146	157-158	171-172	185-186	199-200	209-210
Ascarina																						
Castanopsis	13	12	7	11	12	26	20	20	13	31	5	17	25	20	26	24	20	2	3	11	8	9
Cunoniaceae			1										1									1
Dacrydium	1	1																				
Drimys							1														1	
Elaeocarpaceae					1	4			3	2			3	6	1	1	2	5	1	2	1	1
Ericaceae - 40µ																						
Evodia																		1				
Fagraea																						1
Maesa										1												
Meliaceae				1																		
Meliosma	1																					
Myrtaceae							1		1				1								2	4
Nothofagus	10	8	8	6	7	14	19	19	18	6	2	9	12	4	6	9	7		1	14	9	26
?Palmae	1																					
?Pandanus									1													
Phyllocladus	1					1				2	1				1	1	1	1			1	6
Podocarpus - 2 vesiculate					2	1	1	1				1		1								3
Podocarpus - 3 vesiculate																						1
Quintinia									1				1								3	3
Sphenostemon		1																				1
Acalypha	13	9	5	10	7	8	5	5	6	2	2	4	3		1	6	6	14	8	5	38	40
Araliaceae																	1	7	3	5	1	
Casuarina	3	1	2				5	1		1		2			3	1	1		1			1
Dodonaea	2			1		2	1	1		1			1				2			1	1	
Euphorbiaceae															1		2	1				
Glochidion	1																					1
Macaranga	8		2	4	1	2	9	1	7	2		6	4		10	10	3	3	1	6	1	9
Melastomataceae	1		2												1				3	1		1
Moraceae					1												1					
Omalanthus																						
Saurauia												1		1	1							
Schefflera																						
Schuurmansia																						
Trema	6		1	3	2	6	4	2	5	5		2	2	4	3	11	6	123	106	9	55	79
Urticaceae	117	124	153	139	130	114	103	114	95	102	156	113	115	118	51	94	63	35	51	70	28	22
Amaranthus				1							1											
Anielema											1											
Apiaceae	7	1	1	1	1		2	1	3	4		2	9	8		2	2		2			
Asteraceae - CP3	1	1			1		1	1	2		1	2				1	2					
Asteraceae - fenestrate						1				1												
Brassicaceae		1	1	2		2	1	2	1	1	1					1	1					
Drymaria												1					1					
Haloragis		1			1	1			2								1			1		

Core No. M 6

Depth (cm) / Pollen Taxa	4-5	10-11	14-15	24-25	31-32	37-38	41-42	43-44	51-52	61-62	71-72
Ascarina									1	2	
Castanopsis	12	13	4	8	30	15	5	22	28	20	31
Cunoniaceae	1										1
Dacrydium						1		2			
Drimys											
Elaeocarpaceae	1	1				2		2			
Ericaceae - 40µ										1	
Evodia									1		
Fagraea											
Maesa											
Meliaceae											
Meliosma	1										
Myrtaceae	1	2		1					1	1	
Nothofagus	7	7	7	5	9	3	11	12	32	28	21
?Palmae											
?Pandanus											
Phyllocladus		1					2				
Podocarpus - 2 vesiculate	1				2		4		1	2	
Podocarpus - 3 vesiculate					1					1	
Quintinia									1		
Sphenostemon											
Acalypha	3	1	1		18	13	4	26	4	1	7
Araliaceae											
Casuarina	1	1		2	6	7	6	3	2		
Dodonaea	1			1			1	1	3	5	2
Euphorbiaceae					1						1
Glochidion											
Macaranga	1	1	1	1	1	3	1	3	2	3	1
Melastomataceae									1		
Moraceae			1		1	1	1			9	2
Omalanthus								3			
Saurauia	1				5	2		7	3		2
Schefflera					1					1	
Schuurmansia					1					1	3
Trema	1	1	2	2	1	8	3	6	3	5	1
Urticaceae	146	122	242	31	83	97	55	71	102	106	105
Amaranthus									1	1	
Anielema											
Apiaceae	1	6		3	7	6	5	1	2		2
Asteraceae - CP3		1			1		1		2	2	2
Asteraceae - fenestrate											
Brassicaceae		1			4	1		2	4	3	3
Drymaria											
Haloragis											

Core No.	M 1																						M 6										
Depth (cm)	0-1	9-10	19-20	29-30	36-37	40-41	50-51	59-60	63-64	70-71	79-80	90-91	100-101	111-112	121-122	130-131	145-146	157-158	171-172	185-186	199-200	209-210	4-5	10-11	14-15	24-25	31-32	37-38	41-42	43-44	51-52	61-62	71-72
Pollen Taxa																																	
Lamiaceae	1			1						1				1	2					1							1			2	1		1
Plantago lanceolata										2														1						1	1		
Psychotria		1																															
Rumex																								1									
Myriophyllum			1																											1	1	1	
Potamogeton																								32									
Sparganium																								1			9						
Poaceae	143	70	106	157	103	118	135	147	103	153	92	156	163	113	285	202	948	11	27	35	10	16	66	84	97	167	145	585	360	204	189	151	135
Cyperaceae - unmeas.	31	16	8	9	6	3	13	4	10	8	3	10	25	4	3	10	2	1	2	7		2	11	24	10	8	23	9	5	9	16	16	4
Cyperus	16	16		4	2	7	4	7	5	9	1	1	7	4	4	3				1			48	15		15	18		5	6	9	3	6
Fimbristylis	10	14	4	4	7	1		1	2	2	1	3	1									1		6			8				1	3	1
Kyllinga	8	2	1	1		2	2	1	1	1		3	2	15	3					6		1	2	9	2		13	2	3	3	5	3	4
Machaerina	3		1	3	2	1	1	1		1	1					2				1			8								7		
Pteridae - Indeterm.	143	113	151	96	125	23	35	33	20	53	25	79	157	13	24	24	11	5	5	13	2	22	130	165	112	156	115	35	13	44	51	61	40
Monolete - verr. 35µ	3	2	4	2	7	15	12	9	11	3	3	2		1	2	1			1			1	4	5	2	2	3	10	5	12	13	16	14
Monolete - papillate									1	19	2					5				2												4	
Trilete - psilate	2	2	2	1	2	4	1	1	4	3	1	1		4	1			1	2	1	5	7	8	6	4	1	30	4	4	6	5	4	6
Trilete - echinate	1			2			1		1	1			1							1				1		1	1			1	1	1	
Pteris sim.				1		1	1	2	3		1									1			2				3	1				2	
Grammitidaceae			1				1																										
Lycopodium - rug. lge.															1																		
Lycopodium cernuum	3	3	3	1	1	3	11	7	5	1		1			2					1		1											
Lycopodium - retic.			1					1	2													1											
Lycopodium - foss.																1		2	2	3	15	4											
Unknown 2					1														9														
Unknown 3						1																											
Unknown 4															1		1	1															
Unknown 8																					4												
Unknown 9							1										1													1	5		
Unknown 11																																1	
Unknown 13																								1									
Unknown 14	1	1		1				1		3		1				1													2	1	3	2	2
Unknown 16																			1														
Unknown 17																												1					
Unknown 18																					1												
Unknown 19																						1											
Unknown 21																																1	
Unknown 25	1																3				2		1									2	7
Unknown 26																											1						
Unknown 28					1																												1

Core No. M 6

Depth (cm) / Pollen Taxa	81-82	91-92	101-102	121-122	127-128	131-132	134-135	138-139	141-142	147-148	155-156	160-161
Lamiaceae			1									
Plantago lanceolata			2					1				
Polygonum								1				
Solanaceae												
Myriophyllum			1	2								
Potamogeton		1										
Sparganium	2											
Xyris .												
Poaceae	164	196	209	278	204	162	81	342	309	25	22	2
Cyperaceae - unmeas.	10	11	7	13	8	15	2	9	3	1	1	1
Cyperus	13	7	12	13	13	10	3	6	8	6	3	5
Fimbristylis	6		3	2	5	1		1	1			
Kyllinga	3	5	11	18	10	9	4	1	5			
Machaerina		1	2		3							
Pteridae - indeterm.	46	65	48	95	51	25	14	129	232	144	113	24
Monolete - verr. 35µ	23	18	13	24	18	21	7	1	13			7
Monolete - papilliate		2				1		1				
Monolete - scabrate												
Trilete - psilate	12	7	7	4	6	9	3	3				6
Trilete - scabrate												
Trilete - verrucate												
Trilete - echinate		3	5	2	3	1	4	1				
Pteris sim.	4		3	1	7	2	1					
Lycopodium - rug. lge												
Lycopodium cernuum												
Lycopodium - reticulate												
Lycopodium - fossulate												
Unknown 2									1			
Unknown 3												
Unknown 7									2			55
Unknown 9		1	1		2							
Unknown 10												
Unknown 11												
Unknown 12												
Unknown 13												
Unknown 14	7	4	4	6	1	2	1	1				
Unknown 15						1						
Unknown 19		4	1									
Unknown 28												

Core No. DR 159

Depth (cm) / Pollen Taxa	10-11	40-41	70-71	100-101	130-131	140-141	240-245	254-255	274-275	294-295	344-345	369-370	389-390	424-425	444-445	464-465	484-485	511-512	540-541
Lamiaceae								1		1									
Plantago lanceolata																			
Polygonum															1				
Solanaceae																			
Myriophyllum											1					1			
Potamogeton																			
Sparganium															2				
Xyris .																			
Poaceae	65	62	60	37	62	75	113	116	120	153	95	125	48	45	4	6	4	6	2
Cyperaceae - unmeas.	20	31	26	18	14	39	6	8	10	12	13	13	2	4	1	1	1	1	1
Cyperus	12	12	6	7	3		1	1	8	10	9	7							2
Fimbristylis			4								2								
Kyllinga	2	6	1	3	3		5		7	5	1	7				1			
Machaerina	7	10	6	26	24			3								2			
Pteridae - indeterm.	44	9	14	8	6	21	13	5	7	18	15	8	54	15	15	9	5	7	2
Monolete - verr. 35µ	2	3	5				3	1	1	4	1	3	9	2		1	3	7	3
Monolete - papilliate					2			1		1						2			1
Monolete - scabrate			2	3	1		2	2		4	1		1		1	2			
Trilete - psilate	8	4	8	7	1			1	3	5	1	1	5	6	27	9	1	1	4
Trilete - scabrate			1					2						1					1
Trilete - verrucate										3									
Trilete - echinate		2					5	4	6	6	2	5							
Pteris sim.	2			3	3		1	1	1										
Lycopodium - rug. lge	1										1					1		2	
Lycopodium cernuum	5		3	4			3	1	6	7	3	9	5			1			
Lycopodium - reticulate	1																		
Lycopodium - fossulate				1									1						
Unknown 2															1		1		
Unknown 3																			
Unknown 7																			
Unknown 9																			
Unknown 10														1					
Unknown 11														2		1			
Unknown 12														1		2			
Unknown 13			1	1	2		2	1							1		8	3	4
Unknown 14						1	2	3	2		2	2							
Unknown 15																			1
Unknown 19																			
Unknown 28		1	1								1						2		

