# PALAEOENVIRONMENTS OF NORTH SUMATRA : A 30,000 YEAR OLD POLLEN RECORD FROM PEA BULLOK

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ABSTRACT

*Pea Bullok is an important site because it is one of only a handful on dry land from Southeast Asia which extends back through the last glacial cycle, a time of probable human dispersal throughout the islands, many of which were linked to the mainland by a lowland causeway now covered by the shallow seas of the Sunda Shelf. The pollen analysis and radiocarbon dating of Pea Bullok has added significant new information about Late Quaternary climatic and vegetation change in Island Southeast Asia but analysis of more older sites is desirable to build up a pattern of regional vegetation and climatic changes.*

## INTRODUCTION

Pea Bullok is located on a plateau at about 1400 m altitude around 10 km south of an escarpment which descends abruptly to Lake Toba at 900 m A.S.L. in the Toba Highlands of North Sumatra (Figure 1). It is an important pollen site because it is one of only a handful on dry land from Southeast Asia which extends back through the last glacial cycle, a time of probable human dispersal throughout the islands, many of which were linked to the mainland by a lowland causeway now covered by the shallow seas of the Sunda Shelf. All the sites are highland ones except the Mahakam Delta in Kalimantan (Caratini and Tissot 1985, 1988) and Pea Bullok is the only one located north of the equator (Figure 2). The Mahakam Delta has a pollen record extending back into the upper Pliocene but has mainly yielded information on sea-level variation rather than providing a backdrop to human occupation of the island or giving data on the impact of people on the vegetation.

Two of the other sites are from the island of New Guinea: Sirunki (2500 m: Walker and Flenley 1979) and Haeapugua (1650 m: Haberle 1993). The central Sumatran site of Danau di-Atas (Newsome and Flenley 1988) is at the lower altitude of c.1535 m. So all of the sites differ in altitude and they also vary considerably in topography which makes it difficult to compare the data from each. There are problems with the older radiocarbon dates from Danau di-Atas which we will discuss elsewhere (Maloney and McCormac in prep.). Pea Bullok is unique in that two cores have been examined rather than only one. The oldest deposits were encountered in a core from the edge of the peat swamp but a 3.5 m long core from its centre was around 20,000 years old at the base.

## PRESENT DAY CLIMATE, VEGETATION AND SOILS

The nearest climatic recording station is at Siborongborong, two kilometers to the south of the site. This indicates that mean annual rainfall is about 2000 mm, enough to allow forest development. There seem to be no temperature records but mean annual temperature is probably around 20 degrees Celsius and has a daily range greater than the average annual range.

Pea Bullok itself has a herbaceous vegetation dominated by sedges. Its near environs are dominated by a largely shrubby vegetation in which *Rhodomyrtus tomentosus, Leptospermum flavescens, Melastoma malabathricum* and the pteridophytes *Dicranopteris linearis* and *Pteridium aquilinum* are conspicuous. A planted *Pinus merkusii* stand immediately to the north of the site is the nearest forest vegetation. This has shrubby *Schefflera aromatica* at its margin. An area of remnant lower montane forest occurs at Silangit c.3 km to the west.

