

The Excavation of Khok Phanom Di

A Prehistoric Site in Central Thailand

Volume II: The Biological Remains (Part I)

Edited by

C. F. W. Higham and R. Bannanurag

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Edited by

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PREFACE

KHOK Phanom Di is a large prehistoric site located in Chonburi Province, Central Thailand. This is the second of a series of volumes which will report on the excavations we undertook there in 1985 as part of our project on the prehistory and early history of the lower Bang Pakong Valley. We are deeply indebted to many individuals and their institutions for the support which has made this project possible. First, we owe a debt to our respective institutions, the University of Otago and the Fine Arts Department, for allowing us the time and resources to devote to research in the Bang Pakong valley. To Sir Robin Irvine, Vice-Chancellor of the University of Otago, and Thaweesak Senanarong, Director General of the Fine Arts Department, we can only reciprocate with our thanks, coupled with this volume and its companions.

Financial support for the programme and subsequent analyses was provided by a number of institutions. The Ford Foundation through Dr Thomas Kessinger, then representative in the South-East Asian Regional Office in Jakarta, provided funds to underwrite excavation costs and for Pirapon Pisnupong, Rachanie Bannanurag and Phrapid Choosiri to undertake research on the data in New Zealand. The University of Otago also provided a research fellowship which supported Amphan Kijngam in New Zealand.

The Shell Company of Thailand Limited assisted by the provision of a vehicle, a computer and a generous subsidy to defray the costs of producing this volume. To M.R. Sarisdiguna Kitiyakara, Chairman, and Precha Phonprasert, Public Affairs Manager, we offer our thanks for such support, and for the enthusiasm of their visits to the site.

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We acknowledge the invaluable contribution made by Hugh Chapman of the Society of Antiquaries of London, Margaret Sharman and Graeme Mason in improving this volume. Gillian Alexander (Queen's University, Belfast), Leslie O'Neill and Martin Fisher prepared the illustrations. Last, but by no means least, we owe a considerable debt of gratitude to Graeme McKinstry of the University of Otago Computing Centre Advisory Service for his guidance and advice in using the Latex typesetting programme.

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WE owe a deep debt of gratitude to the authors of this volume, who have contributed their skill and time towards an understanding of the environment and activities of the occupants of Khok Phanom Di.

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I. GENERAL INTRODUCTION

By C. F. W. Higham and R. Bannanurag

KHOK Phanom Di is a large prehistoric site located in Chonburi Province, Central Thailand (Fig. 1). Its excavation in 1985 was part of a long-term project to examine human adaptation to a tropical marine and riverine environment, which is demonstrably one of the richest known (Odum 1971, Russel-Hunter 1970). In the first volume of the report on the excavation, the site's location, stratigraphic sequence, chronology and the mortuary sequence were described (Higham and Bannanurag 1990). The area excavated was located in the centre of the mound and reached the natural substrate at a depth of 6.80m below datum (Figs. 2-3). The stratigraphy was complex, and will be described in detail in a later volume in this series. Aitken (pers. comm.) has noted that the initial settlement was located on a deposit most similar to a riverine floodplain, but, as will be shown below, it must also have been close to the estuary of a large river. The cultural deposits have been divided into eleven cultural layers. The earliest, layer 11, comprised a series of ash, shell and sand lenses thought to represent domestic activities, such as the shaping and firing of pottery vessels. These activities continued into the lower parts of layer 10, but the first six human inhumation burials were also encountered, set in shallow graves with the heads pointing in an easterly direction. Subsequent burials maintained this practice, and were found in distinct clusters. These clusters maintained their integrity through time, as successive burials were placed over their predecessors. Throughout layers 10-5, therefore, we encountered part of the Khok Phanom Di cemetery. In the final volume of this report, it will be argued that this phase saw a number of pits and midden deposits which essentially represent ritual feasting for the dead.

Layers 4-3 reveal a very different range of activities. Layer 4 may well represent a period when the site, or at least this part of it, was abandoned. Thereafter, the area was again used as a pottery workshop, with raw and stored clay and anvils used to shape vessels being recovered. No further burials were found after layer 5.

As a convenient shorthand notation, this sequence has been divided into three stratigraphic 'zones', and these will be employed in some of the following chapters. Zone A (layers 11-10) recognizes the distinct complex of superimposed lenses, mainly comprising shellfish and other biological remains. Layers 9-5 (zone B) continue the mortuary tradition, but with rather distinct associated cultural build-up, while zone C (layers 4-2) represents the post-mortuary material. The thickness of the layers encountered made it desirable to remove them in ten-centimetre spits. The text below will often refer to such 'spits' as operational units for the analysis of the distribution of biological remains. Despite the considerable depth of the cultural deposits at Khok Phanom Di, the radiocarbon determinations suggest that zones A-B accumulated over a period of about five centuries from 2000 BC. We have no dates from zone C contexts for lack of charcoal.

From the earliest planning of the excavation at this site, it was considered crucial to apply palynological and sedimentological techniques to illuminate the environmental history of the area.

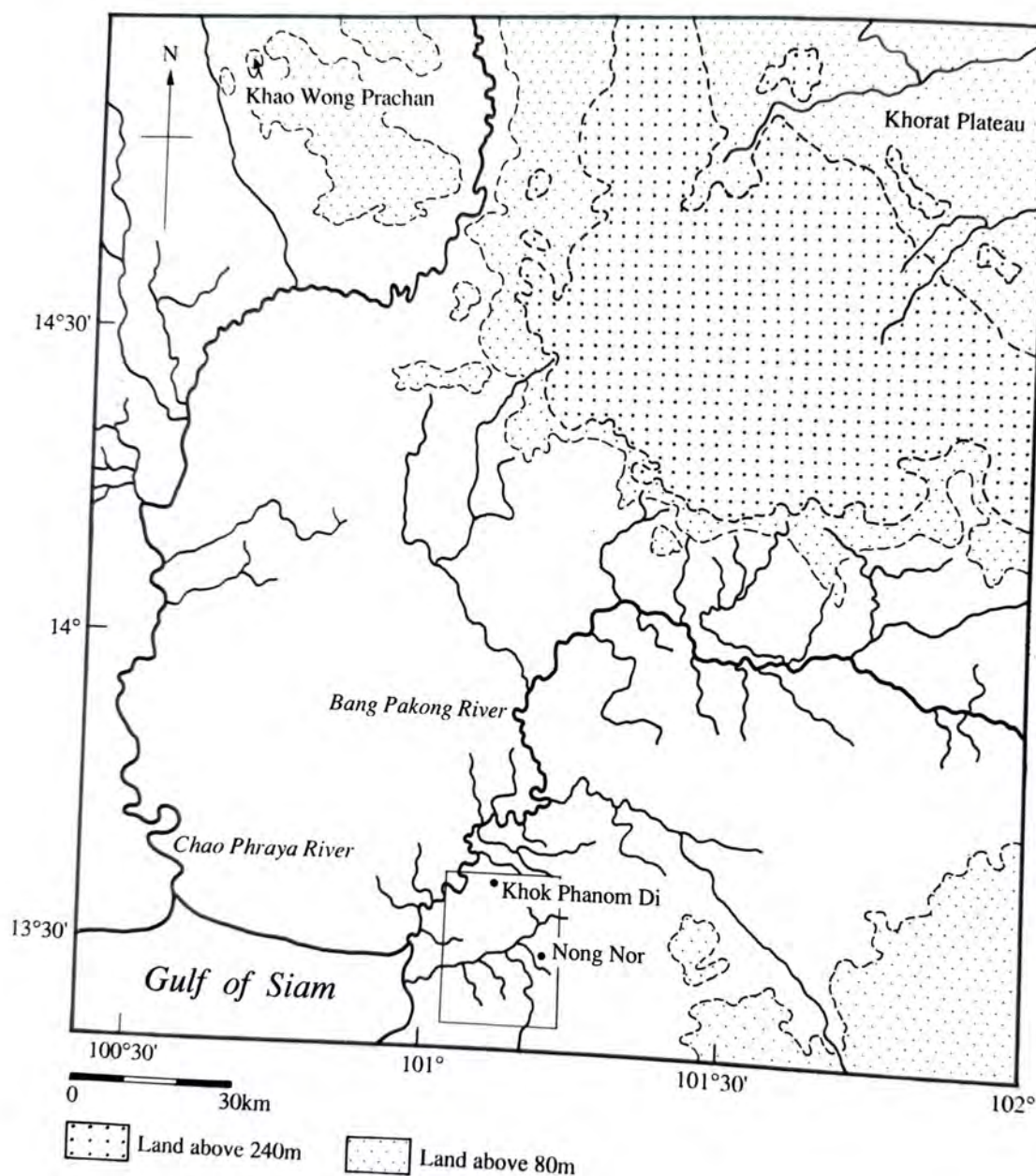


FIG. 1. The location of Khok Phanom Di

This reflects the fact that the lower Bang Pakong River valley has been moulded by particularly active natural forces, not least the oscillating sea level. Bernard Maloney was able to participate in the fieldwork, and not only collected invaluable botanical samples from the site and its environs, but also extracted a series of sediment cores. From these, he has extracted pollen grains, fragments of