2.5

Core No. N & cont. UH 159

Depth (cm) / Pollen Taxa	81-82	91-92	101-102	121-122	127-128	131-132	134-135	138-139	141-142	147-148	155-156	160-161	10-11	40-41	70-71	100-101	130-131	140-141	240-245	254-255	274-275	294-295	344-345	369-370	389-390	424-425	444-445	464-465	484-485	511-512	540-541
Anacardiaceae																													1		
Ascarina													1	2																	
Castanopsis	36	35	28	51	32	33	11	27	7	5	7	5	22	10	14	16	22	17	18	21	12	21	16	10	11	8	29	33	33	19	16
Celastraceae																										1	1		1		
Cunoniaceae	1			3										1	2	1						1	1				3	1		2	
Dacrydium				1	2								1				1			1											
Drimys																											5				1
Elaeocarpaceae	1		1	1	2	4		1	1		2				1	1	2		2	1				1		1	5	15	10		12
Epacridaceae - 30µ						1																						1		1	
Ericaceae - 40µ			2																1												1
Evodia													1					2						1					1		
Fagraea																												1			
Helicia																											1				
Ilex		1																													
Maesa																			1				1					1			3
Meliosma					1																										
Myrtaceae					1	2		1			2				1				2		1				7	4	6	4	3		3
Nothofagus	17	27	32	33	23	24	17	8	13	2	3	2	24	9	15	22	20	18	11	11	14	14	5	6	33	115	272	393	225	192	332
?Pandanus												1									1	20	1		3	5		1			
Phyllocladus		1			1	1	3	1	2				2	3	2			1					2			1	2	4	13	6	16
Podocarpus - 2 vesiculate		2	6	5	3	1		2	1		1		6	2	2	1	3	2	1		2						6	4	1	2	
Podocarpus - 3 vesibulate						2						1																			
Quintinia				1	1												1				3	3			1			1	1		
Rutaceae																	1		1												
?Sapindaceae															2																
Sphenostemon																2															3
Sterculiaceae								1																							
Acalypha	6	5	4	8	5	4	5	6	2	1	149	8	15	4	9	10	5	1	3	2	6	3	5	2	4	1				1	1
Casuarina	6		2		1						1		16	6	9	4	4	7	8	1				1		2			2		
Dodonaea	4	6		4	2	2	6	3				2	8	3	2	3	3										1				
Euphorbiaceae				1		1							1	3	1		1			1								1			2
Macaranga	1	2	3	8	2	4	3	1	2	2	3	2	9	4	11	10	10	10	10	9	6	6	1	6	10	1	4	3	8	5	1
Melastomataceae								1								1			1			2							1		
Moraceae	1		1	1	3	1																						2			1
Polyscias													1																2		
Rhamnaceae		1																													
Saurauia		4				4	1	1	3										1		1	1		1	1						
Schefflera	1		1		1				1		1						1											1	2	1	
Schuurmansia			2																								1	1			2
Trema	4	9	5	8	6	3	6	8	2	1	3	6	2	7	16	26	9	11	8	2	1	2		6				1	1	1	2
Urticaceae	74	57	70	32	82	92	122	46	11	84	31	28	25	16	14	25	20	10	13	15	84	18	24	10	9	12	10	11	7	6	15
Amaranthus	2	1	1	2	1																										
Aniellema			1																												
Apiaceae	1	2	2	1	1	2	1	2	9	4		2				1			1					2	1						
Astelia																						1						2			
Asteraceae - CP3		1	1	1	2	2		1			1									2	1	1	1	2	1	1					
Asteraceae - fenestrate														1					1			1				1					
Brassicaceae		2	4	3	2			1	1		2				3				1	1	2				3						
Drymaria			3						1							1															
Fabaceae																	1														
Gunnera																							1								
Haloragis							1	1					1						1	1	7	5	2			3					

DR SWII/29

Core No.																												
Depth (cm)	9-10	29-30	49-50	69-70	89-90	104-105	124-125	144-145	175-180	204-205	224-225	244-245	264-265	294-295	304-305	324-325	344-345	364-365	394-395	424-425	464-465	484-485	524-525	544-545	624-625	664-665	684-685	704-705
Pollen Taxa																												
Ascarina				1		1											1				4	4	4	8	11	7	8	6
Castanopsis	12	19	32	9	22	28	27	17	16	20	9	0	5	2	7	1	5	1	9	24	18	32	41	13	20	17	34	11
Cunoniaceae	4	1							2														25	1			2	
Dacrydium			1	1									1								1						1	
Drimys																2						10	1	1				
Elaeocarpaceae	1			1	1	6	4	2			2	2	4			2	2	1	1	16	2	11	16	80	2	4		5
Epacridaceae - 30µ											1		6	2	11	2			1			72	1			1		
Ericaceae - 40µ	2		1	7	2	2											3	1	3	1								
Evodia				1													3			1		1	14	3	6	1		3
Fagraea		1	1	2													1				2	3	3					
Helicia																								1			1	
Ilex											1										1		1					
Maesa			15						1											1								
Myrtaceae					1	1		1			1	1	2	1	2		4	1	1	29	2	8	9	42	9	28	2	8
Nothofagus	11	19	24	9	13	11	12	6	4	11	21	70	268	19	62	290	342	266	271	85	48	112	51	55	60	51	79	38
?Palmae																							1		1			
?Pandanus	1										27	1		10	17								1				1	
Phyllocladus	1	1			1		1	1		1	2	2	4	1		6	1	2	1	8	63	1	2	1	2	1	7	4
Pittosporum																					2	6		9		2		4
Podocarpus - 2 vesiculate	1		1				2	1			12	6	21	12	7	6	1	7	3	3	2	18	2	1	4	1	1	1
Podocarpus - 3 vesiculate															1	1		1				25	4		1			2
Quintinia			1													2				3		1		4	2			
Rapanea																				1	1		3					
Symplocos										1											2	4	2	1				
Acalypha	4	8	1	7	4	2	2		1		2		1	1	1	1				2	1	3	4	1	2	4	3	5
Casuarina	2	8	5		2		2	1		1					1										1		1	
Dodonaea		2				1				1																		
Euphorbiaceae		3		1		1		1		1	1								3					2	2	2	3	1
Macaranga	3	6	4		6	5	8	10	3	5	4		1	4	5	1		1	1	8	2	2		2	2	10	16	20
Melastomataceae			1	3			1																	1				
Moraceae						1																						1
Polyscias						3														1				1			2	
Saurauia							2				1											4	1					
Trema	10	13		3	1	2	2	2	2												1	1						
Urticaceae	4	13	8	7	11	15	11	6	5	10	16	26	2		5		1			2	3	9	3	2	4	3	5	4
Apiaceae																					1							8
Astelia															10							1	3					
Asteraceae CP3								1											1									
Asteraceae-Fenestrate		1		1																								
Brassicaceae	3			3		1		1	1	1	1							1									4	
Galium															1						2			1				
Gunnera																											3	
Haloragis								1							3												2	

Core No. DR SVII/29

Depth (cm) / Pollen Taxa	9-10	29-30	49-50	69-70	89-90	104-105	124-125	144-145	175-180	204-205	224-225	244-245	264-265	294-295	304-305	324-325	344-345	364-365	394-395	424-425	464-465	484-485	524-525	544-545	624-625	664-665	684-685	704-705
Lamiaceae				1		1	1	1	1		1													1				
Plantago lanceolata																	1											
Psychotria																				1	1	1	1	1				
Solanaceae																1			2					4				
Wahlenbergia															3	2				1								
Eriocaulon																									23			
Myriophyllum		9	26	6		2	1				20			8	4					2	15	2		1		1	119	4
?Utricularia											1																	
Poaceae	91	104	98	38	65	49	94	135	91	71	24	27	5	4	14	3	5	3	6	8	7	5	20	13	5	54	72	7
Cyperaceae - unmeas.	10	6	9	10	11	3	4	13	24	11	12	3	6	6	5			5	3	14	5	1	12	9	35	9	29	32
Cyperus	4			1	3	1			1					1					1	4								
Fimbristylis	2		1			3														1					26			44
Kyllinga	1					5			3	3									1	2								
Machaerina	4			5	1	6	3		5														3					
Pteridae - indeterm.	12	21	27	61	28	29	27	11	13	10	55	40	41	23	44	28	13	22	31	12	18	29	9	14	21	9	24	9
Monolete - verr. 35u	5	4	40	41	36	56	2		3		7	7	39	3	3	16	7	2	11	7	3	8		30		3		3
Monolete - papilliate	1		1																									
Trilete - psilate	6	1	15	7	1	32	62		3	8	3	33	4		4		75				1	3			1	2	3	1
Trilete - scabrate				3		5			1																			
Trilete - echinate					2																							1
Pteris sim.					1						2			2		1											1	
Grammitidaceae																	4			3		1						
Lycopodium 'rug. lge'		5	1	4	7	19	42				4	1	2	1	1	1								5			1	
Lycopodium cernuum	3	16	19	13	30	54	25	10	2	33	3	8		2								4		4				
Lycopodium 'reticulate'												2			1	1												
Lycopodium 'fossulate'												1																
Unknown 1																								1				
Unknown 3																	1											
Unknown 9															1			1			1					1		
Unknown 10								1					20		5	14	1	2	4	1	11			1	4		7	1
Unknown 11		1																										
Unknown 14	2		1	2	1																							
Unknown 17																									1			
Unknown 19				1																								
Unknown 20																												3
Unknown 22																							1					
Unknown 24										1																		
Unknown 27																						1						
Unknown 28		1	1																1									
Unknown 29		1																										

Core No.	DR SVII/40A										DR SVII/40D												
Depth (cm) / Pollen taxa	4-5	29-30	54-55	69-70	84-85	104-105	154-155	164-165	179-180	189-190	4-5	29-30	54-55	83-84	109-110	124-125	154-155	164-165	174-175	189-190	203-210	223-230	245-250
Anacardiaceae																			1				
Ascarina						1							1		1	1						3	1
Castanopsis	21	21	19	11	15	15	7	11	10	17	12	12	21	20	18	18	20	25	25	11	12	10	18
Cunoniaceae		1			1										1					1			
Dacrydium																							1
Elaeocarpaceae		1		1	2		3	2	2	1			1	1	1	3		3	4	1	1	4	4
Epacridaceae - 30µ														1									
Ericaceae - 40µ		1																					1
Evodia									1														2
Fagraea																					1		
Ilex		1		1				2							5	16	1	14					
Myrtaceae						1	1	1	1						2	3	1				1	4	
Nothofagus	14	16	13	5	7	11	7	10	8	6	10	11	13	8	14	3	10	9	22	7	79	85	2.5
?Palmae																							2
?Pandanus	2				1		1				4				3	14	1	7			28	23	10
Phyllocladus				1					1	2	3		1			1		1	3			1	3
Pittosporum					1				1										1				
Podocarpus - 2 vesiculate					1	1			4	3			2	1	1	2	2	3	1		5	5	4
Podocarpus - 3 vesiculate					1		1														3	1	
Quintinia							1									1		1				1	2
Acalypha	6	4	5	2	1	1		1	3	1	3	3	5	1	7	2	2	2	2	2	1		
Casuarina	4	7	5	4		2	1	4	1		8	7	6			2	1	2	2				
Dodonaea	1		1	1							2	3											
Euphorbiaceae												1		2									
Macaranga	3	7	4	3	7	5	1	5	5	4	4	6	10	2	4	7	1	3	5	5			
Melastomataceae			1									1	1	1		9	1	7			3	2	2
Moraceae				2								1	1		1	1							
Saurauia														1									
Schefflera	1			1																			2
Trema	7	5	11	8	7	4			2	1	10	9	8	1	2	1	7		6	1			
Urticaceae	4	3	6	5	2	8	6	3	9	9	10	12	19	3	16	7	8	14	11	22	20	12	5
Apiaceae			1	1		1			1		1						1						
Asteraceae CP3												1						1					
Asteraceae - fenestrate		1															1						
Brassicaceae	2	1					2	2	1	7				2	1	1	1	6	4	2			3
Drymaria									1														
Fabaceae													1										
Haloragis				2	1			5				1	1	1	3	3		1				4	
Lamiaceae	1		1	2				2	6				3		3	1	1	1	2	1	1		
Plantago lanceolata					1				1												1		

Core No.	DR/SWII/40A										DR/SWII/40B												
Depth (cm) Pollen taxa	4 - 5	29-30	54-55	69-70	84-85	104-105	154-155	164-165	179-180	189-190	4-5	29-30	54-55	83-84	109-110	124-125	154-155	164-165	174-175	189-190	205-210	225-230	245-250
Eriocaulon																							1
Myriophyllum															1						14	3	5
?Utricularia									1	1			1		3			1	1				
Xyris																		2	3				
Poaceae	125	123	137	128	144	122	174	137	142	95	152	127	136	145	141	108	152	123	121	83	14	64	8
Cyperaceae - unmeasured	10	11	14	7	10		5	4	4	15	8	9	13	1	17	6	9	10	3	16	2	8	3
Cyperus	4	10	13	10	6	3	3	2	3	66	12	12	12	3	1	5	4	2	7	40	3		
Fimbristylis	4	6	2	6	6	11	2	5	9	18	11	16	11	5	6	5	8	3	5	5		3	
Kyllinga		6	3	5	2	4	4	5	5	7	2	3	5	2	1			3	3	7	4		
Machaerina	10			3	6	6	4	1	6	12	1	4	6	4	3	1	3	14	8	7	2		1
Pteridae, - indeterminate	11	13	26	8	10	10	14	14	4	14	26	21	15	9	21	25	16	48	8	18	21	37	29
Monol. Verr. 35μ	2	1	1	1		1	2	4		1	2	1				3	1	2	1	2	3	3	21
Monol. Papillate (Hypolepis sp.)					3									3									
Monol. Scabrate					2						1	1			1	20	3		4				
Trilete Psilate (Cyathea)	2	6	1	3	3		2	3			16	7	4	1	4		6		2			11	1
Trilete Scabrate					2																		
Trilete verrucate																						3	3
Trilete echinate	6	3	4	14	5	4	4	6		1	2	6	3	4	7	2	2		3				
Trilete 2 wall 1 verrucate (Pteris)				2		1				1												1	1
Lycopodium 'rugulate' large																	1						
Lycopodium cernuum	4	1	4	1	2	2	1	4	4	11	3	1	4	2	4	18	4	8	7	1	2		
Lycopodium 'reticulate'					1			5						1						1		1	
Unknown 9															3	2	3					1	
Unknown 12																				1			
13	1					1		1	1			1			1			2			1	2	1
14			1		4	6	4	5				5	2	1	5								
15																				1			

APPENDIX 3

DESCRIPTION OF STRATIGRAPHY

The appearance and properties of each stratigraphic layer in the cores was recorded following Troels-Smith (1955). He considers that in the description of deposits three factors are important:

1. PHYSICAL FEATURES i.e. the appearance and mechanical qualities of the deposit.
2. HUMICITY i.e. the degree of decomposition of the organic substance.
3. THE COMPONENT PARTS i.e. the nature, as well as the proportion, of the elements of which the deposit is composed.