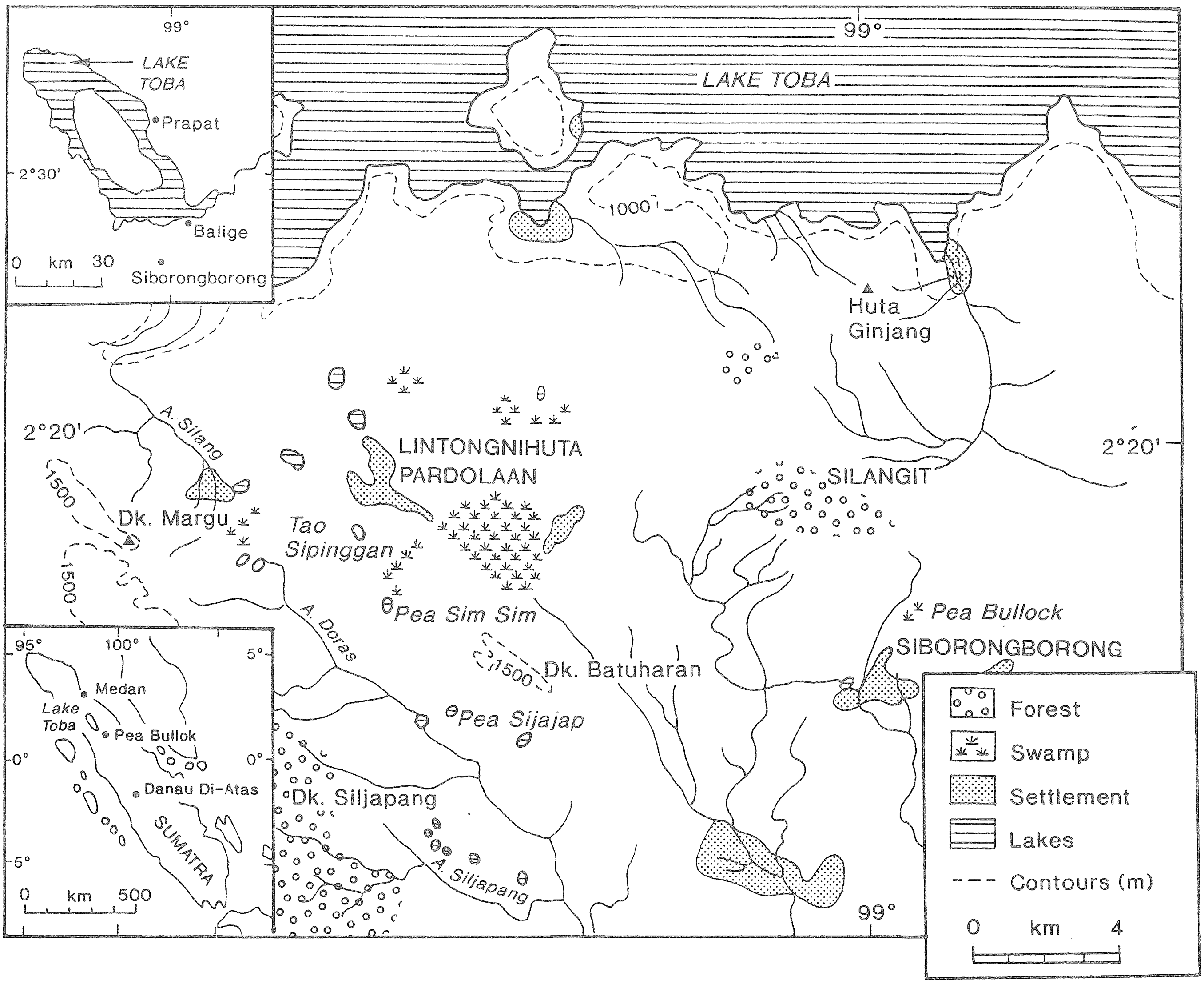


*Figure 1: The location of Pea Bullok*

Taxa present in this include *Castanopsis* sp., *Lithocarpus* sp., *Eugenia* spp. and *Litsea* spp.

The local soils derive from Toba tuff and may have had a lengthy period in which to develop. Recent K-Ar dating (Chesner *et al.* 1991) suggests that the last major eruption of Toba took place c.74,000 years ago. Like most plateau soils, those of the Siborongborong area are shallow and, where they have not been converted into surface water gleys by wet rice cultivation, resemble acid brown earths and weakly developed podzols similar to those of temperate regions.

## FIELD AND LABORATORY METHODS

The stratigraphy of Pea Bullok contains much wood and this, with the extreme wetness of the bog surface, makes coring very difficult. Several attempts were made during late 1973-early 1974 to obtain long cores using a Russian peat borer, with a Dachnowsky piston sampler for the stiffer material. Most were frustrated. However, the final try in February 1974, which was really aimed only at collecting data for stratigraphic description, resulted in considerable success: an 8 m long core was extracted from the edge of the site. However, only a few samples