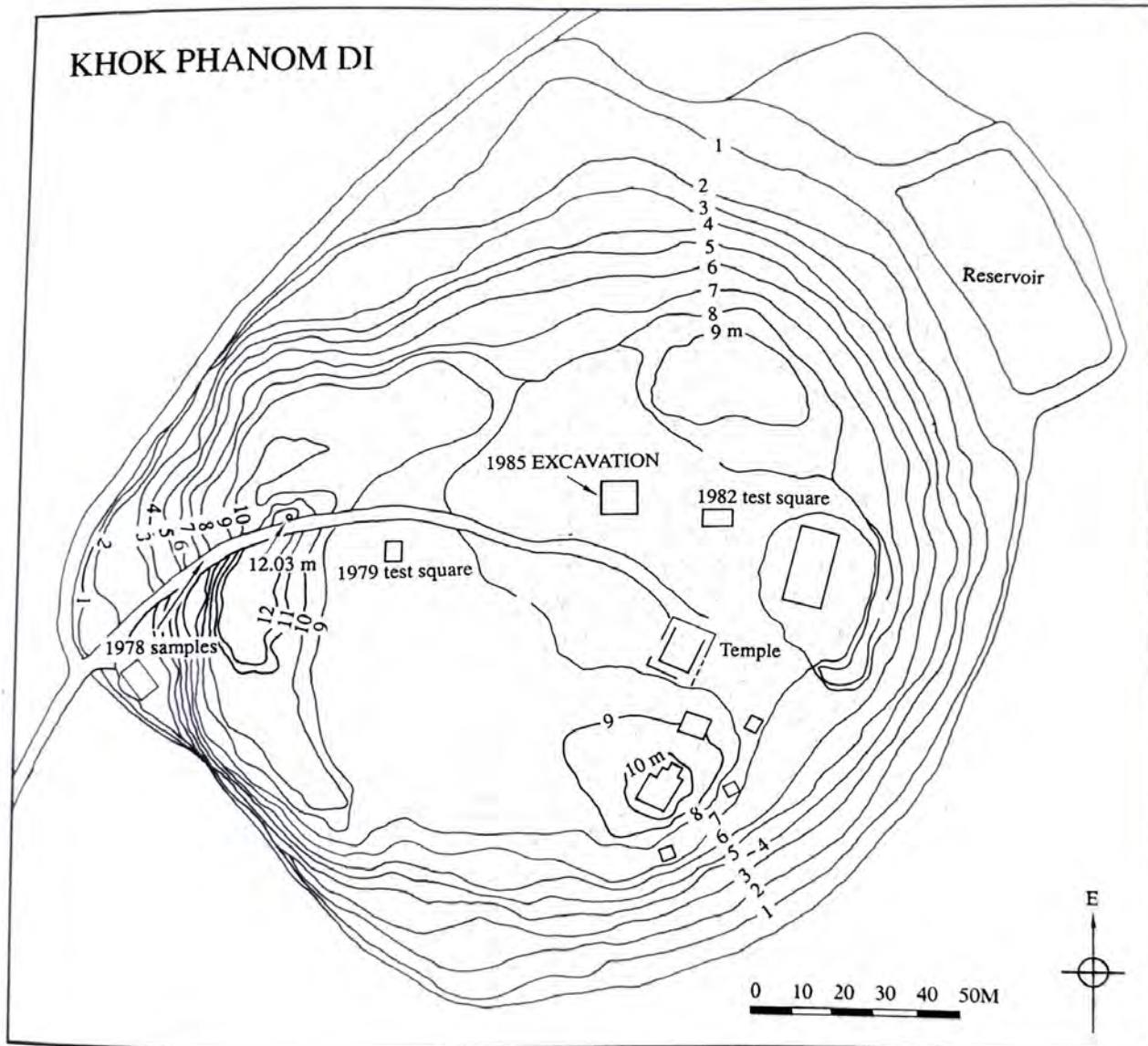


FIG. 2. Site plan of Khok Phanom Di, showing the area excavated

charcoal and fern spores. We believe that his analysis is the first time in mainland South-East Asia that we have such a conjunction of prehistoric cultural and palynological data set against a deep, dated, natural sediment sequence. In reading his contribution, it is important to appreciate that only

the upper parts of these cores bear the imprint of the occupants of this site. Much of the evidence he advances for a coastal habitat dominated by mangrove taxa, periodically subjected to burning and the proliferation of grasses and ferns, describes events which long antedate the occupation of Khok Phanom Di itself.

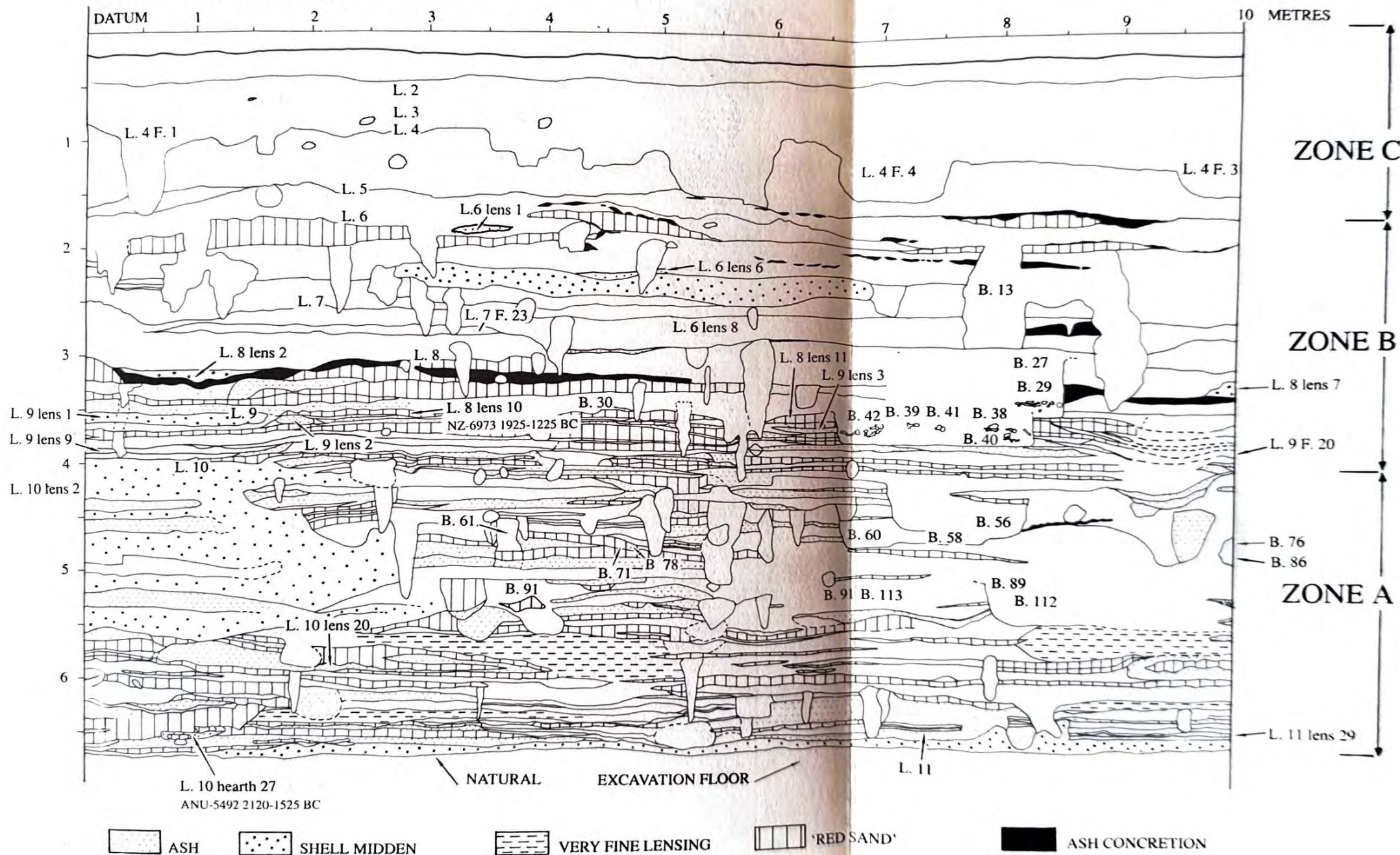
Some of the biological remains from the cultural material from Khok Phanom Di itself are described in Maloney and Rovner's preliminary discussion of the phytoliths, and McKenzie's consideration of the ostracodes and foraminifera. The latter contribution is based on samples taken from the eastern section and, once again, the recovery of such data and their interpretation is a pioneering one in South-East Asia.

The non-human bones from Khok Phanom Di are treated in three chapters. When the mammalian bone reached the laboratories at the University of Otago, it was sorted into species identifiable within the constraints of the modest comparative collection available, with a second subsample comprising specimens requiring more comprehensive comparative data. The former material is described in the contribution by Grant and Higham. The latter was studied by Barbara West at the British Museum (Natural History). Her material includes the remains of small and some rare large mammals, birds and crocodiles. Ampham Kijngam undertook a survey of the remains of fish, crabs and turtles but his analysis took place in Otago, and he was handicapped by a lack of locally available comparative data. His chapter is therefore unfortunately brief and he is continuing his research in Thailand with a view to assembling a larger sample of modern material. Cassaidy, however, followed the very considerable task of sorting completed by Kijngam by taking and reviewing dimensions from the remains of the crab *Scylla serrata*.

Chapter XVI calls on a number of authorities, who comment on the remains of coral, a mite, insects, hair and parasite eggs. Burial 56 contained probable food residue from the stomach area, and the fish and stingray remains are described. It must be appreciated that rice was also found in this sample, and this will be considered in a later volume of this report. The last three chapters comprise Graeme Mason's description of the larger shellfish remains and Bryan Manly's description of the statistics used to investigate their distribution in the site. It is again stressed that Khok Phanom Di was rich in terms of biological remains, and the constraints of time mean that Mason treats only the larger species in his section, reserving the small molluscs for a later description.

This volume is described as The Biological Remains, (Part I). Part II will appear in a later volume of this report on Khok Phanom Di. It will include a description of the rice remains, the charcoal and seeds by Jill Thompson, the smaller shells by Graeme Mason, the human remains by Nancy Tayles and, it is hoped, the remains of root and tuber tissues by Jon Hather.