For all three classes of parameters he used a 5 class scale for characterization, where zero denoted a real class and always implied the absence of, and 4 the maximum presence of, the quality in question, or the sole occurrence of the component concerned.

Class value	0	0	- absence of
" "	1	$\frac{1}{4}$	- minor presence of
" "	2	2/4	- medium presence of
" "	3	$\frac{3}{4}$	- major presence of
" "	4	4/4	- maximum or sole presence of
Traces	+	1/8	- slight presence of

1. The physical properties considered include:

NIGROR - degree of darkness

NIG. 0 lightest shades occurring in deposits e.g. clear quartz sand, lake marl.

NIG. 1 light shades e.g. marl. gyttja, calcareous clay.

NIG. 2 medium shades e.g. coarse detritus gyttja, fresh swamp peat.

NIG. 3 dark shades e.g. coarse detritus gyttja containing dy; partly decayed swamp peat.

NIG. 4 darkest shades e.g. dy, completely disintegrated peat.

STRATIFICATIO - the degree of stratification

STRF. 0 indicates complete homogeneity of the deposit, or (and) that the deposit breaks with equal ease in all directions.

STRF. 1 - 3 intermediate stages.

STRF. 4 indicates that the deposit consists of very thin minor layers or (and) that it splits very easily in very thin horizontal layers.

ELASTICITAS - the degree of elasticity

ELAS. 0 indicates total absence of elasticity e.g. plastic clay, sand, diatom deposits, fen peat, completely disintegrated swamp peat.

ELAS. 1 - 3 intermediate stages.

ELAS. 4 highest degree of elasticity occurring e.g. fresh sphagnum peat, swamp peat.

(By the elasticity of a deposit is meant its ability to regain its original form after being exposed to pressure, squeezing or bending; the greater its power of resistance, the greater its degree of elasticity).

SICCITAS - the degree of dryness

SICC. 0 clear water

SICC. 1 deposit thoroughly saturated with water, its consistency being very soft, or like thick gruel.

SICC. 2 deposit saturated with water i.e. the condition in which deposits normally occur below the ground water level.

SICC. 3 deposit not saturated with water.

SICC. 4 deposit air-dry. An air-dry deposit always feels warm, whereas a moist deposit feels cold.

COLOUR - the spectral colour of a deposit often reveals essential facts regarding composition, condition etc.

STRUCTURE - STRUC. - under this head it is recorded whether the deposit is homogeneous or heterogeneous, whether it is granular, laminar fibrous or felted etc. Plasticity, cohesion etc. may also be recorded here.

LIMES - LIM. - boundary - a boundary appears between two strata which are different as regards physical conditions, colour, composition etc. The smaller the zone of mixture between the two deposits, the more well-defined the boundary.

2. HUMICITY : This should indicate the degree of decomposition of the organic substance of all kinds of Turfa.

HUMOSITAS - HUMO. - the degree of humicity

HUMO. 0 plant structure fresh and well preserved, no homogeneous ground substance present. A lump of peat, when squeezed in the hand, yields clear, colourless water.

HUMO. 1 plant structure well preserved, homogeneous ground substance present in slight quantity. Squeezing yields more or less dark-coloured, perhaps turbid water. One quarter, at most, of the mass is squeezed out between the fingers, in the form of a homogeneous ground substance.

HUMO. 2 plant structure partly decayed, though distinct. Squeezing yields up to half the mass in the form of homogeneous substance.

HUMO. 3 plant structure in advanced stage of decay, and indistinct. Squeezing yields up to three quarters of the mass in the form of a homogeneous ground substance.

HUMO. 4 plant structure hardly discernible, or completely absent. By squeezing, the whole of the peat mass, or nearly the whole of it passes out between the fingers.

3. COMPONENT PARTS : Troels-Smith states that almost all deposits are mixtures of various components and that if the essential elements can be distinguished, indication of their proportions in any one deposit will provide a means of characterizing that deposit. He distinguishes turfa, detritus, limus, argilla and grana as main component elements and includes also a special element, substantia humosa as 'in certain cases it may be difficult to decide whether a homogeneous, organic black substance is due to complete disintegration of turfa, ... whether it consists of Limus humosus, or is the remains of partly oxidated or disintegrated organic matter as e.g. in arable soil - in which case the neutral term substantia humosa may be used.' He continues, 'besides, it is possible through this element to express the degree of humicity in a deposit as a proportion of substantia humosa and the remaining non-disintegrated part of the deposit.'

Substantia humosa - Sh - humous substance, consists of completely disintegrated or nearly disintegrated, or decomposed, organic substances or precipitated humic acids, and appears as a dark or blackish homogenous substance without macroscopic structure. If in the field, it cannot be ascertained whether a given deposit, or part of it, is Limus humosus (dy, or gel-mud), completely disintegrated Turfa (peat), completely disintegrated or decomposed Detritus, the deposit may be characterized as Substantia humosa.

Turfa - of macroscopic structure, and may consist of mosses or of roots of woody or herbaceous plants. Stumps, trunks, stems, etc. belong to Turfa if connected with the root system. According as Turfa is made up of mosses, ligneous or herbaceous plants, distinction may be made between T. bryophytica, T. lignosa and T. herbacea. Humified turfa may be characterized in two ways, either 1) through the degree of humicity of 2) as the proportion of Sh and T.

Detritus - consists of fragments, varying in size, of the super-terranean parts of plants. It may be divided into three groups:
1) D. lignosus, parts of wood and bark
2) D. herbosus, herbaceous plant portions, and
3) D. granosus, comprising fragments <2mm and >0.1mm of wood and bark, as well as of herbaceous parts of plants.

Humicity may be indicated but is usually very difficult to ascertain.

Limus - a mudlike, homogeneous, non-plastic deposit, consisting of particles or colloids <0.1mm; consequently its structure is not macroscopic. L. detrituosus, L. humosus, L. calcareus etc. may be distinguished.

Ld^{o} - L. detrituosus - is a homogeneous soil, as a rule highly elastic, non-greasy, non-adhesive, consisting of more or less decayed and decomposed micro-organisms, or parts of higher plants <0.1mm. Colour is variable, but as a rule it is light, with greyish, yellowish, greenish and reddish shades. The deposit often becomes darker under the influence of oxygen. When dry, the colour is lighter and the deposit shrinks considerably.

Ld^{4} - (Lh) - L. humosus - is a homogeneous deposit element, sometimes slightly gritty, as a rule little elastic, often very greasy and adhesive, consisting of humous substance. The colour is dark brown, or nearly black and may have a faintly greenish tinge; on drying the element shrinks considerably, while the colour stays much the same.

Lso - L. siliceus organogenes - is a homogeneous deposit element consisting of siliceous skeletons of plants or of animals. When moist the deposit is comparatively heavy, inelastic and greyish white in colour. When dry, it becomes extremely light of weight and assumes a very pale, chalk-white colour, and easily crumbles to fine dust. It is not soluble in dilute hydrochloric acid.

Lc - L. calcareus - is a non-indurated, usually homogeneous soil, consisting of calcium carbonate. When moist is greyish white and comparatively heavy; when dry, it is chalk white and very light. It is soluble in dilute hydrochloric acid.

Lf - L. ferrugineus - is a non-indurated, homogeneous soil, consisting of iron oxides which may be of organic, as well as of mineral origin. The colour may be blackish, bluish, or greenish, or vary from yellow to reddish and blackish brown. Usually lighter in colour when dry, and is non-elastic.

Argilla - consists of mineral particles <0.06mm; thus like Limus it has no visible grainy structure. It is comparatively heavy in dry condition and is plastic when moist. Unlike Grana after drying up Argilla is coherent and comparatively solid.

As - A. steatodes - consists of colloids or grains <0.002mm; it becomes as hard as stone when dried up and has pronounced plastic qualities when moist. Colour is dark.

Ag - A. granosa - consists of grains, the size of which ranges from <0.06mm to 0.002mm. Plasticity is slight, colour light; the soil remains coherent when dry but the surface may be easily rubbed into dust.

Grana - consists of solid particles 0.06mm, which may be of mineral origin, or of organic origin. In dry condition is non-coherent or but slightly coherent. The single grains may be directly observed with a strong magnifying glass or felt between the teeth. Grana are grouped according to the size of the grains, into Ga, Gs, Gg etc.

Other accessory elements are also classified by Troels-Smith but these were not followed in detail in the present study.

APPENDIX 4

STRATIGRAPHIC SAMPLING EQUIPMENT

The investigation of stratigraphy and collection of pollen analytical cores at Draepi was difficult due to the variety of sediments and the surface conditions present there, namely open water and floating vegetation mat.

A raft was constructed for working over the open water. Four empty 44-gallon petrol drums were welded in pairs with iron rods, and long bolts were welded on the top of each to carry two 4 in x 2 in timber stringers. A 10 ft x 6 ft platform was bolted to the stringers using 4-6 in x 1 in planks. Boring was carried out through a central 6 in square hole. The units were transported by landrover to as near the site as possible and then carried. The raft was built fairly quickly in the field and left moored in the correct position with polythene ropes attached to poles driven into the basal sediments near the shore. A rubber dinghy was used to reach the raft.

The raft was too heavy to pull over the floating mat, so for use in the second field season and for elsewhere an alluminium flat-bottomed dinghy was purchased. A central hole (22 cm diameter) was cut in this and a centre-case welded around it (Plate 39 B). The whole was supported by a 30 cm wide plank onto which the baseboard could be clamped. Other boards could also be fitted alongside so that the core could be extruded and sectioned. The dinghy was positioned by ropes fore-and-aft, tied to shore posts; it proved most satisfactory for use on small ponds and could be pulled through or over the floating vegetation mat relatively easily.