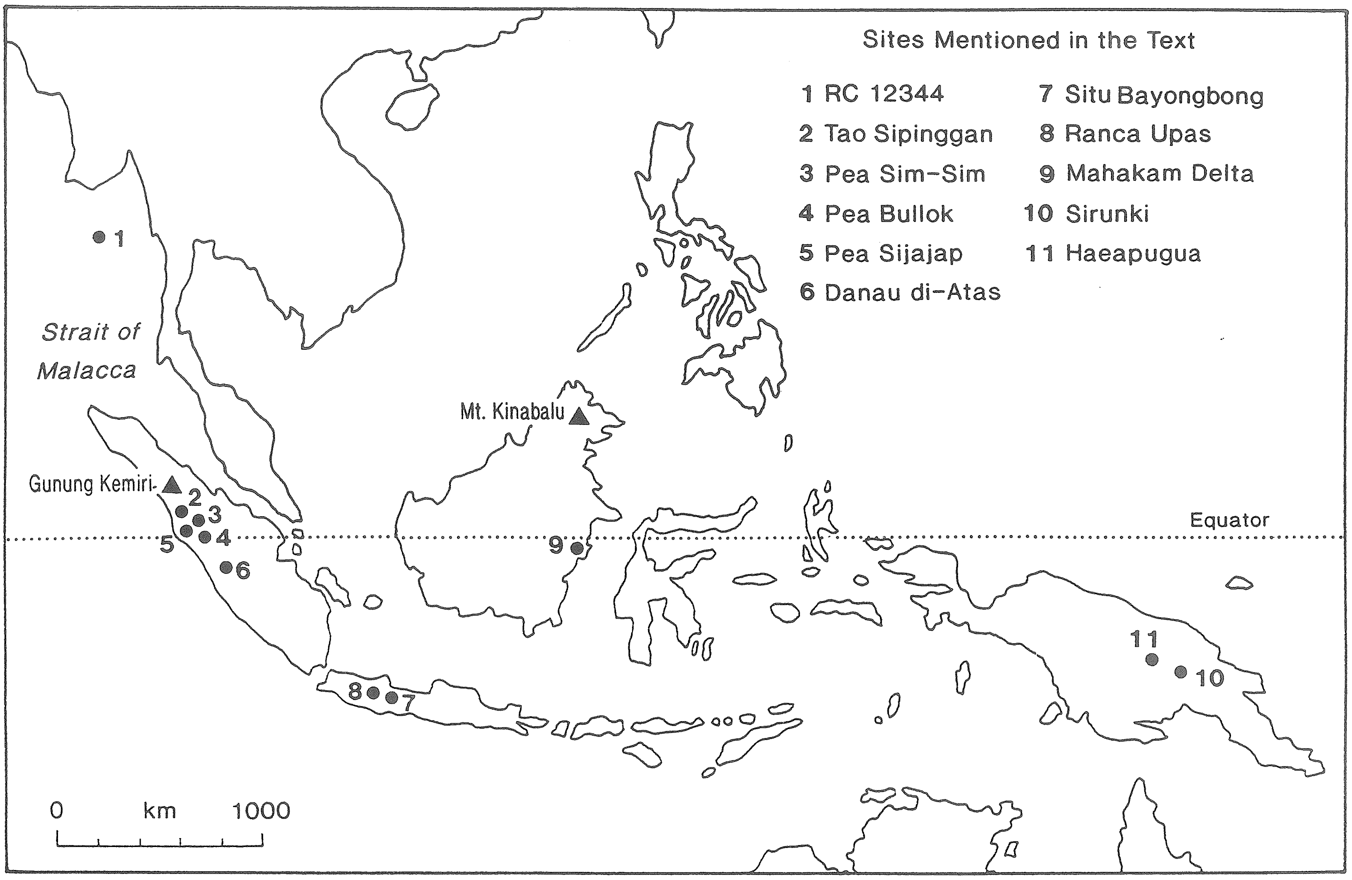


*Figure 2: Locations of Southeast Asian pollen sites with 30,000-year records*

from the last metre were kept as it was assumed that it would be possible to core again taking samples rather than just describing the stratigraphy. In fact it was not possible to get beyond 6 m during the second coring. So there is an unfortunate gap in the core (Core A) from the edge. The infill base was not reached either in the 8 m core or the shorter core from the centre of the site.

The Russian borer yielded 50 cm semi-cylindrical core segments of 4.2 cm in diameter. The Dachnowsky piston sampler gave cores 30 cm long and c.8 cm in diameter.

The second core considered here (Core B) is from the centre of the site. At present samples from the upper 3.5 m of a 4 m core have been analysed.

The samples were cut into 10 cm blocks and dried overnight at 100$^{o}$C. to derive figures for weight loss (not presented here) at the University of Hull in 1975. The main reason for this was so that they could be easily transported and stored after the first author left Hull until time was available for them to be worked on. The disadvantage of this is that samples for pollen analysis could only be taken from the centre of each block as the tops and bottoms were not labelled.

Fortunately, the lowermost half metre of Core B was not dried and was rediscovered in the deep freeze when a tidy out was conducted at Hull. This section is over 20,000 years old (see below) and will be sampled centimetre by centimetre in due course.

The samples already analysed have been pretreated in the laboratory at Queen's using standard procedures, but *Lycopodium* spores were added to some (cf Stockmarr 1971) in an attempt to derive pollen concentration figures. However, because of the unanticipated slowness of the peat accumulation, insufficient spore tablets were often used and most of the results are not statistically valid. Therefore they will not be discussed further here.

The pollen spectra have been interpreted using data from surface sediments presented in Maloney (1979) and