KHOK PHANOM DI: WEST SECTION



II. PALAEOENVIRONMENTS OF KHOK PHANOM DI: THE POLLEN, PTERIDOPHYTE SPORE AND MICROSCOPIC CHARCOAL RECORD

By B. K. Maloney

INTRODUCTION

THIS section of the monograph considers the palaeoenvironment of Khok Phanom Di and is based principally but not exclusively on data from pollen core stratigraphies and pollen analysis. The pollen diagrams presented are not only the most detailed associated with any South-East Asian archaeological site but they also stand in their own right as the most thorough from a mangrove area of the mainland. If this statement appears immodest, it should be hastily qualified by the additional comment that South-East Asian palynology still has a long way to go before diagrams of equal resolution to those available from the United States of America or Western Europe can be presented. We are not yet out of the pioneer stage, but the more research which is undertaken now, the easier it will be for others to follow and refine identifications, interpretations and process larger numbers of samples in a shorter time. Perhaps the most innovative and probably therefore the most readily criticized part of the research undertaken around Khok Phanom Di has been the attempt to reconstruct vegetation change in the near environs of the archaeological site in three dimensions. It must be admitted at the outset that this approach has not been entirely satisfactory, as a larger number of cores than could be envisaged given the comparative simplicity of the present-day vegetation would need to be analysed to build up an adequate perspective of change over space: more from near the site and certainly some taken at a distance of 500 - 1000m from it. The pursuit of a three-dimensional perspective is unique for lowland South-East Asia. It is hoped that others will take up, develop and refine this method as it holds promise not only for tracing vegetation change *per se* but, assisted by mathematical and statistical techniques, for the explanation of individual pollen curves in terms of the population biology of the taxa which produced them, as advocated by Flenley (1985). However, it is probably better applied in an area with closed-basin environments than that of Khok Phanom Di, where the pollen catchment area at any particular instance in time is difficult, if not impossible, to establish. There is a further problem that there may be hiatuses in the stratigraphies either due to non-deposition or erosion of sediments under tidal influences. Redeposition of pollen from older to younger deposits is also a real possibility and care has to be exercised in interpretations because bioturbation could have occurred.

It is difficult to conceive of a more difficult set of materials for the pollen analyst to work on than those from around Khok Phanom Di but, in the absence of more suitable coring locations, there was no alternative other than to use what was available, and the interesting work by Caratini and Tissot (1985) on sediments from the equally complex environment of the Mahakam delta on

the east coast of Kalimantan has provided a stimulus to continue and try to derive as much information as possible from the Khok Phanom Di cores.

PALYNOLOGICAL INFORMATION FOR HUMAN IMPACT ON THE SOUTH-EAST ASIAN VEGETATION

The number of pollen diagrams available from South-East Asia is growing slowly, with research proceeding in Thailand, peninsular Malaysia, Sabah, Indonesia and the Philippines. With the exception of Caratini and Tissot's (1985) diagram from Kalimantan and a few pollen spectra from the South China Sea presented in Biswas (1973), off Timor (Zaklinskaya 1978), from Central Java (Semah 1984), and, most significantly, van der Kaars (1990) on deep sea cores from eastern Indonesia, there is no information concerning the lowlands pre-dating the Holocene and none of these works is directly concerned with human impact on the vegetation although it would, undoubtedly, have been mentioned had any been detected. Few pollen analytical data are available from archaeological contexts or the near environs of archaeological sites. The only published exceptions refer to Laang Spean, Borobudur, Satingpra and Balanghai 1 (Thanikaimoni 1977, 1983, Thanikaimoni in Stargardt 1983, Bulalacao and Ranin 1987).

The Satingpra diagram will be considered in detail later as it has some relevance for the interpretation of those from Khok Phanom Di, but it should be stated firstly that most evidence for disturbance and clearance of forest vegetation comes from the climatically marginal environments of the Indonesian highlands (Maloney 1985a, Golson 1985, Flenley 1988, Newsome and Flenley 1988), where vegetation may not recover as quickly and where soil poverty can add to climatic stress. Pollen analysis of even these areas has not revealed which basic food crops were cultivated, although both Morley (1982) and Maloney (1985a) claimed that certain plants may have been encouraged if not actually planted. Fortunately, as far as Khok Phanom Di is concerned, we are not trying to trace the history of tuber exploitation and domestication, but we are most definitely concerned with rice agricultural origins. As indicated by van Zeist (1984), the attempt to trace cereal cultivation in Western Europe using palynology has met with some success, despite provoking many and continuing disputes, but, as he also states, and as elaborated in Maloney (1990), it has not been possible to distinguish rice pollen from that of other grasses: unlike the pollen of wheat, barley and oats, it shows no tendency towards gigantism. Even if it did, rice pollen could not be certainly distinguished from that of wild grasses using pollen grain size alone as several genera, e.g. *Themeda* and *Coix*, produce large pollen grains. If pollen in the size range of rice, and with a similar surface patterning, occurs in the sub-fossil record, because the wild annuals are wind pollinated and the cultivar is not, it is more likely to be from these than from the cultivar. Numerous agricultural publications indicate that cultivated rice pollen is only dispersed over very short distances, less than a metre, and that rice does not produce much pollen anyway. Under the condition of inundation cultivation employing bunds, however, it might be concentrated by washing from fields into deposits laid down by the streams or rivers flowing from the fields. So, the problem of detecting rice agriculture using palynology alone is no easier than tracing the origins of cultivated yams or taro. Nevertheless, as indicated in Maloney (1990), it is worthwhile both to measure every grass pollen grain recorded during analysis and to keep notes on their surface patterning, since

conclusions about whether or not rice could have been present can then be made. As far as Khok Phanom Di is concerned, definitive data can only be derived from the plant macrofossil remains uncovered during excavation and possibly, but less certainly, the inclusions in the temper of pottery.

While a number of Holocene pollen diagrams are now available from the lowlands of Malaysia, Thailand, Sulawesi, Sumatra and Kalimantan (Muller 1963, 1964, Anderson and Muller 1975, Gremmen 1990, Haseldonckx 1977, Morley 1981a, Hastings 1983, Hillen 1983, Hastings and Liengsakul 1983, Pramojanee and Hastings 1983, Supiandi and Furukawa 1986, Somboon 1988 and Thanikaimoni in Stargardt 1983), the only ones which show traces of human impact on the vegetation are those of Morley (1981a) from Tasek Bera in peninsular Malaysia (and the base of the sequence is only c. 4000 years old) and Thanikaimoni's undated diagram from Satingpra, Thailand. Morley claimed that forest clearance was evident from c. AD 1300 (uncorrected age) at Tasek Bera, but Maloney (1985a) suggested that it began at least a little earlier, if not a lot earlier. It is difficult to make much sense of the Satingpra diagram, based as it is on just seven samples and not being directly dated, partly because the palynological data are scattered throughout the unwieldy volume by Stargardt (1983) on the environmental and economic archaeology of the area. The impression is given on p. 55 that *Acrostichum* spores indicate the presence of clearings in the mangrove from the base of the diagram, claimed, on very tenuous grounds, to date from c. 2000 BC upward. One has to take issue with this: there are two species of *Acrostichum* in Thailand, *A. aureum* L. and *A. speciosum* Willd., and these cannot be separated using spore morphology. *A. speciosum* is a short shade-tolerant fern (Macnae 1968:93) while *A. aureum* enters clearings, where it can form dense stands.

The argument might have been better sustained if microfossil charcoal particle counts had been made as has been done here. The further criticism that the increase in spore percentage from a lower to higher sample may be an artefact of the lack of independence of the variables concerned, in this case pollen and spores, can also be made. A change in the percentage of any one taxon included in the pollen sum will alter the percentages of all others. Without counts of pollen and spore concentration, and dating of a number of samples to enable calculation of sedimentation rates so that absolute pollen counts can be derived, the problem is insurmountable and perhaps this criticism is harsh. All the Khok Phanom Di samples have been prepared so that concentrations can be presented, but absolute pollen counts cannot be calculated reliably without the intensity of dating just mentioned.

The Satingpra sample from early historical times contained 15 per cent grass pollen and 10 per cent *Borassus* (sugar palm). The latter is exceedingly high for a palm and the conclusion (p. 57) that it was planted is almost certainly correct, although Smitinand (1980) listed *B. flabellifer* L. as an exotic, and this cannot be proved on the basis of pollen morphology. The suggestion that the increase in grass pollen indicated a change from broadcast riziculture to planting on banded fields is mere conjecture. No statistics on measurements of grass pollen grains or comments on surface patterning have been presented by Thanikaimoni in Appendix A: he simply stated (p. 224) that the Gramineae pollen grains in the sample measured between 25 and 30 μm . He admitted that this was small for cultivated rice (detailed measurements of numerous Indonesian cultivated varieties (Maloney 1990) revealed a modal peak at 35 μm), but he was not prepared to commit himself on whether the pollen was from wild diploid rice. This was prudent, as many wild grass species which occur in Thailand, including the noxious weed *Imperata cylindrica*, have pollen grains in this size range.

The diagram from Balanghai, Mindanao, (Bulalacao and Ranin 1987) seems to cover the last few centuries but is interesting insofar as it has pollen of *Cocos* and the weedy *Mimosa pudica* in the upper part of the stratigraphy. Carbonised particles present were not counted.

The Senanivate (Bangkok) housing site (Somboon 1988) pollen diagram shows a slight increase in grass pollen above 2.5m in depth but is dominated by mangrove pollen throughout most of the record. Unfortunately, no pollen has been recovered from the upper 1.10m of the section.

The palynological evidence for human impact on the vegetation of lowland mainland South-East Asia in prehistory is thus lamentably thin. Fortunately rather more information is available on natural changes in mangrove vegetation and it is to this that we now turn.

PALYNOLOGICAL INFORMATION FOR NATURAL VEGETATION CHANGES IN AREAS OF SOUTH-EAST ASIAN MANGROVES

Perhaps the most relevant diagrams to discuss first are those of Somboon (1988) from the Bangkok area and Pramojanee and Hastings (1983) from the Chanthaburi area of South-East Thailand. The Senanivate (Bangkok) outcrop was subjected to analysis for its mollusc content as well as the pollen, but Somboon (1988) did not indicate the size of samples used to recover the molluscs nor the methods of extraction employed. The base of the section, pre-dating 7800 BP (no laboratory number given), was interpreted as a riverine deposit, possibly old channel sediments from 16.99–19.36m depth. Pollen was absent below 13.80m depth and this may result from oxidation under a seasonal climate or dilution due to very rapid accumulation of sediment. The presence of a pisolithic layer from 12.55–12.63m depth and pisolithic inclusions in a dark brown silty clay from 12.63–13.80m below the surface are suggestive of a seasonally dry climate as induration does not occur under ever-wet conditions. The 12.63–13.80m section of the exposure was low in pollen and a high proportion remained unidentified. The dominance of the rest by grasses and sedges is claimed to be indicative of a freshwater environment. While also low in pollen, the pisolithic layer saw the increase in mangrove elements.