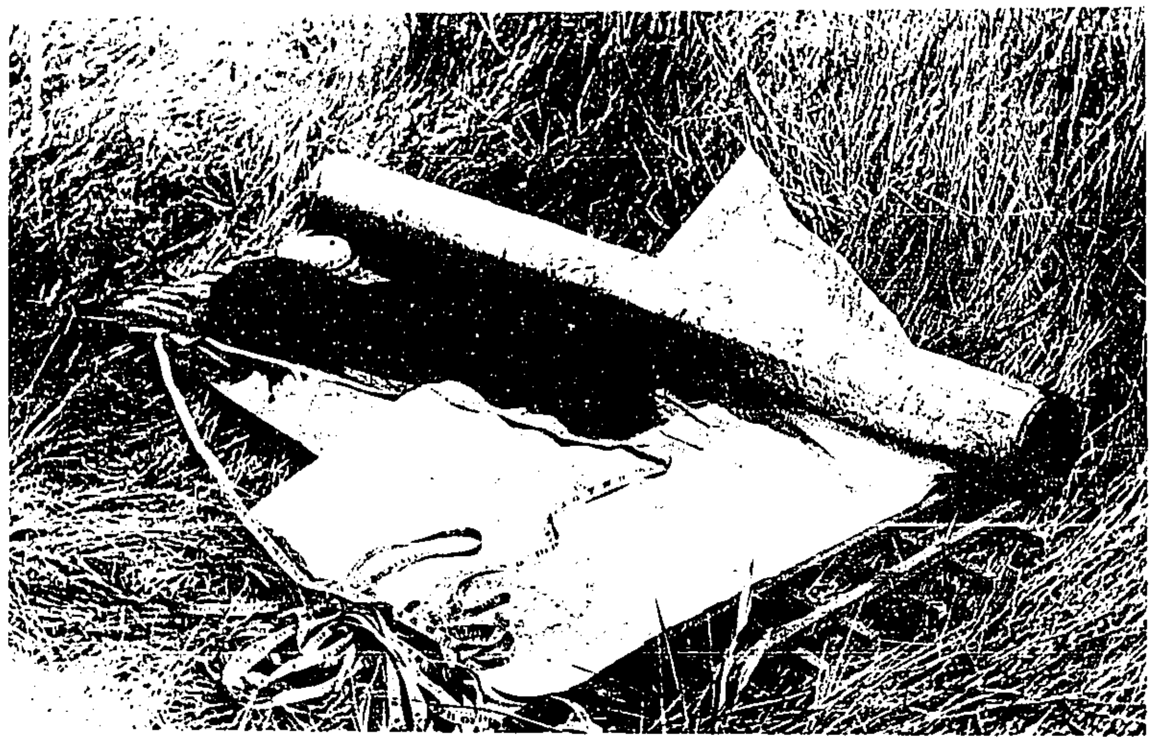
The samplers used during the study were a side-filling sampler similar to a Hiller (Thomas, 1964) sampler and an end-filling piston sampler (Walker, 1964), similar to the Vallentyne sampler (Vallentyne, 1955). Both were attached to extension rods and handles with Lichtwardt joints (Lichtwardt, 1952). The piston sampler was used preferentially for stratigraphy and collecting of pollen analysis cores as it gave clean, undisturbed 1m length cores. It was not very suitable for some of

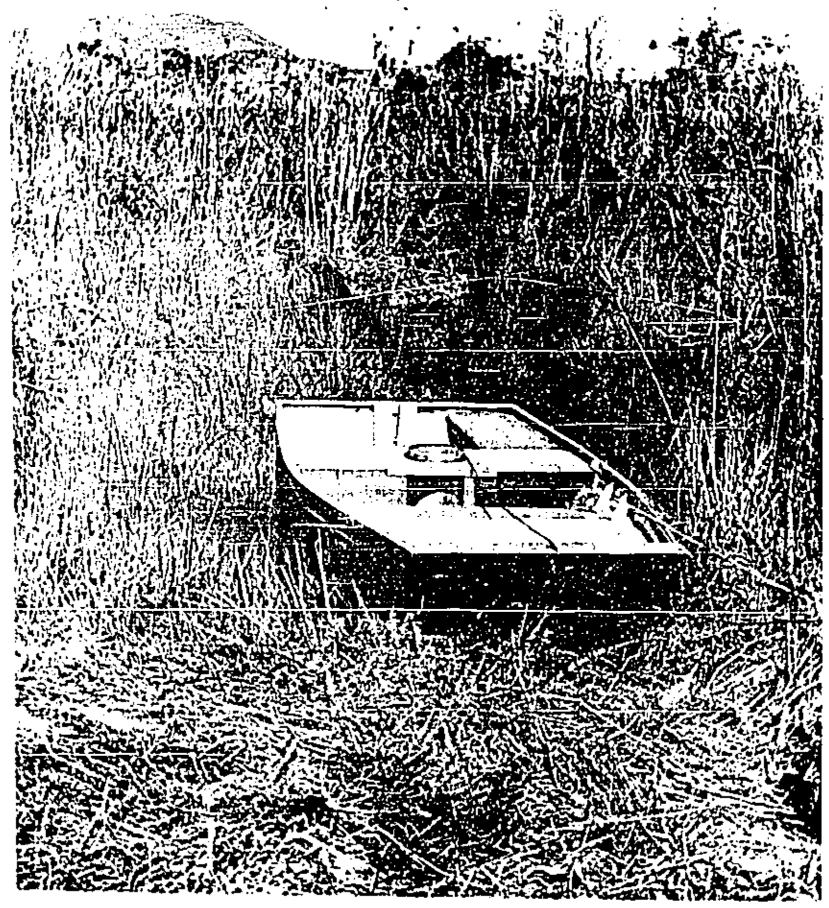
PLATE 39A

The surface sampler used to collect coarse fibrons peat at Draepi.

PLATE 39B

The modified aluminium dinghy with central hole for bore-hole sampling on small lakes.





the sediments present at Draepi. Some of the problems were :

a) it would become plugged with fibrous peat and not collect the full length of core at times,

b) it could not be driven through any obstruction, such as wood or stiff clay - if forced the screws holding the tube head in place would sheer off,

c) it was difficult to work in very wet conditions as the base-board was often under water; the wire would twist, fray and break,

d) the piston was difficult to adjust to the correct diameter,

e) penetration of mixed hard and soft sediments resulted in considerable compression of cores, and

f) it could not be used to collect the uppermost 1m of peat, working from the swamp surface.

The following modifications to design were suggested :

1) The tube head plate should be solid with the tube head; this could be done by threading at the top of the tube. The whole is then drilled vertically for the wire,

2) If the upper end of the piston was machined to take a spanner or wrench it could be easily adjusted. An hexagonal head screw should be used to hold the piston head together,

3) Plaited stainless steel wire should be used,

4) Positions on tube head and piston rod should be permanently marked to aid extrusion of cores,

5) For easier replacement of the piston and head plate after cleaning, the barrel should be grooved and the head plate tongued; there would then be little possibility of the wire twisting around the rod.

In addition, it was considered that a 50 cm length sampler would be useful to sample the harder sediments, possibly with a different type of handle which could be lightly driven.

A base-board was designed for use in situations where the raft could not be used but the standing water depth was such that a standard base-board was continually under water. It comprised :

a) a lower board, 150 cm square (5 ft) and 2.5 cm (1 in) thick, divided into three sections for ease of transport. The sections are locked together by 2 steel bars passing through brackets on the underside. The central section has a 10 cm (4 in) diameter hole to allow passage of the sampler and 4 smaller holes, 5 cm diameter, to take the supports for the top board. A 2.5 cm (1 in) diameter hole is present in each corner (centred 10 cm (4 in) in from each side) to allow for the use of anchoring rods, and, or ropes for towing.

b) a top board, 60 cm x 50 cm (2 ft x 1 ft 8 in) and 2.5 cm thick, which can be raised 30 cm, 45 cm or 60 cm (12, 18 or 24 in) above the lower board by means of 4 pegs. It contains in addition a central 10 cm (4 in) diameter hole to allow passage of the sampler, a small vice and a spring-loaded reel to carry the wire attached to the piston. The vice, reel and centre of the hole are in alignment, the reel mounted so as not to obstruct the operation of the vice. At each corner of the top board a 3 cm diameter hole is drilled, centred 5 cm in from each side, to take the support pegs.

c) a spring-loaded reel, of 8 cm or 10 cm diameter, which should be able to swivel through 360^{o} to allow free movement of the wire whatever the position of the sampler. It should be spring-loaded so that it will recover wire whenever this is not under load. The reel fitting should be readily detachable from the board.

d) the steel bars and brackets : the steel bars require to be of a minimum cross section which will resist bending. One end is bent upwards for 2.5 cm to prevent sliding and a 5 cm extension is allowed at the other end for ease of dismantling. The bars are thus ca 160 cm in length. They are held in place on the underside of the board by 3 brackets. The brackets are fastened to the centre of each board, 54 cm (18 in) in from each end, with coach bolts.

e) supports for top and lower boards must be turned from a single piece of round-sectioned hardwood. Three sets should be made for use under differing conditions. In all cases the uppermost 2.5 cm (1 in), fitting into the top board is of 2.5 cm section, and the lowermost 10 cm, fitting into the lower board and extending below it is of

5 cm section. The middle portion of 8 cm (3 in) section, is of varying length, namely 30, 45, or 60 cm length.

f) an extrusion board, of 3/8 inch plywood, 150 cm x 40 cm, can be fitted onto the top board, thus allowing the core to be laid out on a firm, clean surface. It is held in place by 2, 2.5 cm wide strips of wood, attached to the lower surface.

Plans for this base-board are held by the author. It was used successfully during the second field work period. The lower board, even when well under water will offer a good foothold (together with outside slatted boards) for driving and extracting the sampler and the upper board remains above the surface at all times, thus providing a surface for examination of extruded material. In drier conditions the top board can be used on its own, or placed directly on top of the lower board.

The side-filling Thomas sampler was useful where the piston sampler could not be used. It could be twisted through obstructions and hence could give a more complete record of stratigraphy. However, the core collected was disturbed and was not easy to extract. Also the sampler did not open and shut very well in very soft muds and would not cut the upper coarse, fibrous peat present at Draepi.

Two simple surface samplers were constructed to collect the upper peat during the second field season. Both were 2m long, 12 cm diameter, galvanized iron downpipes, one with a square section, the other round. The square-section sampler was fitted with a hinged 'trap-door' at the base, the round-sectioned one with 10 cm long spring-steel 'fingers', to hold in the collected sample. A handle could be fitted to each and a wooden plate was designed to fit tightly into the top, using heavy rubber bands, to help hold the sediment in place. The samplers were operated by cutting through the fibrous peat with sharp knives around the circumference of the sampler and at the same time gently pushing it down through the sediment. A fine cutting shoe attached at the base would probably be sufficient in less fibrous sediments. The lid was then fitted and the whole pulled to the surface and the core extruded. The sampler with the basal spring-steel fingers proved the more successful of the two (Plate 39 A).

APPENDIX 5

ARCHAEOLOGICAL REPORT ON THE MINJIGINA SITE

The following archaeological report, written by Mr R. Lampert,ANU Dept. of Prehistory, covers the excavation carried out by him at Minjigina. The columns for pollen analysis were collected in May, 1967, soon after the modern drains were dug; by November, the peat had consolidated somewhat and hence Lampert's stratigraphic levels show a difference of 20 cm from those used in the thesis.

MINJIGINA - ARCHAEOLOGICAL INVESTIGATION

The main purpose of this small excavation was to obtain samples from a horizon of charred vegetable matter appearing 110-120 cm below the surface of the swamp deposit. It was hoped that the identification of macroscopic plant remains, particularly those of crop types usually harvested before flowering and not represented in the swamp as pollen, would supplement Miss J. Wheeler's palynological investigation.

With the help of two local workmen the site was excavated during one week in November, 1967.

Site stratigraphy and occupational history

The 3 x 2 metre trench was made in the north face of a modern drainage ditch at a point where an exposed layer of charred plant remains was at its richest. Cutting through this layer from a higher level was a prehistoric ditch which had been sectioned at right angles by the modern drain. The sides of the modern ditch show the general stratigraphy in the vicinity of the excavation, described here from the bottom upwards:-

	Depth in cm.	Description
A	145 +	Very dark brown fibrous peat
B	120-145	Peat of same colour as A but with less obvious fibrous structure.
C	110-120	Band of charred plant remains concentrated at place where archaeological excavation was undertaken.

	Depth in cm.	Description
D	75-110	Very dark brown fibrous peat indistinguishable in appearance from A.
E	75	A break in deposition is evidenced, at some places by a thin band of light grey-brown clay, generally by a horizontal shrinkage crack in the dried out face of the modern drain where earlier formed peat has slumped away from more recent.
F	34-75	Very dark brown fibrous peat indistinguishable from A and D.
G	30-34	Light grey-brown clay band.
H	0-30	Very dark brown fibrous peat indistinguishable from A, D and F.

The first evidence for human occupation is the layer of charcoal which contained in the area excavated a number of fire-blackened stones apparently used for cooking. The charcoal filled depression seen in the drawn section was possibly a cooking pit though stones were not concentrated in it.

The second archaeological feature is the ditch cut from 75 cm below the present surface, a level at which cracking and clay bands indicate a break in the depositional history of the swamp at least for an area cut by the 100 metres or so length of modern drain examined. However, this is the only prehistoric ditch visible in that length.