Table 1: Radiocarbon dates for Pea Bullok

| laboratory number | depth ( cm ) | radiocarbon dates ( yrs B.P. ) | error ( + ) | error ( - ) | delta 13 C ( 0/00 ) ( - ) |
|---|---|---|---|---|---|
| Pea Bullok Core A | | | | | |
| UB 3732 | 50-60 | 3330 | 65 | 65 | 29.78 |
| UB 3700 | 90-100 | 7963 | 55 | 55 | 29.71 |
| UB 3735 | 220-230 | 14485 | 72 | 72 | 28.68 |
| UB 3695 | 230-240 | 11798 | 69 | 69 | 28.91 |
| UB 3701 | 300-310 | 18088 | 109 | 109 | 28.13 |
| UB 3696 | 330-340 | 20081 | 106 | 106 | 28.41 |
| UB 3644 | 440-450 | 20992 | 139 | 139 | 26.96 |
| UB 3702 | 470-480 | 21379 | 249 | 249 | 28.51 |
| OxA 3794 | 540-550 | 24140 | 260 | 260 | 27.1 |
| OxA 3240 | 720-725 | 28840 | 460 | 460 | 27.2 |
| Pea Bullok Core B | | | | | |
| UB 3694 | 40-50 | (-) 255 | 98 | 98 | 28.76 |
| UB 3697 | 110-120 | 5132 | 53 | 53 | 29.25 |
| UB 3733 | 130-140 | 9273 | 51 | 51 | 28.98 |
| UB 3734 | 140-150 | 10579 | 55 | 55 | 28.94 |
| UB 3698 | 170-180 | 14868 | 67 | 67 | 27.68 |
| UB 3699 | 230-240 | 17859 | 107 | 107 | 28.27 |
| UB 3736 | 300-310 | 18496 | 100 | 100 | 28.68 |
| UB 3693 | 340-350 | 19263 | 121 | 121 | 28.43 |
| | | Delta 13 C error of UB dates = +/- 0.2, error of OxA dates not known | | | |

Newsome (1988), by reference to an ecological survey of the Toba area and to the botanical literature.

## Radiocarbon dating

Pea Bullok is now the most thoroughly radiocarbon dated site from Sumatra (Table 1). Initial inspection of pollen in the 7.2 m sample suggested that it was older than anything hitherto found in the region and that AMS dating would be needed because of the smallness of the sample. Eventually sufficient funding was obtained to have two samples AMS dated at Oxford. The second author subsequently suggested attempting to date another sample known to be stratigraphically younger by conventional radicarbon decay methods at the Palaeoecology Centre in Belfast. This was successful and another 15 samples from the cores were processed, considerably refining the chronology, and allowing the two cores subjected to pollen analysis to be correlated directly. One sample proved to be modern and there is an inverted date of c.14,000 BP in the core from the edge. It was thought initially that there would be a correlation between this sample and that with the Younger Dryas date from the centre. The 4000 year discrepancy can be explained by a not-unexpected more stable pattern of peat accumulation at the centre of the basin and margin erosion and redeposition at the edge which could be a result of movement along faults. However, Hehanussa *et al.* (1987) suggested that substantial movement along faults ended around 17,000 years ago in the region west of the site although the last earthquake which seemed to occur in the region took place in 1921 (Braak 1929).

Unfortunately, although there are many peat samples remaining which should date to 20,000 BP and older, there are very few from the later phases which are those likely to be of most interest to prehistorians.

## RESULTS OF POLLEN ANALYSIS AND DISCUSSION

It is hoped in due course to publish a research monograph detailing the complete pollen results from the two cores analysed including descriptions of the 350 pollen and pteridophyte spore types identified among the 90,000 plus counted. What follows here is merely an outline of the main findings relaing to the regional vegetation changes of the last 30,000 years based on selected pollen and pteridophyte spore taxa (Figures 3 and 4). Variations taking place on the bog itself will only be mentioned where there are overlaps of pollen taxa which could either be from plants growing on the bog surface or on dry land.