Despite a number of lithological changes, the contribution of the total mangrove percentage remained quite consistent throughout the rest of the section. Unfortunately the 0.35–1.10m samples stated to comprise light grey silty clay with plant roots and gypsum needles were not subjected to pollen analysis. Therefore the end of the marine transgression is not clearly marked. There is a minor increase in grass pollen post-dating 4600 BP (a date based on shell) and *Avicennia* is also commoner in what is largely Somboon's pollen zone 1, but most variations are indistinct. His interpretations of changes through intertidal to sublittoral marine-intertidal are supported by the mollusc record. The main sublittoral-shallow marine phase lies between radiocarbon dates of c. 7500 and 4600 BP (c. 5500–2600 BC, uncorrected). *In situ* mangrove wood was dated at c. 7800 BP (c. 5800 BC, uncorrected). The interpretation of fluctuating sea levels as opposed to a steady post-glacial rise is in accord with data from other parts of South-East Asia.

Unfortunately, the Chanthaburi samples are not well dated. It was suggested (Pramojanee and Hastings 1983) that the regression in sea level associated with the last glaciation began around 14,000 BC, a date which is far too late given that the last glacial maximum was at c. 16,000 BC. (CLIMAP Members 1976), and dates of c. 13,000–38,000 BC on terrestrial deposits from the Bangkok area (Somboon 1988).

Pollen was fairly scarce in the small core 14,000 BC section subjected to analysis but is said to have consisted mainly of swampy and back-mangrove types with a few upland taxa (Pramojanee and Hastings 1983). The sediments overlying the regression deposits comprised a mottled grey clay with a laterite cap. As laterites only became indurated when drying out occurs, this finding concurs with those of Somboon (1988). It is difficult to see how this sequence indicates a temperature reduction as claimed by Pramojanee and Hastings (1983:44). Somboon (1988:206) put the maximum age of the marine Bangkok clays at c. 6000 BC while Pramojanee and Hastings (1983) gave a date of $6400 \pm$ (? uncorrected) for the onset of the marine transgression in South-East Asia and c. 3200 BC in the Bangkok area (Hastings and Liengsakul 1983). If the 3200 BC date is correct, the advancing sea would have reached Chonburi Province before 3000 BC, radiocarbon dates from cores KL 2 and BMR 2 confirming this (chapter IV). The retreat of the sea from its post-glacial maximum seems to have begun about this time (Somboon 1988) but the course of the rise and fall, as suggested from some other parts of South-East Asia, e.g. by Tjia *et al.* (1983) was not smooth. A radiocarbon date of c. 1800 BC has been obtained (presumably from the base) from a peat swamp at Doe Dang, Narathiwat, near the border with peninsular Malaysia. This is thought to have formed in response to the sea's transgression though how is not disclosed, or soon after its maximum, which appears more likely (Hastings and Liengsakul 1983).

The longest core from Chanthaburi only covered 3.5m before a stiff plinthitic (lateritic) clay or oxidized sand was encountered. This thinness, not matched by cores from the near environs of Khok Phanom Di or the Bang Pakong Valley, is attributed to very gradual, continued uplift during the Holocene. Unfortunately, the sampling resolution is poor: the two most useful diagrams, labelled CH3 and CH4, seem to be incompletely published and neither has been radiocarbon dated. The c. 6400 BC date is from CH6, and evidently contains extremely small amounts of pollen. CH3 (13 samples counted) is the longest core, extending down to 3m depth and this began with what Pramojanee and Hastings (1983) call transitional swamp, a vegetation dominated by palm and grass pollen, allegedly with *Allophyllus*. Taxa of tidal mangrove and freshwater vegetation, the latter probably derived from nearby upland areas, also occurred. Development continued with an increase in *Rhizophora*, claimed to indicate a continued rise in sea level, and then a change to lagoonal conditions evidenced by a mixture of various pollen types and the presence of micro-foraminifera. CH 4 (2.3m), the more complete diagram, began with transitional swamp showing little or no freshwater influence. *Barringtonia* and *Nypa*, indicative of a tidally influenced river, were present, and increased before a change to freshwater swamp took place with *Eugenia* replacing *Barringtonia* and *Nypa*. This is interpreted as indicating that increased siltation in the river resulted in the formation of a bar across its mouth, changing the channel shape and thus water volume. There followed a return to a more transitional swamp with suggestions of a tidally influenced river and then dominance by back mangrove (*Rhizophoraceae*, *Intsia*, *Brownlowia*, *Melastoma*, *Acrostichum*, etc.). How *Melastoma* has been palynologically separated from *Combretaceae*, trees of dry land vegetation, is not explained. Despite this quibble, the interpretation that a continued rise in sea level is evident cannot be doubted and is indeed substantiated by the increase of *Avicennia*, *Sonneratia* and *Rhizophora* (swampy mangrove taxa), followed by evidence for a falling sea level. This is an important pollen diagram, but it cannot be used to help interpret those from Khok Phanom Di as the topography of the two areas is in no way comparable. It should also be noted at this stage that, judging by Indian vegetation data, *Avicennia* is not always confined to swampy mangrove but can dominate back mangrove (Blasco 1975). Palynologists may be paying too much

attention to the schematic representation of mangrove zonation presented in Watson (1928) to assist interpretation, whereas the reality may be very different.

The lowest part of the Narathiwat diagram dates to c. 1800 BC (Hastings and Liengsakul 1983). It has a diverse pollen flora but palm pollen, especially *Areca* (? cultivated), dominates but taxa common in freshwater swamp forest are also present. This section overlies what appears to be an acid sulphate soil. The other nine samples are dominated by dryland-freshwater swamp elements such as one might have expected in the Bang Pakong valley at this time under natural conditions.

Hillen (1983) has processed and published, albeit incompletely, considerably more samples (c. 100) from a number of lowland localities in Perak, peninsular Malaysia, but none of his seven cores has been radiocarbon dated. His core A7 comprised fairly uniform greenish grey clayey silt material with a moderate amount of shells and is lithologically comparable with some deposits from near Khok Phanom Di (see chapter V). More than that, the samples, which were prepared using potassium hydroxide treatment, heavy liquid separation, hydrofluoric acid and acetylation, were poor in pollen, a problem encountered for the Khok Phanom Di samples which was overcome by using tetrasodium pyrophosphate as a deflocculant and harsh HF treatment (see chapter III). The A7 diagram was dominated by *Rhizophora* (60-80 per cent of total pollen content) and this is suggested to indicate deposition in a shallow offshore environment. However, Pramojanee and Hastings (1983) stated that the presence of shells in a deposit pointed to the occurrence of low tidal flats, but Hillen (1983) has discovered that peninsular Malaysian tidal flat (and offshore samples) contained only 30-40 per cent mangrove pollen.

Hillen's core B1, in contrast, comprised homogenous olive and greenish-grey clay, with a moderate amount of plant remains below 7m, few shells, and 85-95 per cent of the pollen was from mangrove taxa. He interpreted this as indicative of an intertidal mangrove environment but did not point out that the comparative uniformity up profile is suggestive of bioturbation. In contrast, core B10, taken c. 2km away from B1, had mangrove deposits covered by about 3.5m of ombrogenous peat. The lower samples from the pollen diagram contained more than 90 per cent *Rhizophoraceae* pollen while those from the transition zone had high percentages of *Oncosperma* (a palm) and the upper three samples were dominated by freshwater taxa (*Stemonurus*, *Ilex*, and *Campnosperma*). No peat has formed near Khok Phanom Di and the taxa present in peninsular Malaysian samples can provide no guide as to whether peat was present in the pollen catchment areas as the floristic composition of peat swamp in both countries is likely to differ considerably.

Core C11 was selected as a means for establishing the pollen content of a fluvial deposit but pollen analysis indicated that the lower spectra were of marine origin. The sediment comprised clayey silt at the top and sandy silt at the bottom. Unfortunately, the freshwater indicators may not be comparable to those which might be found in similar deposits from Thailand, and this diagram is of limited value in interpreting spectra from Khok Phanom Di.

Core E3 is from a deltaic/estuarine environment. It has a clayey silt upper horizon with sandy silt below it, then sand with silt layers, some gravel, shells and shell fragments. The lowest part (7.4-8.7m depth) comprised silt with thin sand layers. The pollen zone below 6.5m had high *Rhizophoraceae* percentages (c. 80 per cent per sample) decreasing above this level where *Sonneratia* had particularly high (c. 10 per cent) percentages for a poor pollen producer and palms (mainly *Oncosperma*) reached 15-35 per cent of the pollen sum. These upper spectra showed some resemblance to those of Pramojanee and Hastings's transitional forest. However, here the high *Oncosperma* probably represents riverine vegetation, while *Sonneratia* may be indicative of pio-

near vegetation in or along the estuary or delta. Again, use of these data to interpret past conditions in the Khok Phanom Di area must be treated with some circumspection, although, in the absence of modern pollen samples from Thai deltaic/estuarine environments, any shred of evidence which assists must be grasped.

It is not impossible that the Khok Phanom Di mound began as a sand chenier, so Hillen's F5 is worthy of close inspection. Lithologically this consists of yellowish silt and clay with minor sand inclusions over a whitish grey clay apparently somewhat similar to the basal sediment (chapter III) of cores KPD DG a and b from the south-west edge of Khok Phanom Di, and core BMR 2 from the northern environs of the site, but stated to represent a palaeosol sandwiched between two marine deposits, as greenish-grey clayey silt is present below it. The upper and lower parts of the core have 55–80 per cent mangrove pollen, but the palaeosol is barren, and it is suggested that they were formed in an offshore environment.