The bottom of the ditch was not exactly located because it lay below the present water table. The earliest infilling found is a reddish brown peat near the top of which the only implement from the site was found; a short, pointed digging stick.

Above the reddish brown peat was a 10 cm thick layer of very dark brown silt. This could be washed in garden soil, assuming the ditch was part of a water control system for horticultural land, which seems likely since a horticultural implement came from the lower fill.

The upper most sediment infilling the ditch is a light grey-brown clay which is continuous with a thin widespread layer of the same material. This thin layer appears to have intermittently covered the land surface from which the ditch was cut. Thus the final infilling was part of a general deposition of clay apparently water borne from a source not in the immediate vicinity of the site. It suggests fairly widespread flooding of the area, which could explain the presence of several tree branches lying horizontally in the lower part of the clay within the ditch.

A second band of light grey-brown clay some 40 cm above the first can be interpreted in a similar way. There is no direct evidence to link either of the floods indicated by them to human activity, though they possibly result from human interference with the higher watershed, such as gardening on the hill slopes surrounding the swamp. Apart from this very tentative interpretation of the thin layers of clay there are no archaeological features later than the ditch in the excavated area.

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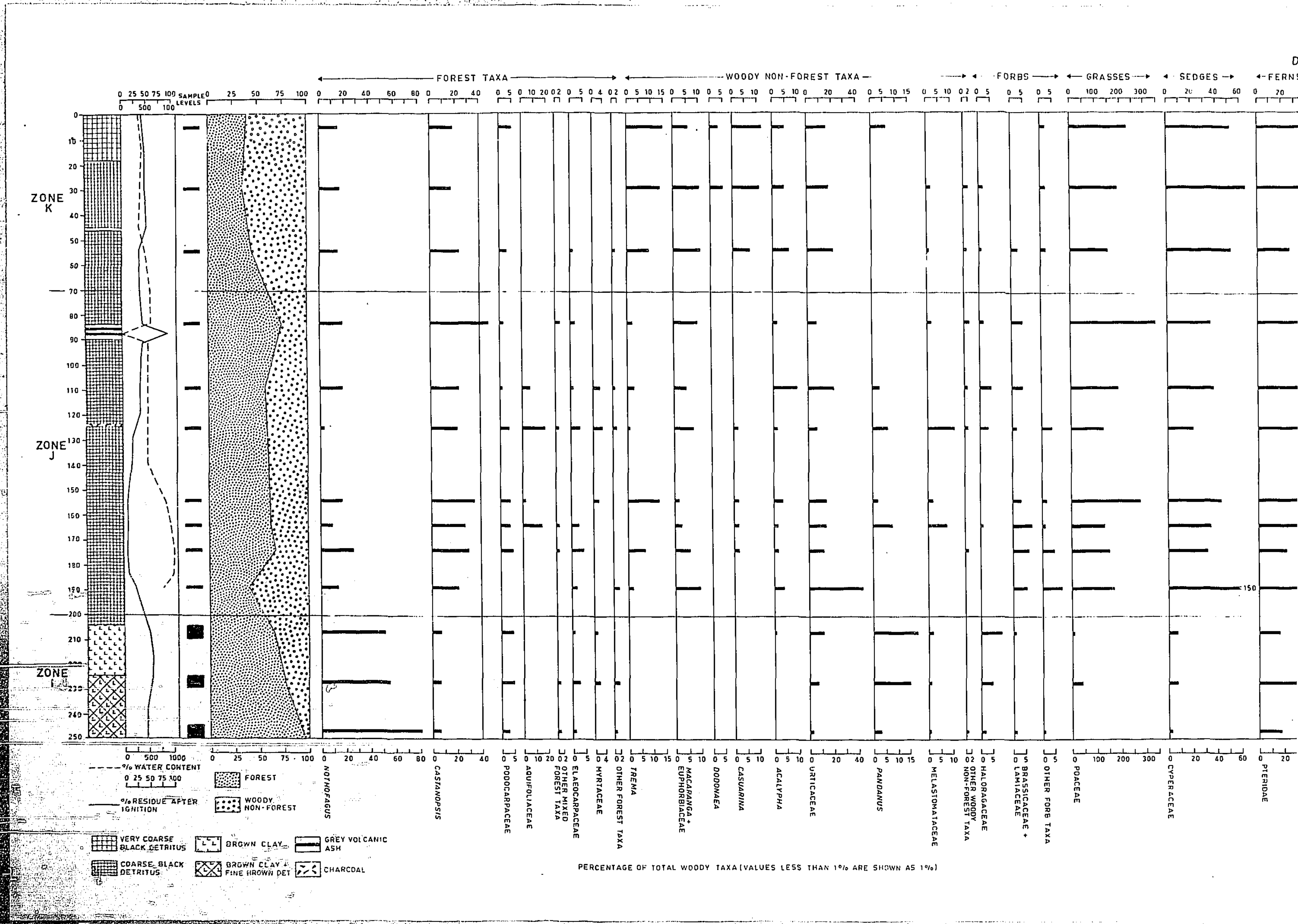

FOREST TAXA
WOODY NON-FOREST TAXA
FORBS
GRASSES
SEDGES
FERNS
SAMPLE LEVELS
ZONE K
ZONE J
ZONE L
% WATER CONTENT
% RESIDUE AFTER IGNITION
FOREST
WOODY NON-FOREST
VERY COARSE BLACK DETRITUS
COARSE BLACK DETRITUS
BROWN CLAY
BROWN CLAY + FINE BROWN DET
GREY VOLCANIC ASH
CHARCOAL
NOTHOFAGUS
CASTANOPSIS
PODOCARPACEAE
AQUIFOLIACEAE
OTHER MIXED FOREST TAXA
ELAEOCARPACEAE
MYRTACEAE
OTHER FOREST TAXA
TREMA
MACARANGA + EUPHORBIACEAE
DODONAEA
CASUARINA
ACALYPHA
URTICACEAE
PANDANUS
MELASTOMATACEAE
OTHER WOODY NON-FOREST TAXA
HALORAGACEAE
BRASSICACEAE + LAMIACEAE
OTHER FORB TAXA
POACEAE
CYPERACEAE
PTERIDAE
PERCENTAGE OF TOTAL WOODY TAXA (VALUES LESS THAN 1% ARE SHOWN AS 1%)

PRÉCIS

The purpose of this thesis has been to investigate the impact of man on the vegetation of the Mt Hagen region, now and in the past. The chosen area of the New Guinea Highlands proved suitable for both parts of the work : a fairly large indigenous population practise subsistence agriculture there and sites suitable for pollen analysis were available. In addition, the discovery and excavation of archaeological material stratified into organic deposits provided evidence of prehistoric human activity which could be directly correlated with the vegetation history.

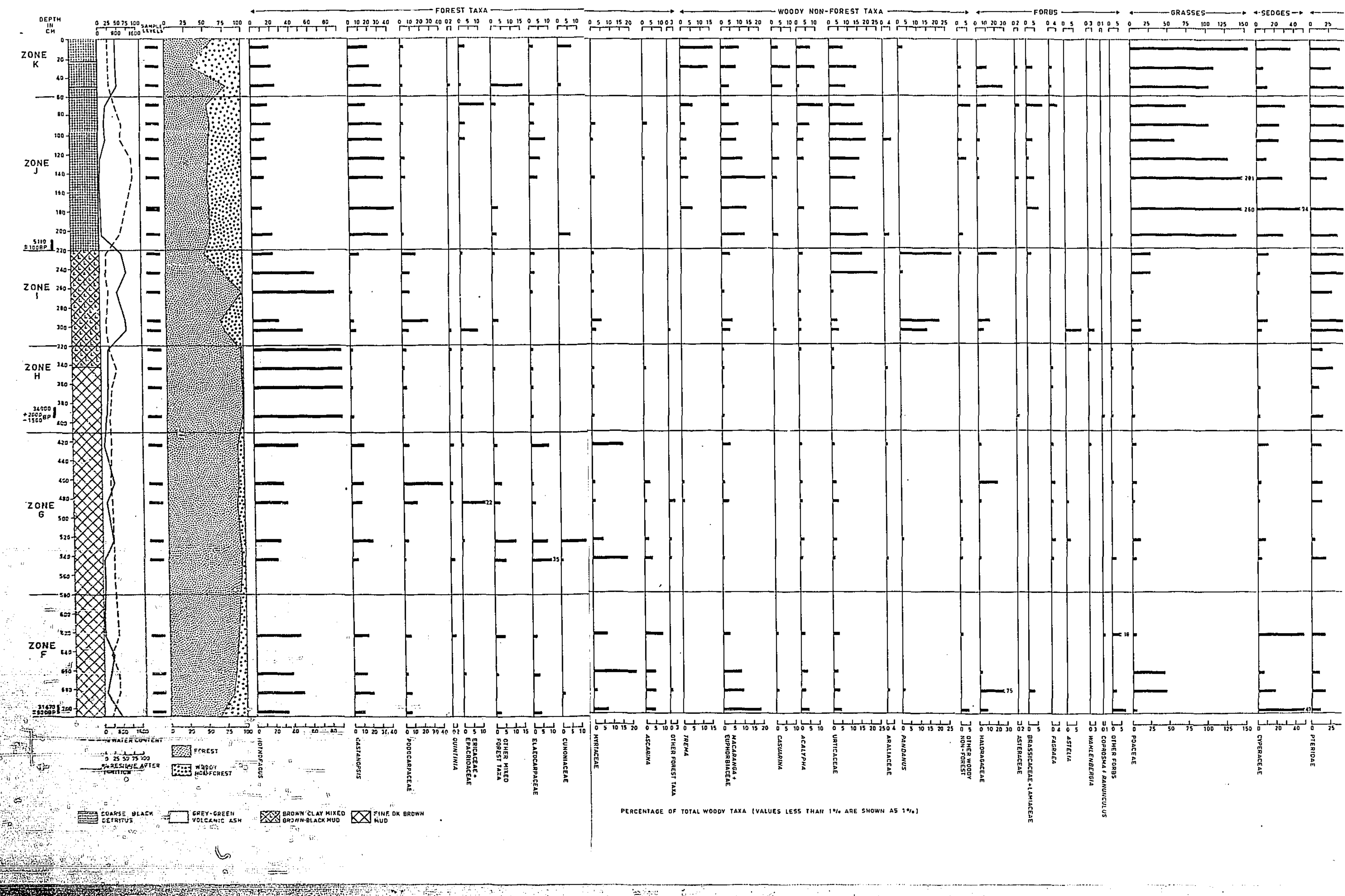
In Chapters 3-5, the present vegetation is described; certain forest and non-forest vegetation types are distinguished and their species composition, areal extent and successional status discussed. The forests are relatively stable, their species distribution influenced mainly by climatic and anthropogenic influences; the non-forest vegetation, on the other hand, is unstable, and the distribution of the various types is determined almost entirely by human influences.