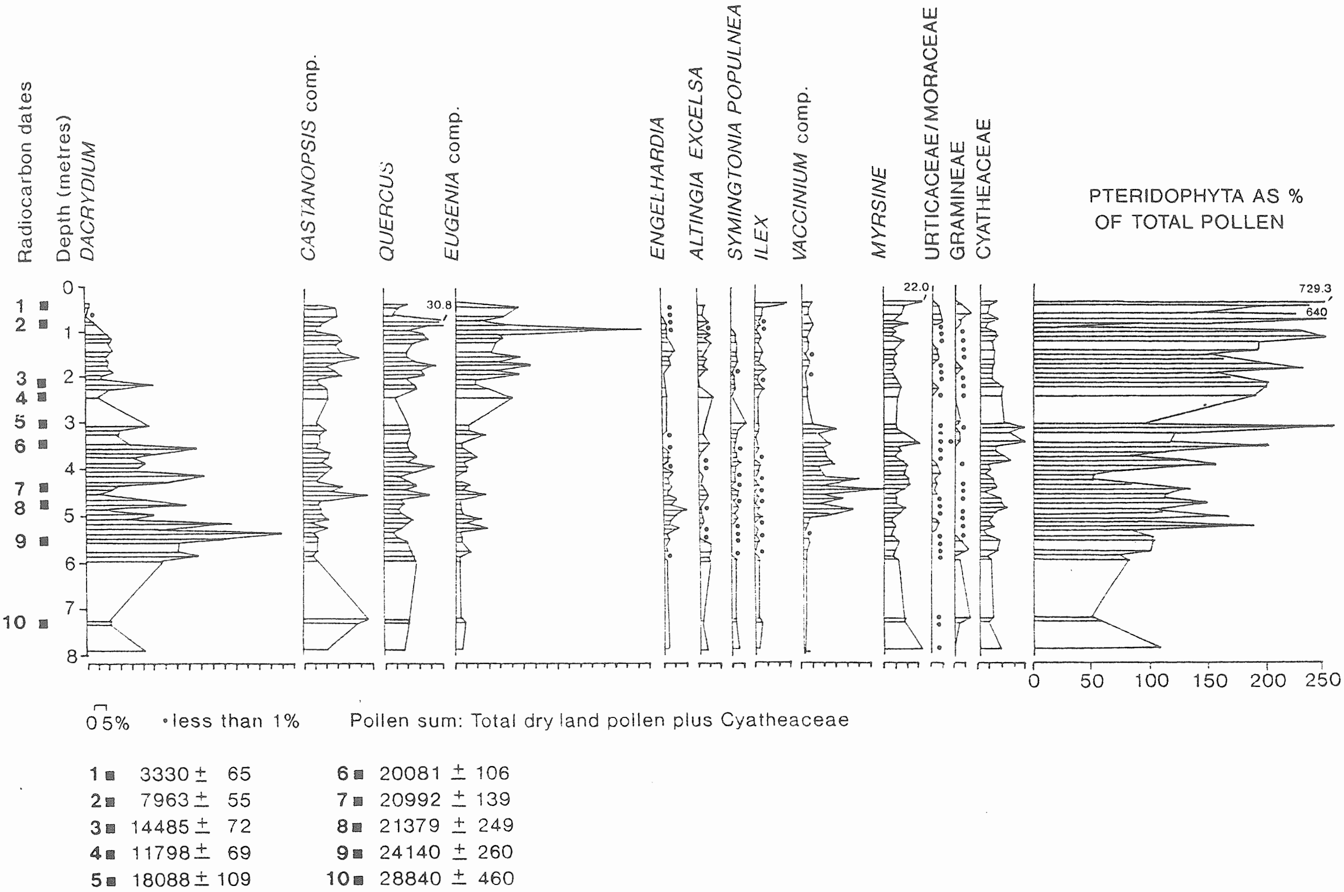


*Figure 3: Pea Bullok Core A (selected pollen and pteridophyte spore taxa only)*

It is best to use the results from Core A, which is the longest and oldest, as a basis of comparisons between the two sets of analyses and with findings published elsewhere from other sites in the Toba area and further afield. It must be emphasised that only a small number of the pollen and pteridophyte spores types which occur are discussed here.

The oldest sample to be analysed is that from 7.95 m depth and that could be up to 32,000 years old or older. There is probably enough material left for an AMS date but not for radioactive decay counting. The key pollen types are *Dacrydium (D. elatum), Castanopsis* comp. *(Casta-nopsis/Lithocarpus), Quercus* and *Myrsine. Myrsine* is a possible sub-alpine indicator (cf Walker and Flenley 1979) but has been reported from swamps in the region (Polak 1933). *Dacrydium elatum* is a possible swamp forest component but can also be found in mid-mountain forest. The general impression is of lower montane Fago-Lauraceous forest such as might be found at 1400 m altitude in the area under natural conditions today. So, the main indications are for warm, wet conditions similar to those at present. However, if van der Kaars (1991) is correct a low percentage of pteridophyte spores relative to total pollen is suggestive of dryness.

The samples from 7.20-7.23 m depth, which encompass the AMS date of c.29,000 BP, see a decline in *Dacrydium,* and an increase in *Castanopsis* comp. and the pteridophyta: total pollen ratio is almost at its lowest in the whole diagram. Again, lower montane forest is represented but perhaps conditions were somewhat drier than at present. *Altingia excelsa* and *Symingtonia populnea* are everwet indicators but the pollen percentages are so low that no conclusions can be drawn from them.

The gap between these sediments and 6 m is particularly unfortunate as the age often cited for the onset of the last glaciation in the northern hemisphere is 27,000 BP (cf Sirocko *et al.* 1993). The core is continuous from above the 6 m level. The increase in *Dacrydium* is a likely indicator of climatic cooling but the pteridophyta : total pollen ratio continues to suggest dryness although