Core H7 was extracted from near the Perak River. The sediments were characterized by sand and coarse silt, often with oxidation features and, not surprisingly, were either very poor in pollen or contained none at all. A silty peat layer was present 6.3–7.4m below the surface and a humic sandy silt beneath this. Only five samples were subjected to pollen analysis. The lower two contained high grass, Rubiaceae and Euphorbiaceae percentages; and the upper two of the four which contained pollen were dominated by *Pandanus*, which presently forms forests in the coastal areas of eastern peninsular Malaysia.

The reader may think that the details of Hillen (1983) have been reiterated at excessive length but this is a very important paper in relation to interpretation of cores from near Khok Phanom Di. If a number of dates were available to give some indications of the rate of vegetation change over time it would have been even more important.

Haseldonckx (1977) studied shallow peat over sandy, riverine sediments older than 2900 BC at its base from Pekan Nanas, Johore. Only twelve samples were counted but the lowest one was dominated by *Oncosperma*, with a small frequency (c. 10 per cent) of *Rhizophora*. Cyperaceae and *Lycopodium cernuum* replaced *Oncosperma* as a marginal peat swamp facies with river-bank vegetation developed.

The Marudi, Sarawak, pollen core (Anderson and Muller 1975) had some *Rhizophora* pollen, with *Nypa*, indicative of tidally influenced riverine conditions, and *Oncosperma* present before c. 2000 BC, and it is suggested that this 'mangrove' was replaced by various peat swamp formations thereafter. Two cores from ombrogenous peat swamp in South Kalimantan also have a small percentage of mangrove pollen, including the above, at their base (Morley 1981a). Unfortunately these diagrams are undated.

There are no well-dated Holocene mangrove pollen diagrams from South-East Asia and the sampling intensity of most published to date is rather coarse. There is some degree of acceptance by tropical palynologists (cf. Flenley 1979) that the interpretation of fossil spectra is best based upon a study of the pollen content of surface sediments related to the results from a vegetation survey. Of the literature cited above, only Anderson and Muller (1975) contains any reference to modern pollen rain. Fortunately there are more detailed studies available in Caratini and Tissot (1985), referring to Kalimantan, and from India (Caratini *et al.* 1973). These will be considered later in relation to the results from the Khok Phanom Di area.

EVIDENCE FOR HOLOCENE CLIMATIC CHANGE

There is general acceptance that the Holocene began around 8000 BC in Western Europe and North America and that there was a fairly complicated series of climatic changes at least in the former. These changes may also have been experienced in the tropics at the end of the last glaciation (Roberts *et al.* 1981). Glaciation was most widespread in the high mountains of Irian Jaya and Papua New Guinea (Verstappen 1960, 1964, Reiner 1960, Bik 1972, Blake and Löffler 1971, Löffler 1970, 1971, 1972, 1980, Hope and Petersen 1975, Hope *et al.* 1976), but Mt Kinabalu, Sabah (Koopmans and Stauffer 1966) was also glaciated as were some higher peaks in Aceh, North Sumatra (Whitten *et al.* 1984). Mt Kinabalu (4100m) was deglaciated (Flenley and Morley 1978) by about 7200 BC and Mt Kimiri in Aceh by 5600 BC (van Beek 1982). Both dates are minimal as they are derived from the lowest sediments deposited in small lakes and do not, therefore, provide a satisfactory basis for definition of the opening of the Holocene. Indeed, ice has only recently melted from Mt Trikora (Wilhelmina) in Irian Jaya (Hope and Petersen 1975) and is still present on Mt Jaya (Bik 1972, Allison and Kruss 1977), although it has been in retreat from c. 12,000 BC (Hope and Petersen 1975). Löffler (1980) has concluded that ice began to melt around 13,000 BC, that it was absent even from areas now glaciated by 8000–7000 BC, but that the existing glaciers began to develop following a decline in temperature after 3000 BC. Frerichs (1968) claimed that faunal evidence from the Andaman Sea indicated that the Pleistocene – Recent boundary dated to c. 6700 BC, but palynological data from Indonesia and Papua New Guinea suggests that it is probably best to regard 8000 BC as the date for the beginning of the Holocene, although the course of climatic change is by no means uniform throughout the area (Flenley 1979, 1985). Holocene climatic fluctuations are best detected in cores from the highlands but the only (unpublished) Thai diagram, from Doi Inthanon, Chiangmai, covers just 4300 years (Hastings and Liengsakul 1983). It is claimed to show a change from a climate with a pronounced dry season to present day ever-wet conditions. A Thai weather poem written around AD 1464 indicates that the climate by then was broadly similar to that now existing (Aranuvachapun and Brimblecombe 1979).

The older pollen records from North Sumatra (Maloney 1980, 1981) give no clear evidence for important Holocene climatic changes but Morley (1982) stated that present-day vegetation types did not become established near Danau Padang (950m) in central Sumatra until c. 6600 BC and Newsome and Flenley (1988) stated that the temperature was probably less than 1.5° cooler in the area before c. 7100 BC and c. 0.6° cooler around 3400 BC. The later parts of all these diagrams (Maloney 1985a, Newsome and Flenley 1988) show variations more readily attributable to human impact than climatic change.

Van Zeist *et al.* (1979) has suggested that a decrease in *Altingia* and rise of *Castanopsis* comp. at Situ Gunung (c. 1000m), west Java, around 3000 BC indicated a change to drier conditions. Alternative causes, however, such as human interference and soil deterioration, cannot be excluded (Morley 1982, Maloney 1985a). Stuijts (1983) found no evidence attributable to an altering climate in the Situ Bayongbong core. This was taken at 1200–1300m in west Java, and covers the entire Holocene.

The most complete record for montane Holocene climatic change is not from South-East Asia *per se*, but from Papua New Guinea (Hope 1976). Ice retreated completely from Mt Wilhelm between 8200 and 6600 BC and the greatest development of forests and shrublands took place

The Bang Pakong watershed covers c. 19,252km² and the river originates in springs on the northern slopes of the Chanthaburi Mountains near the Cambodian border at an altitude of 500 to 600m and others in the Samkhamphaeng Mountains at c. 600 to 700m. The lower parts of the river system are at the same altitude (2 to 3m) as the Bangkok Plain and an extensive network of canals used for irrigation, drainage and transportation form links with the Chao Phraya. The Bang Pakong River is tidal for many kilometres inland and is subject to sudden floods which frequently overflow the banks. The Royal Irrigation Department has recorded the downflow at Kabinburi since 1941. Discharge there ranges from 218 to 383m³ per second (with a peak of 431m³ per second in September) between July and October. The lowest flow (7.21m³ per second) occurs in May, the mean discharge is 128.4m³ per second and the annual runoff is 4052 million m³. Unfortunately the flow at the mouth has not been monitored.

The lower valley geomorphology has not been mapped in detail but, like the lower Mekong, comprises several landscape elements: the channel of the river with adjacent levees or river bank deposits; backswamps, largely reclaimed for agriculture, connected to the main channel by distributaries and which probably acted as natural flood regulators following monsoon rainfall; the alluvial plain and low terraces, the latter being remnants of earlier alluvial plains and not normally flooded; and the uplands and hills of Chanthaburi (van Liere 1980). Active tidal flats of recent marine and brackish water deposits are present at the river mouth and former tidal flats occur behind these (Donner 1978).

Takaya (1971: Fig. 1) distinguished areas of high and low deltaic flats in Central Thailand (Fig. 8), the latter dominated by brackish conditions, but inundated deeply during the rainy season, and containing a large number of ephemeral marshes and swamps. The deltaic highs average 3m above sea level (about 1m higher than that of the delta flat) but occasionally attain 5m. The east-west elongated strip on which Bangkok stands was suggested to be an old barrier or beach ridge and a broad flat west of the Bang Pakong River was stated to resemble a complex of natural levees. Relative local uplift due to differential consolidation of sediments was hypothesized as being responsible for other rises. The contention that a web of old barrier island-like swells and lagoon-like swales exist is not repeated (Takaya 1969:260).

As indicated by Takaya (1969), many of these features are likely to relate either to the period of high Holocene sea levels probably dating to 3000-2000 BC (Streif 1979) or to a later stillstand during a regression. The fragmented nature of the features could be at least partly explained as a result of incision by rivers and streams adjusting to a lowered base level.

The geomorphology of the lower Bang Pakong Valley is clearly not only a product of fluvial erosion and deposition but also of Holocene coastal processes. It is therefore necessary to have access to data about present-day coastal as well as fluvial activity to interpret the landform and stratigraphic record. Unfortunately, information on the former is even more limited than the latter. It is known that extreme flood tides usually occur at Bangkok during May, that the mean tidal range in March and April is 1.80m, and that it is 1.17m throughout the rest of the year (Donner 1978:770). As the Bang Pakong Valley is only 50km east of Bangkok, it is not unreasonable to assume that a somewhat similar tide regime exists there.

Few observations on conditions on the north-eastern Gulf of Thailand have been made. Kenney (1969) reported that the Gulf as a whole was nearly isothermal (26.5–27.7°C) and isohaline (31.7–32.4‰) throughout the water column, probably as a result of water mixing by tidal currents, between December 1967 and February 1968. Current direction measured at 3m below the surface,

mid-depth and 2m from the bottom, recorded continuously, varied with depth with speeds over at least 4 to 6 minutes ranging to a maximum of 0.8 knot. Current vectors changed over short durations and, predictably, the circulation varied with the monsoon although a small anti-clockwise gyre existed in the inner gulf, an area of complex water movement where tidal currents were found to dominate. Higher current speeds occurred during the ebb tide and a southward flow predominated. Readings made off Sattahip in 1961 indicated that current flow was strongly influenced by the tides and coastal topography and was mainly of the reversing type with strong horizontal shear currents. Undoubtedly tides and coastal topography also have an influence at the mouth of the Bang Pakong but what type of currents occur is unknown. Such readings as do exist from this part of the gulf were taken during the inter-monsoon season when winds showed random circulation patterns and tides masked their effect on oceanographic parameters. The tides were mainly diurnal or semi-diurnal with large ranges between successive highs and lows. The results of earlier investigations made in 1959-61, but published later (in the Naga Report, 1974) included only one station in the inner Gulf, from near Sattahip. It was claimed, however, that currents in the Gulf of Siam were a complex mixture of tidal, wind-driven and density currents and that semi-diurnal tides prevailed on the eastern side of the Gulf.