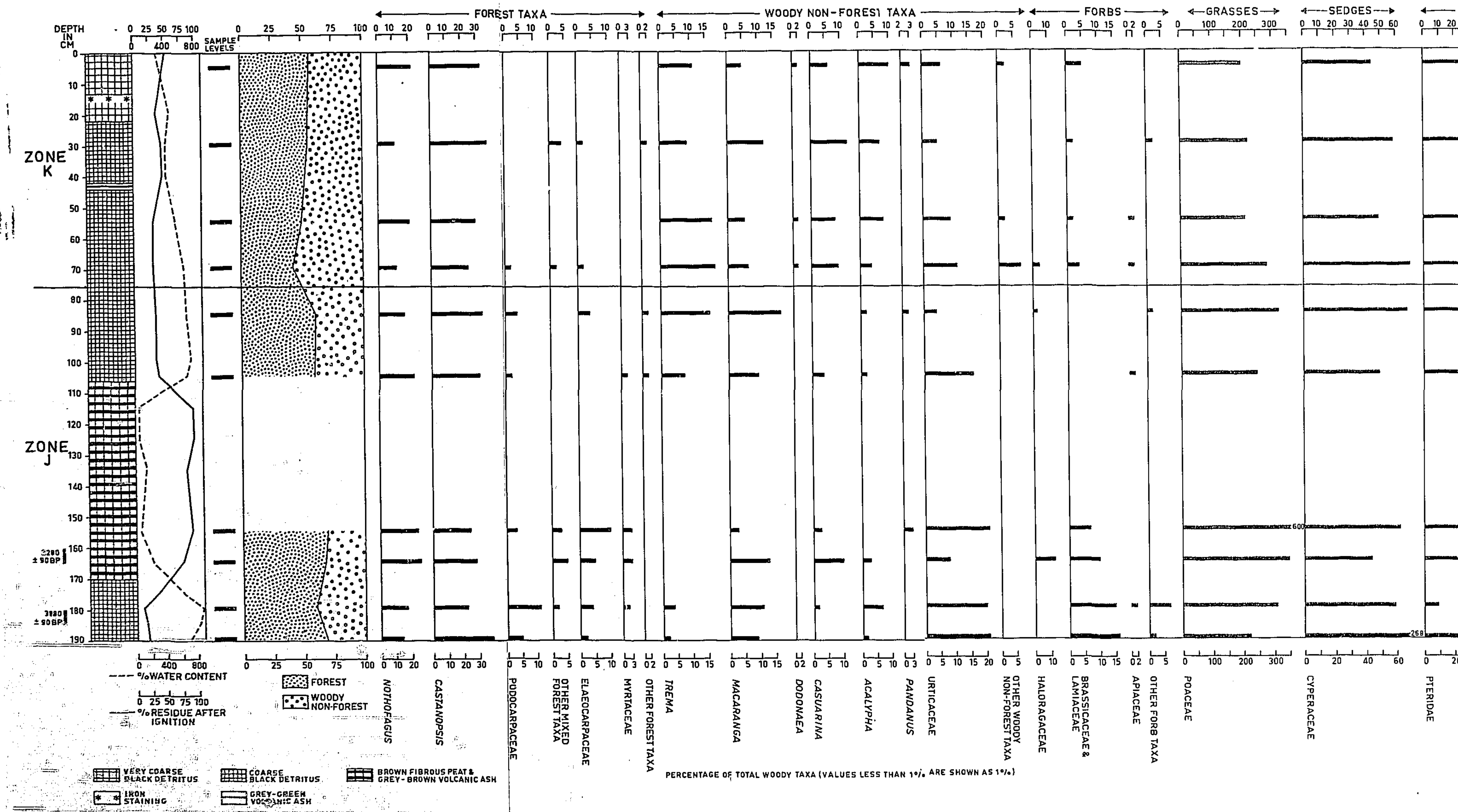
Knowledge of species composition of extant vegetation types is a basic requirement for interpretation of the vegetation history and hence indicator species were sought and found for both forest and non-forest vegetation types.

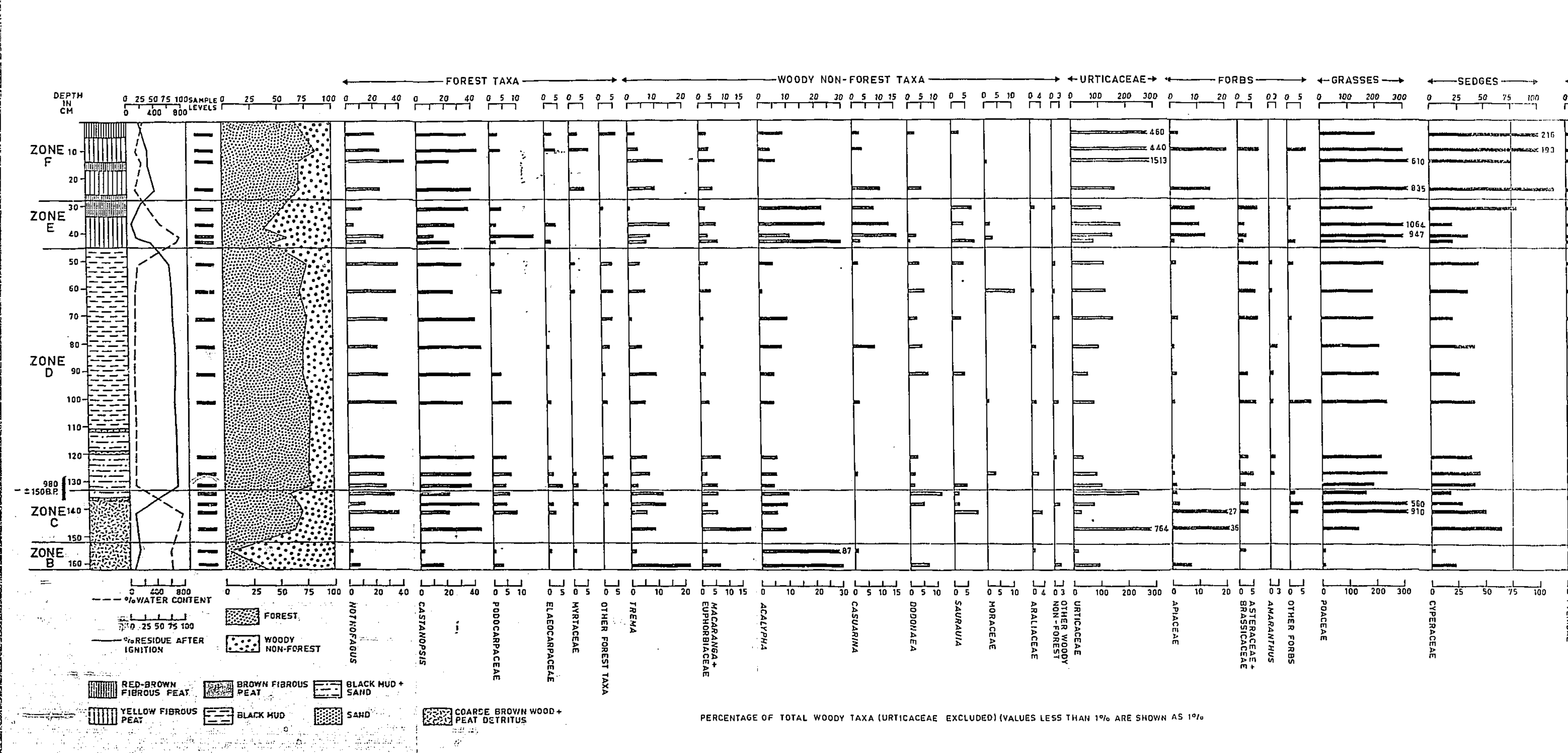
The equation of modern pollen rain spectra with extant vegetation types, considered in Chapters 6 and 7, permits some generalizations about pollen representation and transfer mechanisms to be made and provides a guide to the interpretation of fossil diagrams.

In the last three Chapters the vegetation history of the region is described on the basis of pollen diagrams from two sites, Draepi and Manton's. The facts of human occupation and agriculture are clearly indicated in the stratigraphy and contained artefacts of certain parts of both sites and hence pollen analytical changes at associated levels are ascribed to anthropogenic causes. Some other pollen analytical changes are also interpreted in anthropogenic terms, while others may be ascribed to climatic causes or to natural (autogenic) succession.

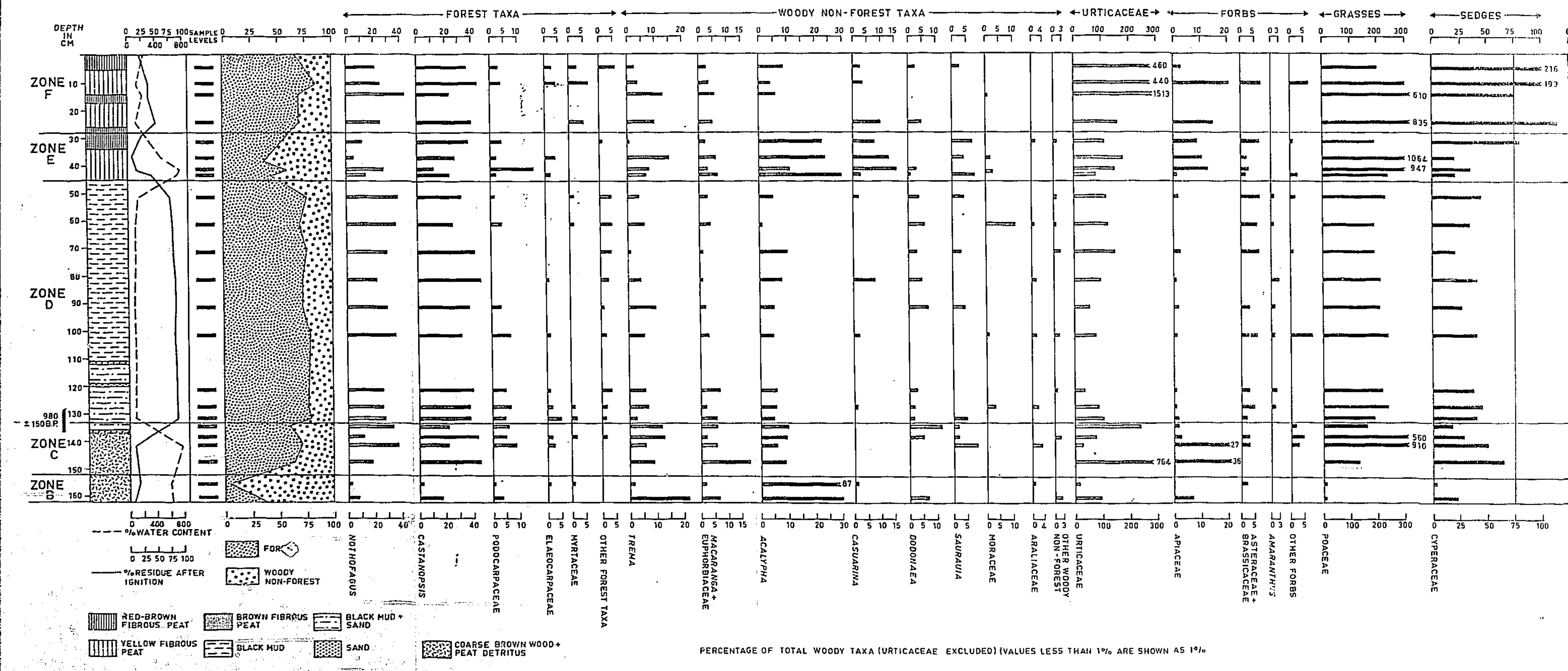
The reconstructed history of the Mt Hagen region is discussed in relation to certain theories of Highlands prehistory and agricultural development and the whole then placed in the context of present knowledge of New Guinea vegetation history.