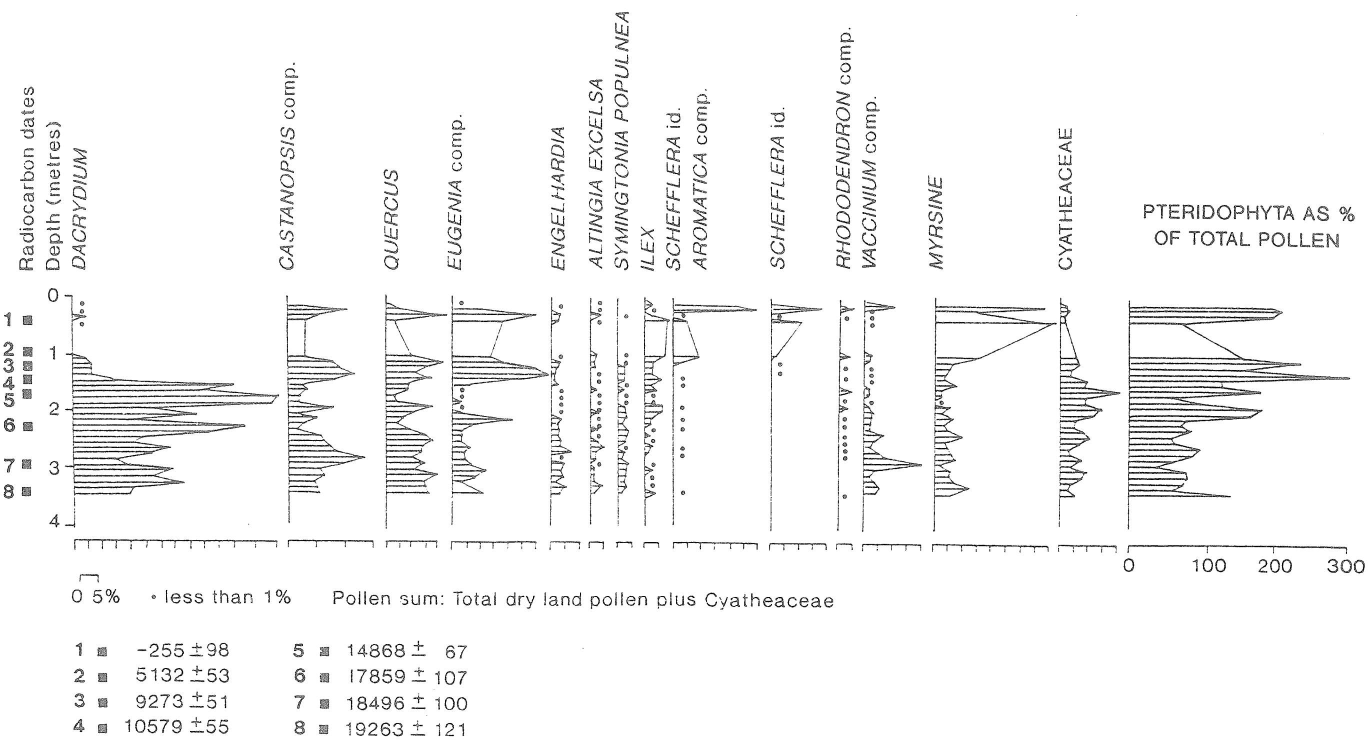


*Figure 4: Pea Bullok Core B (selected pollen and pteridophyte spore taxa only)*

there is a slight increase in *Altingia excelsa* pollen. A strong peak of *Dacrydium* occurs at 5.45 m depth, the percentage of pteridophyte spores in relation to total pollen increases as does *Engelhardia, Vaccinium* comp. (which could be from *Vaccinium* and other Ericaceae) and tree fern spore percentages (Cyatheaceae). Here, around 24,000 BP, we have clear signs for climatic change, certainly to colder conditions and perhaps to increased effective precipitation. However, nowhere in this diagram do we have a clear tropic-alpine indicator. Cyatheaceae were investigated as a possible high altitude indicator but graphing of altitudinal data for the *Alsophila* and *Sphaeropteris* species reported from Sumatra showed overlaps, so even where the perine from the spores was preserved, and this was not all that commonly (most were lost), data on altitudinal shifts in vegetation could not be provided. *Engelhardia* is of note though. Where the pollen well preserved it can be said to be of *E. spicata* type. Yamada (1977) found *E. spicata* most commonly around 1700 m altitude on Gunung Pangrango in west Java. However, Ohsawa *et al.* (1985) found it in cloud forest between 2100-2400 m altitude on Gunung Kerinci in west Sumatra. Newsome (1988) reported that *Engelhardia* pollen was mainly present there in surface samples from 1650-2395 m. A shift in vegetation altitudes is indicated but it is difficult to say by how much. What seems to have been happening is that the vegetation belts were moving down the montains and this must have been accompanied by a lowering in the altitude of the montane cloud belt. There is surprisingly little information on the cloud belt altitudes but on the high and isolated Mount Kinabalu, Sabah, the range (Kitayama 1992) is 1680-2150 m.