The U.S. Naval Weather Service has reported a few visual wave records made by voluntarily observing ships and these suggest that wave height is usually less than 2m and wave period commonly less than 6 seconds but a sizeable number of indeterminate readings throw some doubt on the accuracy of these conclusions.

Sedimentation in the lower Bang Pakong Valley is likely to be the product of monsoon-generated flood deposition and tidally influenced drift which may be onshore or longshore. When or where little or no semi-diurnal tide occurs, the circulation is likely to be stagnant, with higher salinities than normal, and fine-grained sediments will probably be deposited. What information is available suggests that the tide is diurnal or semi-diurnal and over 1m in range, so salinity is not likely to be high and coarser sediments can be deposited.

Knowledge of coastal processes is not only important to interpret the course of landscape change but also to assist in explanation of the fossil pollen record, which is the main concern of this section. Pollen grain size and specific gravity are important in the deposition of pollen in marine sediments but water current patterns are the dominant factor (Muller 1959).

SOILS

A 1:1,000,000 reconnaissance soil map of the Phanat Nikhom area is available. Donner (1978) has made some comments on the soils of South-East Thailand and van der Kevie (1971) has described the acid sulphate soils of the Bangkok Plain and the low-lying parts of the Bang Pakong Valley.

Marine alluvial soils dominate the valley south of Chachoengsao with low-humic gleys on the margins of the northern and Chanthaburi Mountains (Donner 1978). The higher terraces and low plateaux of the southern slopes of the Samkhamphaeng Range and the lower parts of the Chanthaburi Mountains have grey podzolic soils developed on old alluvium deposited over igneous rocks. Red-yellow podzolics are present on old alluvium and latosols on basalt parent material. The former also predominate on acid to intermediate parent materials in the mountains proper but red-brown earths have developed on limestone, alluvial and residual materials in a few places.

The soils present near Khok Phanom Di (Fig. 9) are derived from former tidal flat, acid marine and brackish-water deposits. They comprise, in the main, what van der Kevie (1971) calls younger acid sulphate soils. Acid sulphate soils are fine textured, very acidic and have a high sulphate content and prominent yellow (jarosite) mottles in a subsoil horizon. They cover about 800,000ha of central Thailand and are formed on non-calcareous heavy green, reduced, marine clays and dark grey to grey brackish-water clays. The former were deposited as the sea level rose to its post-glacial maximum and the latter were laid down over them as sea level declined. The older acid sulphate soils began to develop about 3500-4000 years ago when the sea level stopped rising, the coast acid brought about chemical 'ripening': acid sulphate soil formation. Most older acid sulphate soils are moderately to poorly suited for rice cultivation but poorly suited for other crops. Many young acid sulphate soils, possibly formed after the stillstand suggested by Streif (1979) will not provide sustained yields without leaching by seawater, followed by freshwater, and the addition of lime. Returning to Fig. 9, soils of the Rangsit and Ongkhorak series are typical acid sulphate soils derived from brackish water clays but those of the Bang Nam Prieo and Mahaphot Series found nearer the Bang Pakong River are intermediate acid sulphate soils.

VEGETATION

There is little literature detailing the floristics or the vegetation distribution of the Bang Pakong Valley, and the following section is based substantially on the results of fieldwork in the area within a few kilometres of Khok Phanom Di. Information on mangrove and back mangrove derives from various sources including Smitinand (1980) and Thailand Natural Resources Profile (1987), while that of other coastal vegetation types is from elsewhere in South-East Asia. Fortunately, Smitinand (1968) has presented a quite thorough account of the vegetation at Khao Yai National Park in the Nakhon Ratchasima-Nakhon Nayok-Saraburi region north of the Bang Pakong Valley and in its probable pollen catchment area. Most of the National Park ranges from 250 to 1400m in altitude and takes the full force of the south-west monsoon, causing heavy rainfall between July and October. The mean average rainfall is c. 4000mm, but the figure rises along higher ridges. The vegetation ranges from dry evergreen forest through tropical rainforest to hill evergreen forest in the area draining southward (Fig. 10).

Dry evergreen forest occurs at 100-200m altitude along the eastern border in Prachinburi and Nakhon Ratchasima. Its upper stories are characterized by dipterocarps (*Dipterocarpus alatus*, *Vatica cinerea*, *Shorea sericeiflora*, *Hopea odorata* and *H. ferrea* with *Lagerstroemia calyculata*, *Tetrameles nudiflora*, *Lophopetalum wallichii*, *Azelia xylocarpa*, *Pterocymbium javanicum*, *Parkia streptocarpa*, *Erythrophloeum succirubrum* and *Carallia brachiata*). Under-story trees include *Hydnocarpus ilicifolius*, *Aglaia* spp., *Lonicera microstigma*, *Memecylon floribundum*, the palms *Areca triandra* and *Corypha lecomtei*, etc. The ground flora comprises *Musa acuminata*, *Pandanus* sp., ginger and Maranthaceae. A large area at 400-1000m altitude is covered by tropical rainforest. At lower altitudes this is floristically similar to dry evergreen forest but a larger number of dipterocarps occur, including *Dipterocarpus dyeri*, *D. baudii*, *D. gracilis* and *Anisoptera costata*. *Duabanga grandiflora* and *Anthocephalus cadamba* are present frequently along valleys but deciduous species such as *Pterocymbium javanicum*, *Tetrameles nudiflora* and *Adina cordifolia*

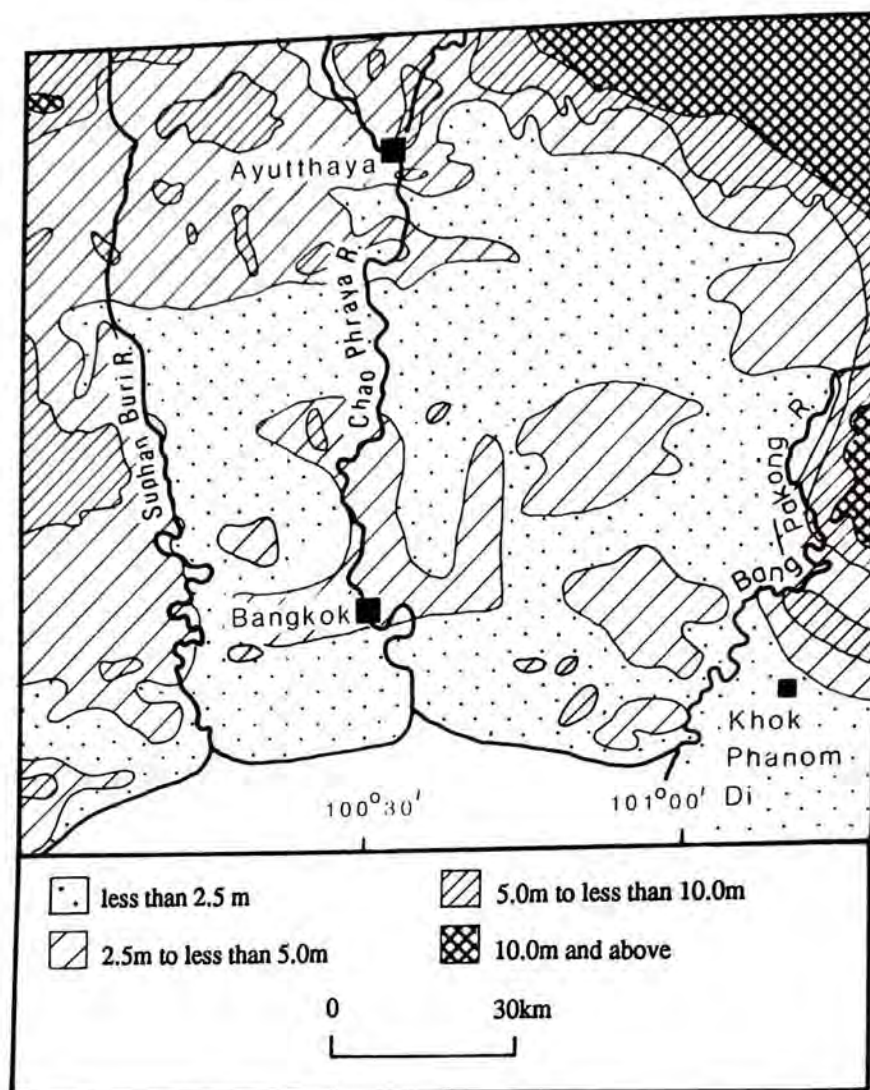


FIG. 8. Contour map of the Bangkok Plain: based on the AMS's topographical map of 1:50,000 surveyed in 1957 (after Takaya 1971)

are very scattered or almost absent. The ground flora resembles that of dry evergreen forest, but is denser. A climbing screw-pine (*Freycinetia* sp.), a climbing fern (*Stenochlaena palustris*) and a creeping aroid (*Anodendron* sp.) are characteristic. *Livistona cochinchinensis*, *Calamus* sp. and *Licuala* are among the most frequent palms. At higher elevations *Dipterocarpus costatus* and *D. macrocarpus* replace *D. baudii*, *D. dyeri* and *Anisoptera costata*. Other trees present in the upper stories include *Shorea sericeiflora*, *Altingia siamensis*, *Poupartia axillaris*, *Aromadendron spongocarpum*, *Calophyllum polyanthum* and *Schima wallichii*. The under-stories contain a number of Fagaceae (*Lithocarpus* spp., *Quercus* spp. and *Castanopsis acuminatissima*). *Palaquium koratense*, *Linociera thorelii* and *Ligustrum confusum* are also present and the shrubby species are: *Uncaria homomalla*, *Mussaenda sanderiana*, *Canthium brunnescens*, *Prismatocarpus tetrandra*, *Psychotria adenophylla*, *Entada phaseoloides*, *Rubus cochinchinensis*, *Itea riparia*, *Aralia armata*