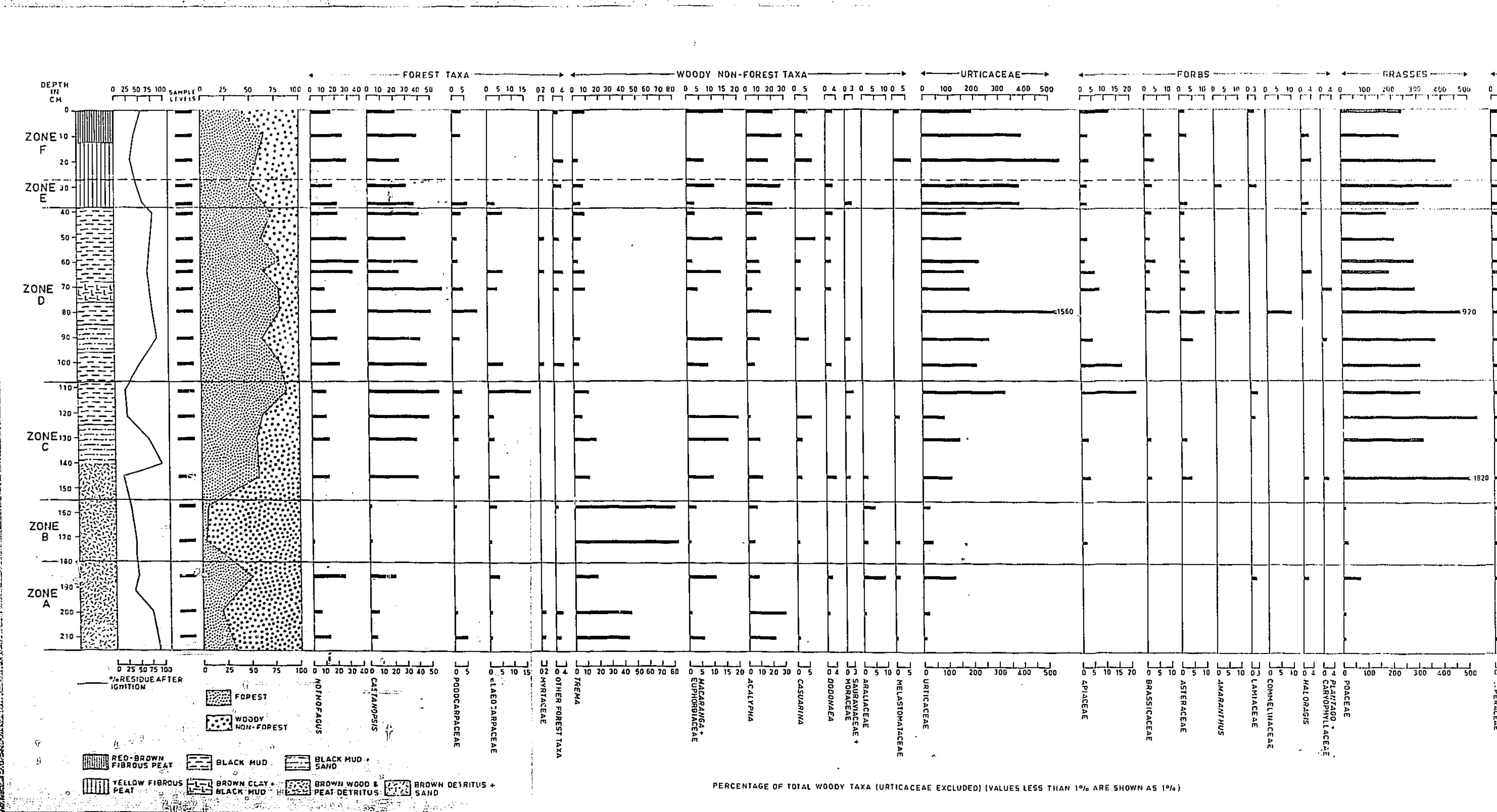

FOREST TAXA
WOODY NON-FOREST TAXA
FORBS
GRASSES
SEDGES
DEPTH IN CM
SAMPLE LEVELS
ZONE K
ZONE J
ZONE I
ZONE H
ZONE G
ZONE F
WATER CONTENT
% RESIDUE AFTER IGNITION
FOREST
WOODY NONFOREST
NOTHOFAGUS
CASTANOPSIS
PODOCARPACEAE
QUINTINIA
ERICACEAE + EPACRIDACEAE
OTHER MIXED FOREST TAXA
ELAEOCARPACEAE
CUNONIACEAE
MYRTACEAE
ASCARINA
OTHER FOREST TAXA
TREMA
MACARANGA + EUPHORBIACEAE
CASUARINA
ACALYPHA
URTICACEAE
ARALIACEAE
PANDANUS
OTHER WOODY NON-FOREST
HALORAGACEAE
ASTERACEAE
BRASSICACEAE + LAMIACEAE
FAGRAEA
ASTELIA
WAHLENBERGIA
COPROSMA + RANUNCULUS
OTHER FORBS
POACEAE
CYPERACEAE
PTERIDAE
COARSE BLACK DETRITUS
GREY-GREEN VOLCANIC ASH
BROWN CLAY MIXED BROWN-BLACK MUD
FINE DK BROWN MUD
PERCENTAGE OF TOTAL WOODY TAXA (VALUES LESS THAN 1% ARE SHOWN AS 1%)

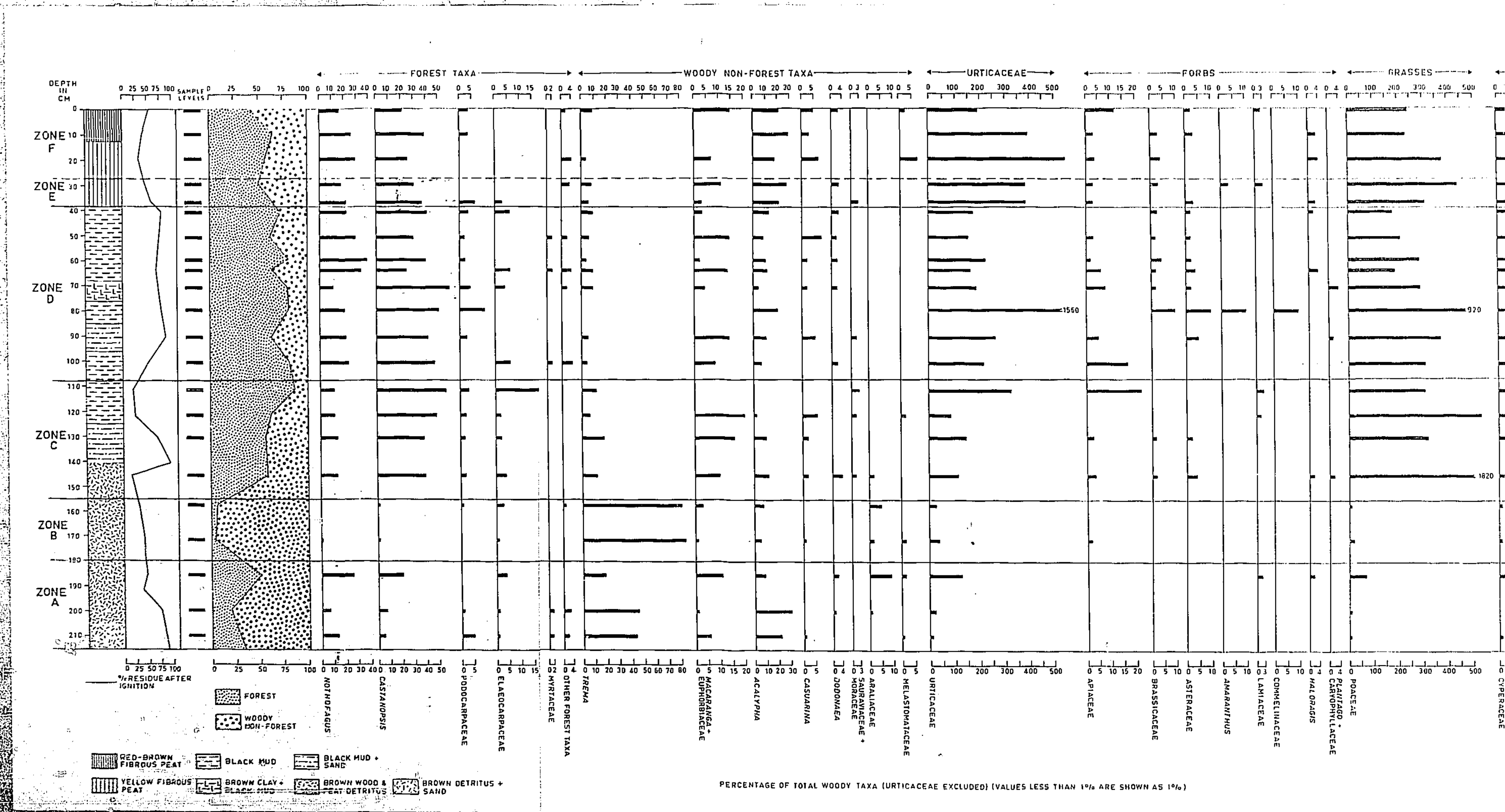

FOREST TAXA
WOODY NON-FOREST TAXA
FORBS
GRASSES
SEDGES
DEPTH IN CM
SAMPLE LEVELS
ZONE K
ZONE J
3280 ± 90BP
3880 ± 90BP
%WATER CONTENT
%RESIDUE AFTER IGNITION
FOREST
WOODY NON-FOREST
NOTHOFAGUS
CASTANOPSIS
PODOCARPACEAE
OTHER MIXED FOREST TAXA
ELAEOCARPACEAE
MYRTACEAE
OTHER FOREST TAXA
TREMA
MACARANGA
DODONAEA
CASUARINA
ACALYPHA
PANDANUS
URTICACEAE
OTHER WOODY NON-FOREST TAXA
HALORAGACEAE
BRASSICACEAE & LAMIACEAE
APIACEAE
OTHER FORB TAXA
POACEAE
CYPERACEAE
PTERIDAE
VERY COARSE BLACK DETRITUS
COARSE BLACK DETRITUS
BROWN FIBROUS PEAT & GREY-BROWN VOLCANIC ASH
IRON STAINING
GREY-GREEN VOLCANIC ASH
PERCENTAGE OF TOTAL WOODY TAXA (VALUES LESS THAN 1% ARE SHOWN AS 1%)



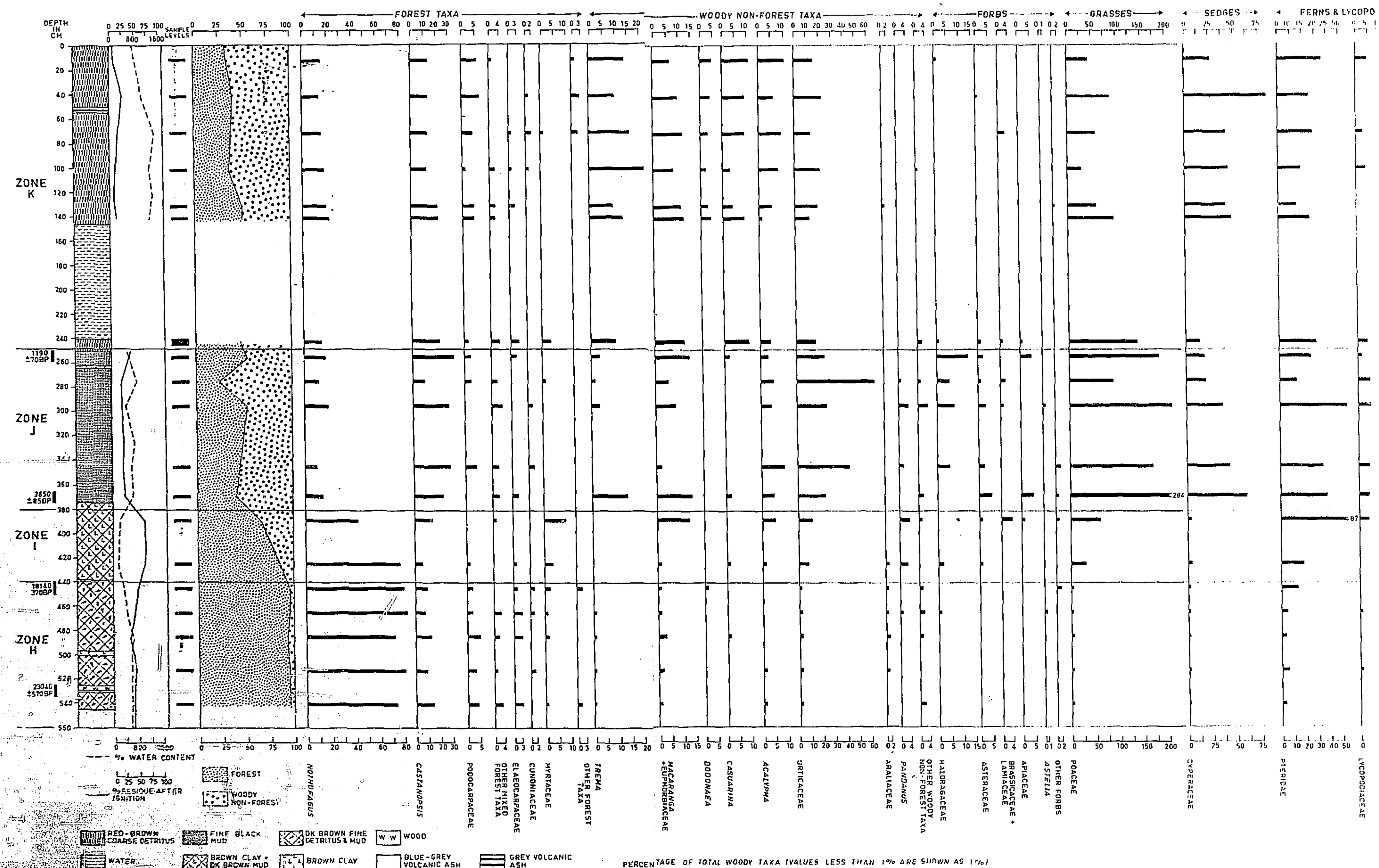
FOREST TAXA
WOODY NON-FOREST TAXA
URTICACEAE
FORBS
GRASSES
SEDGES
DEPTH IN CM
SAMPLE LEVELS
ZONE F
ZONE E
ZONE D
ZONE C
ZONE B
980 ± 150 B.P.
% WATER CONTENT
% RESIDUE AFTER IGNITION
FOREST
WOODY NON-FOREST
NOTHOFAGUS
CASTANOPSIS
PODOCARPACEAE
ELAEOCARPACEAE
MYRTACEAE
OTHER FOREST TAXA
TREMA
MACARANGA + EUPHORBIACEAE
ACALYPHA
CASUARINA
DODONAEA
SAURAUIA
MORACEAE
ARALIACEAE
OTHER WOODY NON-FOREST
URTICACEAE
APIACEAE
ASTERACEAE + BRASSICACEAE
AMARANTHUS
OTHER FORBS
POACEAE
CYPERACEAE
RED-BROWN FIBROUS PEAT
BROWN FIBROUS PEAT
BLACK MUD + SAND
YELLOW FIBROUS PEAT
BLACK MUD
SAND
COARSE BROWN WOOD + PEAT DETRITUS
PERCENTAGE OF TOTAL WOODY TAXA (URTICACEAE EXCLUDED) (VALUES LESS THAN 1% ARE SHOWN AS 1%)