It is the trend for *Vaccinium* comp. which is most notable. *Vaccinium* species can be a component of swamp vegatation but the pollen is not usually very common. Here the peaks generally mirror troughs in the *Dacrydium* curve and may represent periods of fluctuating subalpine or upper montane and montane forest conditions. A general, but not consistent, cooling trend is indicated. This is not surprising as these samples date to the maximum of the last glaciation. The major peak encompasses a radiocarbon date of c. 21,000 BP, 3000 years earlier than that usually cited for the maximum coldness of the last glaciation. The oscillations between

24,000-21,000 BP are difficult to explain as there are no comparably well dated pollen sequences from a site similar in altitude and topography from Southeast Asia. Interestingly, oscillations do occur in the Greenland ice cores but teleconnections over such long distances must be regarded with extreme caution at present. In general the *Vaccinium, Myrsine* and Cyatheaceae curves are suggestive of declining temperatures but with conditions remaining fairly wet. The wetness may be attributed to the fact that extreme altitudinal depression of the vegetation belts would leave the site in the cloud belt. Declining sea levels and a northeast monsoon passing over a much larger area of dry land than at present might lead one to expect a drier climate. This is probably true for lower altitudes but the mountains have their own local climate and the southwest monsoon would have passed over almost as much sea as at present because a reduction in sea level by 100 m for the glacial maximum would not lead to a significant increase in land area in west Sumatra.

The largest peak of Cyatheaceae spores occurs between c.20-18,000 BP and tree ferns remain significant until the opening of the Holocene, while *Vaccinium* comp. declined abruptly after 18,000 BP So, climatic amelioration seems to have been indicated.

The Holocene is characterised by a dominance of Fago-Lauraceous forest taxa and the rise of *Eugenia* comp., which also occurs elsewhere in the region, is very important. Additionally the pteridophyta : total pollen ratio is consistently high. The last major peak of *Dacrydium* is associated with the inverted radiocarbon date of c.14,500 BP. A very pronounced peak of *Eugenia* comp. is present around 8000 BP and thereafter Urticaceae/Moraceae and Gramineae, likely disturbance indicators, become commoner. There are important peaks of *Myrsine* especially, and *Ilex* about 3300 BP. These could suggest that a swamp forest was cleared to be replaced by a scrubby vegetation similar to that which survives on part of the Sigompul Marshes 20 km to the west, or this may have been the vegetation of nearby dryland. It is impossible to be sure which explanation is true but certainly there was a significant oscillation of the pollen curves around 8000 BP then a clear decline in the lower montane forest tree taxa suggestive of the sort of open vegetation which occurs in the area today. Unfortunately it is impossible to trace the forest decline in detail because of poor sampling resolution but it is difficult to rule out an anthropogenic origin in view of the pollen records from Pea Sim-sim, Tao Sipinggan (Maloney 1985) and Pea Sijajap (Maloney 1993).

The 3.5 m long Core B covers the last 20,000 years. As far as the Late Quaternary is concerned, the main differences between the two cores lie in the *Vaccinium* comp. curve. It reaches an isolated significant peak around 18,500 BP while the percentages are generally higher in the core from the edge of the bog. This suggests that most of the pollen may be coming from dryland nearby the site. As in the core from the edge, the main Cyatheaceae representation is later but before the opening of the Holocene. In this instance the last major rise of *Dacrydium* is coeval with the European Younger Dryas. Only two other diagrams from Southeast Asia so far show important changes at this time period: Situ Bayongbong at 1300 m altitude (Stuijts 1993) and Ranca Upas (1750 m). There it is *Engelhardia* which becomes dominant. Perhaps it is significant the *Englehardia* is sometimes a disturbance indicator. However, analysis of many more Late Quaternary cores will be needed before definitive conclusions can be reached.

The major increase in *Eugenia* comp. began around 9200 BP and was declining by 5100 BP. Corrected, this latter date may be almost 6000 years old. A forest disturbance indicator, *Schefflera* id. *aromatica* comp. increased significantly, as did *Myrsine.* Both remained important at the top of the pollen record and are suggestive of forest clearance, but probably only after about 2000 BP. This fits well with data from Tao Sipinggan, a lake site located about 20 km to the west. Amaranthaceae pollen occurs in two samples, the oldest being that from 1.05 m, which may be around 4700 years of age, but it was most frequent in that from 0.77 m, which is possibly c. 3400 years old (Chenopodiaceae, which have similar pollen grains, have not been reported from Sumatra). Here there is a significant peak of c.9 % and the information on disturbance is consistent with that from the core from the edge. While Amaranthaceae can occur as weeds of rice fields they were not present in those of the Toba area and may be more associated with root crops.

## REGIONAL COMPARISONS

Two areas of Southeast Asia north of the equator were glaciated during the last glaciation: the 4000 m high Mount Kinabalu in Sabah and (van Beek 1982) some peaks in Aceh in the extreme north of Sumatra. Unfortunately neither the dates of the glaciation nor its intensity are known exactly. A minimum date for the onset of warmer conditions in Aceh has been obtained from the oldest peat at the bottom of a small lake on Gunung Kemiri. This has a radiocarbon age of 7590±40 BP. The minimum age from Kinabalu (Flenley and Morley 1978) is c.9000 BP.