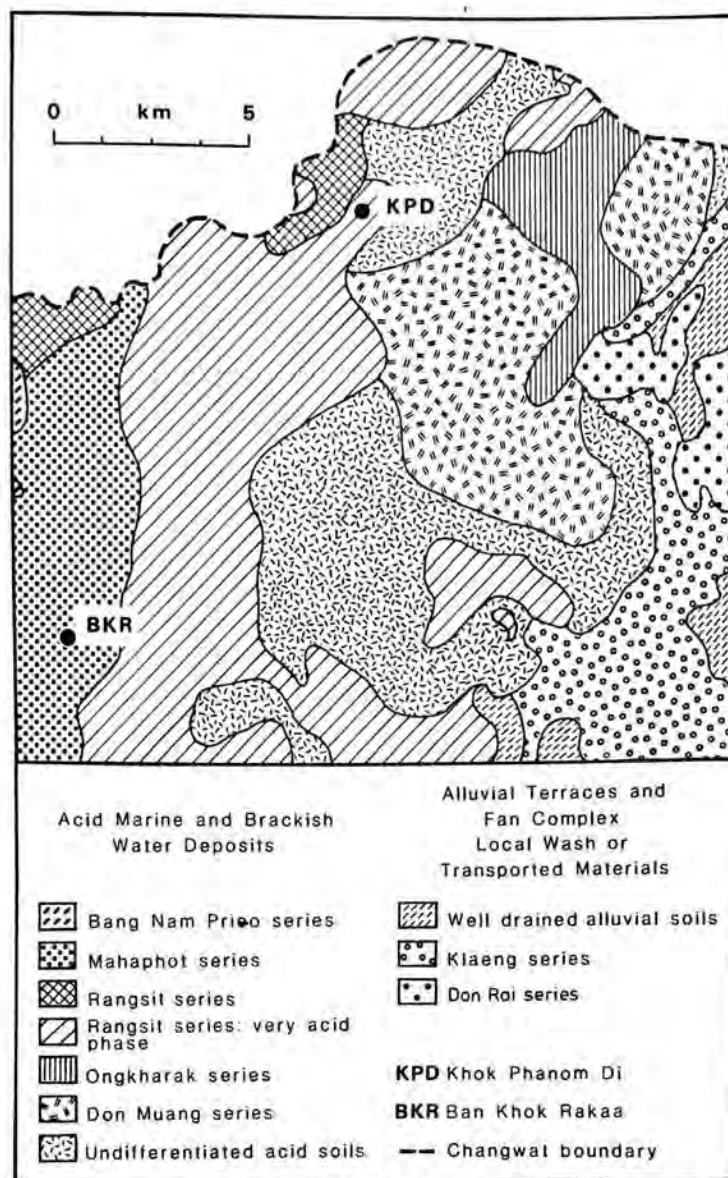


FIG. 9. The reconnaissance soil map of the study area

and *Tupidanthus calyptratus*. Tree ferns (*Cyathea* spp.) occur along stream banks in association with *Cibotium barometz*, *Gleichenia norrisii* and *Dicranopteris curranii*. Epiphytes include a number of orchid species plus the ferns *Drynaria rigidula*, *Photinopteris speciosa*, *Platynerium wallichii* and *Pseudodrynaria coronans*. Filmy ferns in the genera *Hymenophyllum* and *Trichomanes* grow among mosses on tree trunks.

The dipterocarps are replaced by gymnosperms (*Podocarpus neriifolius*, *P. fleuryi*, *Dacrycarpus imbricatus* and *Dacrydium elatum*) in hill evergreen forest above 1000m altitude. Oaks and chestnuts remain important but *Betula alnoides* is scattered along the ridges.

Species of the under-story include *Olea maritima*, *Litsea multumbellata*, *Vaccinium sprengelii*, *Rhus succedanea*, *Adina polycephaloides* and *Syzygium* (*Eugenia*) sp. and shrubs which include,

among others, *Melastoma malabathricum*, *Evodia gracilis*, *Combretum quadratum*, *Brassaiopsis speciosa*, *Macropanax oreophilum*, *Rhamnus cambodianus*, *Psychotria symplocifolia*, *Saprosma latifolium*, *Senecio walkeri*, *Lonicera bournei*, *Embelia kerrii* and *Ardisia eglandulosa*. The flat-topped ridge has *Sphagnum* and other mosses, *Burmannia disticha*, *Osbeckia chinensis*, *Xyris* sp., *Hedyotis* sp., *Fimbristylis trichoides*, *Murdannia* sp. and *Lycopodium cernuum*. A number of epiphytic orchid and fern species occur.

Parts of the park have been cleared for shifting cultivation in the last 40 years and a grassland dominated by *Imperata cylindrica* has resulted. This is accompanied by a number of tall grasses such as *Neyraudia reynaudiana*, *Themeda arundinacea*, *Saccharum spontaneum* and *Thysanolaena maxima*. The pteridophytes *Pteridium aquilinum*, *Dicranopteris linearis*, *Ophioglossum* spp., *Cheilanthes tenuifolia*, *Selaginella* spp. and *Helminthostachys zeylanica* are frequent. With fire control, seedlings and saplings of pioneer trees, e.g. *Macaranga* sp., *Mallotus cochinchinensis*, *Poupartia axillaris*, *Duabanga grandiflora*, *Anthocephalus cadamba*, *Melia azedarach* and *Glochidion* sp. are entering.

Secondary growth associated with road construction (400-1000m) includes the pioneer trees mentioned above together with *Hibiscus macrophyllus*. Above 1000m *Betula alnoides* and *Mallotus* sp. are the pioneers.

Smitinand (1968) has been reported on at length because it seems to be the only survey of forest in the Bang Pakong Valley area and because a number of minor pollen taxa found during the analysis of sediments from Khok Phanom Di are likely to have originated in the vegetation of the mountains, e.g. *Altingia*, and most of the gymnosperms.

A more complete survey of dry deciduous dipterocarp forest is available in Stott (1976) but this refers to North and North-East Thailand. There appears to be no published data on the vegetation of the Chanthaburi Mountains but dipterocarps are likely to dominate. The following taxa were noted in areas of limestone residuals: *Solanum erianthum* D. Don, *Viscum articulatum* Burm.f., *Ardisia* sp., *Acanthus ebracteatus* Vahl., *Gynopetalum cochinchinensis* (Lour.) Kurz, *Thunbergia* cf. *grandiflora*, *Hewittia* sp., *Macaranga* sp., *Dioscorea* sp. and *Tectaria devexa* (Kze) Copel.

It is possible that dry deciduous forest is the natural forest type of the low alluvial terraces and plains but Takaya (1971:388) recorded that some unreclaimed areas of Chao Phraya delta flats were grass covered in 1915/16 and, if undisturbed, these suggest that herbaceous swamp might be expected to exist.

The vegetation of Khok Phanom Di and its surrounds is planted or comprises weedy regrowth. Taxa growing on or immediately around the mound included those listed in Table 1. The undergrowth, best developed near the temple *sala* and on the south slope, was studied in detail. *Boerhaavia diffusa*, *Abutilon indicum*, *Amaranthus gracilis*, *Stachytarpheta indica* and *Cynodon dactylon* were prominent east of the *sala*. *Euphorbia hirta* was quite well established but *Cleome gynandra* was present rarely. Other species present, not all collected, included *Abrus precatorius*, *Caryota urens*, *Desmodium* spp., *Allemanda cathartica*, *Azima sarmentosa*, *Pithecellobium dulce*, *Lophatherum gracile* (a forest grass), *Merremia* cf. *hederacea* and *Ficus* cf. *disticha* (a creeper).

Bamboo was prominent on the south-facing slope and also occurred with *Pandanus tectorius* on the north-west face. Trees present on the mound included *Aegle marmelos*, *Flacourtia jangomas*, *Lagerstroemia speciosa*, *Zizyphus jujuba*, *Ficus elastica*, *Azadirachta indica*, *Tamarindus indica* and *Plumeria acutifolia*. *Licuala peltata* was present in a garden on the north-west side, as were ornamentals such as *Dieffenbachia seguine*, *Hibiscus rosa-sinensis*, *Ixora* spp. and *Staurog-*

yne sp.; and useful plants (*Ocimum basilicum*, *O. sanctum*, *Solanum melongena*, *Alpinia* sp. and *Ricinus communis*). Fruit trees grown locally, some on the mound, included *Annona reticulata*, *A. squamosa*, *Mangifera indica*, *Garcinia mangostana*, *Eugenia jambos*, *Psidium guajava*, *Citrus limon*, *Punica granatum* and *Carica papaya*. Ornamentals, apart from *Plumeria*, included *Delonix regia*, *Euphorbia pulcherrima*, *Epiphyllum hookeri*, *Bauhinia* sp. and Asclepiads. Crop plants cultivated in addition to rice included European vegetables (cabbages, cucumbers, spinach), pineapple (*Ananas comosus*), taro (*Colocasia esculenta*), manioc (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), egg plant (*Solanum melongena*), castor oil (*Ricinus communis*), various Cucurbitaceae (*Citrullus lanatus*, *Cucumis melo*, *Lagenaria siceraria*), etc. Although the study of rice-field weeds was carried out during the dry season, a few fields still had irrigated crops on them and some floristic observations could be made, but collection was only possible at the edges to avoid trampling.