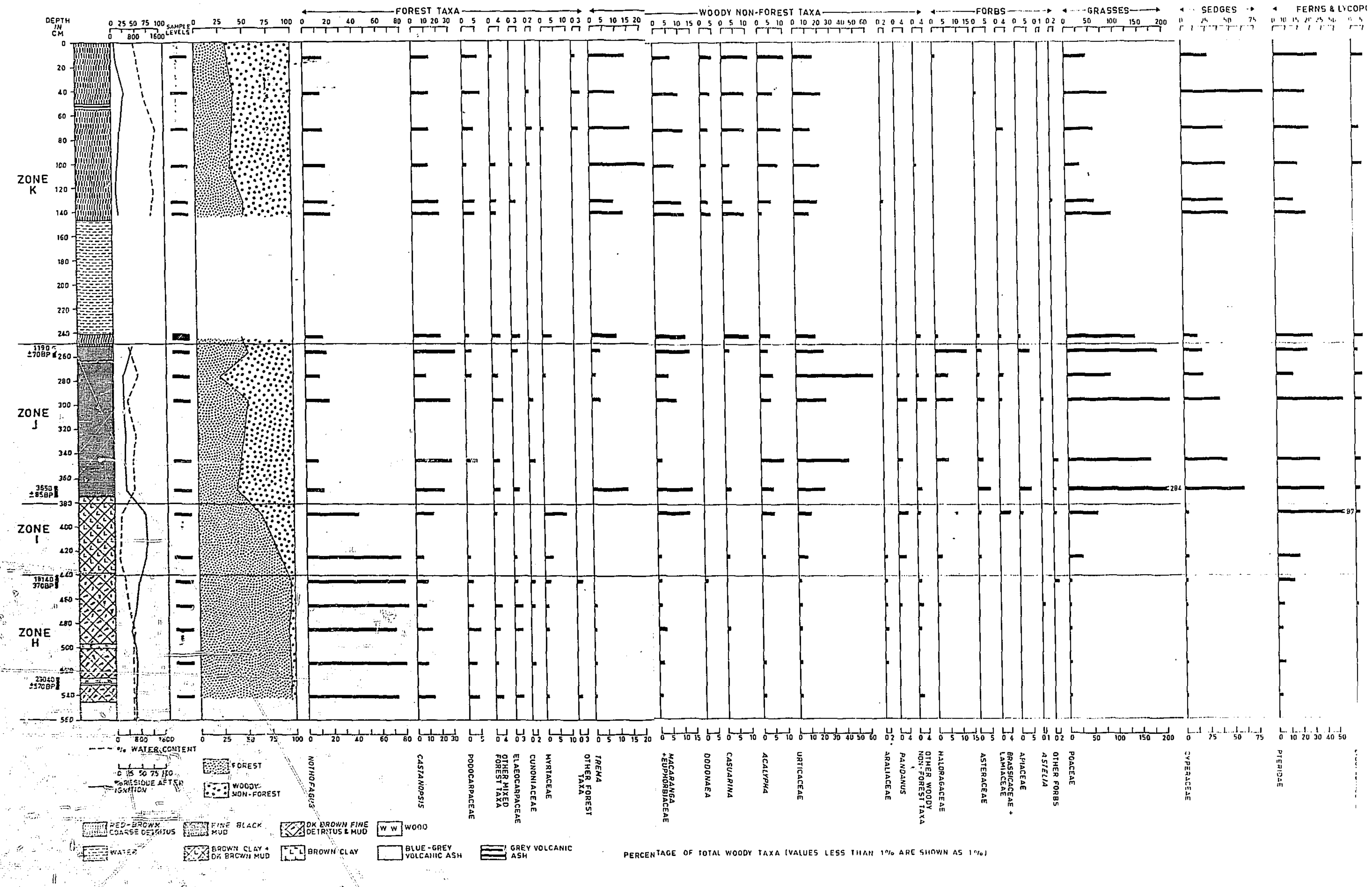

FOREST TAXA
WOODY NON-FOREST TAXA
URTICACEAE
FORBS
GRASSES
SEDGES
DEPTH IN CM
SAMPLE LEVELS
ZONE F
ZONE E
ZONE D
ZONE C
ZONE B
980 ± 150 B.P.
% WATER CONTENT
% RESIDUE AFTER IGNITION
FOREST
WOODY NON-FOREST
NOTHOFAGUS
CASTANOPSIS
PODOCARPACEAE
ELAEOCARPACEAE
MYRTACEAE
OTHER FOREST TAXA
TREMA
MACARANGA + EUPHORBIACEAE
ACALYPHA
CASUARINA
DODONAEA
SAURAUIA
MORACEAE
ARALIACEAE
OTHER WOODY NON-FOREST
URTICACEAE
APIACEAE
ASTERACEAE + BRASSICACEAE
AMARANTHUS
OTHER FORBS
POACEAE
CYPERACEAE
RED-BROWN FIBROUS PEAT
YELLOW FIBROUS PEAT
BROWN FIBROUS PEAT
BLACK MUD
BLACK MUD + SAND
SAND
COARSE BROWN WOOD + PEAT DETRITUS
PERCENTAGE OF TOTAL WOODY TAXA (URTICACEAE EXCLUDED) (VALUES LESS THAN 1% ARE SHOWN AS 1%)


DEPTH IN CM
ZONE F
ZONE E
ZONE D
ZONE C
ZONE B
ZONE A
SAMPLE LEVELS
FOREST TAXA
WOODY NON-FOREST TAXA
URTICACEAE
FORBS
GRASSES
% RESIDUE AFTER IGNITION
FOREST
WOODY NON-FOREST
NOTHOFAGUS
CASTANOPSIS
PODOCARPACEAE
ELAEOCARPACEAE
MYRTACEAE
OTHER FOREST TAXA
TREMA
MACARANGA + EUPHORBIACEAE
ACALYPHA
CASUARINA
DODONAEA
SAURAUIACEAE + MORACEAE
ARALIACEAE
MELASTOMATACEAE
URTICACEAE
APIACEAE
BRASSICACEAE
ASTERACEAE
AMARANTHUS
LAMIACEAE
COMMELINACEAE
HALORAGIS
PLANTAGO + CARYOPHYLLACEAE
POACEAE
1560
920
1820
RED-BROWN FIBROUS PEAT
YELLOW FIBROUS PEAT
BLACK MUD
BROWN CLAY + BLACK MUD
BLACK MUD + SAND
BROWN WOOD & PEAT DETRITUS
BROWN DETRITUS + SAND
PERCENTAGE OF TOTAL WOODY TAXA (URTICACEAE EXCLUDED) (VALUES LESS THAN 1% ARE SHOWN AS 1%)


FOREST TAXA
WOODY NON-FOREST TAXA
URTICACEAE
FORBS
GRASSES
DEPTH IN CM
SAMPLE LEVELS
ZONE F
ZONE E
ZONE D
ZONE C
ZONE B
ZONE A
% RESIDUE AFTER IGNITION
FOREST
WOODY NON-FOREST
RED-BROWN FIBROUS PEAT
YELLOW FIBROUS PEAT
BLACK MUD
BROWN CLAY + BLACK MUD
BLACK MUD + SAND
BROWN WOOD & PEAT DETRITUS
BROWN DETRITUS + SAND
NOTHOFAGUS
CASTANOPSIS
PODOCARPACEAE
ELAEOCARPACEAE
MYRTACEAE
OTHER FOREST TAXA
TREMA
MACARANGA + EUPHORBIACEAE
ACALYPHA
CASUARINA
DODONAEA
SAURAUIACEAE + MORACEAE
ARALIACEAE
MELASTOMATACEAE
URTICACEAE
APIACEAE
BRASSICACEAE
ASTERACEAE
AMARANTHUS
LAMIACEAE
COMMELINACEAE
HALORAGIS
PLANTAGO + CARYOPHYLLACEAE
POACEAE
CYPERACEAE
1550
920
1820
PERCENTAGE OF TOTAL WOODY TAXA (URTICACEAE EXCLUDED) (VALUES LESS THAN 1% ARE SHOWN AS 1%)

DR 159


DEPTH IN CM
SAMPLE LEVELS
FOREST TAXA
WOODY NON-FOREST TAXA
FORBS
GRASSES
SEDGES
FERNS & LYCOPO
ZONE K
ZONE J
ZONE I
ZONE H
1190 ±70BP
3650 ±85BP
18140 370BP
23040 ±570BP
% WATER CONTENT
% RESIDUE AFTER IGNITION
FOREST
WOODY NON-FOREST
NOTHOFAGUS
CASTANOPSIS
PODOCARPACEAE
OTHER MIXED FOREST TAXA
ELAEOCARPACEAE
CUNONIACEAE
MYRTACEAE
OTHER FOREST TAXA
TREMA
MACARANGA +EUPHORBIACEAE
DODONAEA
CASUARINA
ACALYPHA
URTICACEAE
ARALIACEAE
PANDANUS
OTHER WOODY NON-FOREST TAXA
HALORAGACEAE
ASTERACEAE
BRASSICACEAE + LAMIACEAE
APIACEAE
ASTELIA
OTHER FORBS
POACEAE
CYPERACEAE
PTERIDAE
LYCOPODIACEAE
RED-BROWN COARSE DETRITUS
FINE BLACK MUD
DK BROWN FINE DETRITUS & MUD
WOOD
WATER
BROWN CLAY + DK BROWN MUD
BROWN CLAY
BLUE-GREY VOLCANIC ASH
GREY VOLCANIC ASH
PERCENTAGE OF TOTAL WOODY TAXA (VALUES LESS THAN 1% ARE SHOWN AS 1%)


FOREST TAXA
WOODY NON-FOREST TAXA
FORBS
GRASSES
SEDGES
FERNS & LYCOPO
DEPTH IN CM
SAMPLE LEVELS
ZONE K
ZONE J
ZONE I
ZONE H
3390 ±70BP
3550 ±85BP
18140 370BP
23040 ±570BP
% WATER CONTENT
% RESIDUE AFTER IGNITION
FOREST
WOODY NON-FOREST
NOTHOFAGUS
CASTANOPSIS
PODOCARPACEAE
OTHER MIXED FOREST TAXA
ELAEOCARPACEAE
CUNONIACEAE
MYRTACEAE
OTHER FOREST TAXA
TREMA
MACARANGA +EUPHORBIACEAE
DODONAEA
CASUARINA
ACALYPHA
URTICACEAE
ARALIACEAE
PANDANUS
OTHER WOODY NON-FOREST TAXA
HALORAGACEAE
ASTERACEAE
BRASSICACEAE + LAMIACEAE
APIACEAE
ASTELIA
OTHER FORBS
POACEAE
CYPERACEAE
PTERIDAE
RED-BROWN COARSE DETRITUS
FINE BLACK MUD
DK BROWN FINE DETRITUS & MUD
WOOD
WATER
BROWN CLAY + DK BROWN MUD
BROWN CLAY
BLUE-GREY VOLCANIC ASH
GREY VOLCANIC ASH
PERCENTAGE OF TOTAL WOODY TAXA (VALUES LESS THAN 1% ARE SHOWN AS 1%)