The high mountains of Papua New Guinea were glaciated down to 2750 m at their lowest (Loffler 1972; Galloway *et al.* 1973). Ice began to retreat from Mt. Wilhelm around 15,000-14,000 BP and from Mt. Carstenz (Irian Jaya) before 14,000 BP (Hope and Peterson 1975).

So only the information on past glaciations from Irian Jaya and Papua New Guinea helps put the data from Pea Bullok in a regional context. In terms of general glacial cycles, climatic changes resulting from variations in the earth's obliquity might be expected to be more pronounced in Southeast Asia than in Africa and the Indian Ocean, as the withdrawal of large volumes of water from the surrounding seas led to a fall in sea levels by at least 100 m at the maximum of the last glaciation (Geyh *et al.* 1979; van der Kaars 1990, 1991). This must have increased seasonality as the northeasterly winds would have travelled over a considerably larger area of dry land than now to reach the Toba region and the albedo would have been higher. As stated earlier, the impact of the southwest monsoon, conversely, might have been nearly as strong as at present despite the change in the precessional cycle. However, apart from the tenuous indications given by the pteridophyte : total pollen ratios, no clear evidence of former drier conditions has been detected, probably because movement of vegetation belts up and down the mountains would have left the site in the mid-mountain cloud (mossy forest) belt during part of the Late Quaternary.

Comparison with Danau di-Atas, south of the equator, is difficult. The site is located at c.1535 m altitude but in an entirely different topographic situation. Unlike the longest core from Pea Bullok, the Danau di-Atas core is continuous throughout the last glacial cycle, but the authors have reservations about the older dates (Maloney and McCormac in prep.). Newsome and Flenley (1988) claimed that the vegetation belts around the site were 265-865 m lower than now between 31,000-17,900 BP and that temperatures could have been 1.6-5.2$^{o}$ C. cooler than at present. A strong cooling trend is certainly indicated at Pea Bullok but it is likely that the site was in the cloud belt 18,000 years ago and this would have left it warmer than had it been in the drier area above the cloud belt. When climate began to ameliorate it did so rapidly. Neither site gives supporting evidence for the early Holocene intensification of the southwest monsoon resulting from changes in the precessional cycle (Kutzbach 1981; Prell and Kutzbach 1987; Sirocko *et al.* 1991, 1993), probably because of their location. That drier conditions existed during the last glacial in Southeast Asia has been demonstrated by the carbon isotopic record of deep sea core MD 77169 which came from near the Myanmar coast (Fontugne and Duplessy 1986).

The evidence for forest disturbance at Pea Bullok is consistent with that from Danau di-Atas and Pea Sim-sim, but at both sites and others from Sumatra the most major clearances are late, after c.4000 BP, and there is little indication of what crops were grown.

Unlike at Pea Bullok, the vegetation around Sirunki (2500 m A.S.L.) from inferred ages of *c.* 33,000-27,500 BP was stated (Walker and Flenley 1979) to be almost certainly treeless, with subalpine and alpine conditions persisting generally until about 9000 years ago when the final afforestation began. Conditions were extremely cold between 18,500-16,000 BP. However, fluctuations in the proportion of forested to unforested land began about 5000 BP, possibly due to human impact. There are some parallels with the Pea Bullok record but significant differences in detail.

Haeapugua is at 1650 m altitude in the Tari Basin of the Southern Highlands of Papua New Guinea (Haberle 1993) and is a large valley swamp dammed by a Pleistocene lava flow. Only a summary diagram has been published so far. Woody taxa declined from *c.*30,000 BP to present with grassland established near the site around 21,000 BP and becoming dominant at *c.*17,000 BP until 8000 BP. There is a high incidence of carbonised particles in the record around 17,000 BP which is attributed to anthropogenic disturbance. However, this is a time when climate might have been expected to be drier and, indeed, when natural rainforest fires occured in East Kalimantan (Goldammer and Seibert 1989). Again, there are some parallels with the Pea Bullok record but there are also differences due to local factors.

## CONCLUSION

The pollen analysis and radiocarbon dating of Pea Bullok has added significant new information about Late Quaternary climatic and vegetation change in Island Southeast Asia but analysis of more older sites is desirable to build up a pattern of regional vegetation and climatic changes. It is unfortunate from the archaeological point of view that more samples were not available for analysis to trace the course of forest destruction in detail at Pea Bullok from the middle Holocene onwards. It is clearly a site worthy of additional research in this respect but so are some others in North Sumatra. Samples are available for a more detailed analysis of the last 7000 years of vegetation change at Pea Sim-sim and Tao Sipinggan but the duplicate cores from these sites were destroyed several years ago.

ACKNOWLEDGEMENTS

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