Rice fields have a double flora: a different weed composition during the growth phase from when water is drained off. As far as Thailand is concerned, this appears to have only been studied systematically by Heckman (1979) at a rice field near Udon Thani in the north-east of the country. However, many of the same species were collected in fields and irrigation canals near Khok Phanom Di. As at Khok Phanom Di, *Salvinia cucullata*, an aquatic fern, dominated much of the irrigation canal surface during the hot season and was found to extend rapidly by vegetative reproduction. Another floating fern, *Azolla pinnata*, occurred in the rice field during the wet season. *Pistia stratiotes* was present as solid masses on standing water throughout the year, entering the rice field, via the irrigation canals, during the cool season. It was found to reproduce mainly from stolons. *Lemna paucicostata* also entered irrigation canals in the cool season but was displaced by *Salvinia* and *Pistia* in the hot season. *Spirodela polyrrhiza*, another species in Lemnaceae, occurred in irrigation canals during the dry season and on the rice field in the wet season.

Eichhornia crassipes (water hyacinth), an exotic aquatic herb, was common in association with *Salvinia cucullata* or on its own in some irrigation canals near Khok Phanom Di. *Ludwigia adscendens* and *Ipomoea aquatica* were the most important creeping plants at Udon Thani. *Ludwigia* occurred on the surface of the water, buoyed up by floats formed from modified roots, and expanded rapidly in the rice field after the rains ended in mid-October but disappeared by harvest time. It survived the hot season on the surface of a permanent pond adjacent to the rice field. *Ipomoea aquatica*, a rooted plant which sends out long, creeping stems, flowered at the end of the rains in October and set seed at harvest time at Udon Thani. It died off when the water dried from the rice field.

Three species of submerged aquatic occurred: *Utricularia flexuosa*, *Hydrilla verticillata* and *Ottelia alismoides*. *Utricularia* was very abundant throughout the rainy season and grew on all parts of the rice field not covered by floating plants. Flowering took place at all seasons, but most profusely at the time of rice harvest, and a few plants survived in an irrigation canal during the dry season. However, it seemed to reproduce mainly from seeds which remained in the sediment after the rice field dried up.

Hydrilla verticillata was present as dense masses under the standing water of a pond but only occurred in deep water in an irrigation canal during the dry season. It flowered but also produced vegetative propagules. *Ottelia alismoides*, which seemed to reproduce by seed, spread quickly after the rice was planted. *Ceratophyllum demersum* and *Najas kingii* did not appear to be typical components of the rice field flora but were present in an irrigation canal during the dry season.

Five species of emergent, rooted, plants were present: *Marsilea* cf. *minuta* and the grasses *Oryza sativa*, *Paspalum paspaloides*, *Echinochloa crus-galli* and *Pseudoraphis spinescens*. All except the last occurred in irrigated rice fields north of Khok Phanom Di.

The *Paspalum* formed a thick carpet in every flooded part of the rice field from the late cool season through to the early rainy season and flowered continuously. Heckman felt that it had the same habitat requirements as rice. *Pseudoraphis* spread rapidly by creeping stems but was not present during the dry season.

Twenty-three species of littoral plants, mainly grasses and sedges were reported (Table 2). All except *Hydrolea* were represented at the species or generic level on rice fields near Khok Phanom Di. As at Udon Thani, the two *Alternanthera* species, *Hedyotis corymbosa* and *Emilia sonchifolia* were sometimes present at the edge of rice fields, but were commoner along road and track sides. *Ludwigia octovalis* was common in damp places but *Enydra fluctuans* only occurred frequently in one damp field north of Khok Phanom Di.

Hydrolea zeylanica appeared in great numbers on muddy ground left by the receding water before the rice harvest at Udon Thani and flowered until late in the dry season before setting seed and drying. The various sedges were indicative of damp conditions but *Paspalum scrobiculatum* inhabited the landward side of the littoral habitat beyond *P. paspaloides*, and *Eragrostis atrovirens* and *Eriochloa fatmensis* are terrestrial grasses widespread in wet places during the rainy season. While *Panicum repens* was very common, *Eragrostis japonica*, *Ischaemum rugosum*, *Panicum paludosum* and *Sporobolus* sp. occurred uncommonly at the edge of the rice field. *Panicum repens* can grow in shallow water with rice and under terrestrial conditions but it only occurred during the late rainy season and the first few weeks of the dry monsoon.

As far as regrowth vegetation in the Khok Phanom Di area is concerned, a small partly infilled pond located c. 150m north-west of the site contained floating-leaved *Lemna* sp., *Ipomoea aquatica*, *Nymphoides indicum* and young *Salvinia cucullata* and *Eichhornia crassipes* in the water, *Ludwigia* sp., *Neptunia oleracea*, *Fuirena* cf. *ciliaris*, *Scirpus mucronatus* and the fern *Ceratopteris thalictroides* in damp places with *Cynodon dactylon* and *Imperata cylindrica* as significant elements of the surrounding vegetation.

A few days before pollen core BMR 2 was extracted, (see chapter VI), the land at the edge of a rice field was inundated and occupied almost entirely by an *Eleocharis* species, with isolated individuals of *Monochoria hastata*. Other wet rice field margins, also north Khok Phanom Di, had *Marsilea* sp., *Eleocharis* sp., *Cyperus* spp., *Enydra fluctuans* (sparse) and several taxa commoner on dry fields and bunds: *Chloris barbata*, *Cynodon dactylon*, *Eriochloa procera*, *Imperata cylindrica*, *Paspalum* cf. *scrobiculatum* (all grasses), *Emilia sonchifolia*, *Vernonia cinerea* (composites), *Hedyotis corymbosa*, *Coldenia procumbens*, *Solanum aculeatissimum*, *Abutilon* cf. *persicum* and, rarely, *Talinum triangulare*. The following taxa were found amid rice awaiting transplantation: *Marsilea* sp., *Echinochloa crus-galli*, *Dactyloctenium aegyptium* and *Eclipta prostrata*.

The reservoir south-east of Khok Phanom Di had a floating vegetation including *Eichhornia crassipes*, *Nymphoides indicum* and *Salvinia cucullata*. These were present in irrigation canals but several grass species also occurred in shallow water too: *Cynodon dactylon*, *Echinochloa colonum*, *Eriochloa procera*, *Imperata cylindrica* and *Paspalum* cf. *scrobiculatum*. Less abundant taxa included *Ludwigia* sp., *Coldenia procumbens*, *Ipomoea* cf. *purpurea*, *Merremia* cf. *hederacea*, *Hedyotis diffusa*, *Trianthema decandra*, *Fimbristylis miliacea* and *Cyperus* spp. mainly in dried out or damp canals.

Dried out rice fields often contained some *Oryza sativa* in flower or regenerating spontaneously on burnt-over ground, *Cynodon dactylon*, *Eriochloa procera*, *Imperata cylindrica* and, less commonly, *Eleocharis* sp., *Scirpus mucronatus*, *Ipomoea* cf. *purpurea*, with (rarely) *Coldenia procumbens*, *Hedyotis diffusa*, *Eupatorium odoratum*, *Synostemon bacciformis*, *Talinum triangulare* and (in moist patches) *Scirpus juncoides*. One damp field edge south of the mound had a flora dominated by *Hedyotis pinifolia* with some *Cynodon dactylon*, *Marsilea* sp., *Eclipta prostrata*, *Alternanthera philoxeroides*, *Ipomoea aquatica* and young *Pithecellobium dulce* occurred less commonly.

Many rice field bunds were not wide enough to be well vegetated but most of the major ones were planted with bananas or trees, including oil palm (*Elaeis guineensis*), pine and mango. One narrow bund south-east of Khok Phanom Di contained *Imperata cylindrica*, *Cyperus flabelliformis*, *Commelina* cf. *salicifolia*, *Sesbania sesban* and the rare pandan (*Pandanus* sp.). A wide bund with bananas and mango trees some distance east of the mound was dominated by *Eriochloa procera*, *Imperata cylindrica* and *Paspalum* cf. *scrobiculatum*. Only two other species occurred: *Coldenia procumbens* and *Passiflora foetida*. Another with oil palm, bananas and mango located north-east of Khok Phanom Di had all these species except *Coldenia procumbens* but had a much richer flora with *Cynodon dactylon*, *Panicum cambodgiense*, *Echinochloa crus-galli*, *Eupatorium odoratum*, *Commelina* cf. *salicifolia*, *Gynura* cf. *procumbens*, *Abrus precatorius*, *Desmodium heterophyllum*, *Indigofera trifoliata*, *Abutilon* cf. *persicum*, *Vaccinium bracteatum* and (rarely) *Enydra fluctuans*, *Momordica cochinchinensis*, *Hedyotis diffusa* and *Trianthema decandra* also present. A bund north-west of the mound, planted with pine, had some of the same species, particularly on the slopes, away from the acidic pine litter: *Cynodon dactylon*, *Eriochloa procera*, *Abrus precatorius*, *Commelina* cf. *salicifolia* plus *Abutilon indicum*, *Alternanthera sessilis*, *Dolichos lablab*, *Hedyotis pinifolia*, *Solanum aculeatissimum*, *Stachytarpheta indica*, *Passiflora foetida* and *Pithecellobium dulce*. Pine, cashews (*Anacardium occidentale*) and *Eucalyptus* were planted around the reservoir south-east of the site and the undergrowth there was especially sparse beneath the trees, although elsewhere *Zoysia matrella* and *Imperata cylindrica* were abundant.

The vegetation along the roadside north of the site contained most of the species found on the wider bunds but *Sida acuta* was sometimes present.

If dry deciduous forest was not the natural vegetation of the plains around Khok Phanom Di, some sort of freshwater or tidal forest might be expected to have existed. The most complete account of freshwater swamp from mainland South-East Asia refers to the much richer floristic area of South Johore and Singapore and may provide a misleading guide (Corner 1978). However, the taxa listed in Table 3 have central and south-east Thai names (Smitinand, 1980) and might be the components of freshwater swamp forest. Thai tidal forest has, likewise, not been described and the occurrence of *Nypa fruticans* in large areas of the western side of the Bang Pakong River mouth is misleading as it is largely planted, but it is present sporadically, and perhaps of natural origin nearer to Khok Phanom Di, where *Acanthus* spp. are found in the undergrowth. Other taxa which might occur in such forests will be mentioned later as the vegetation of mangrove transitions is considered.

Thai mangrove has not been especially well studied and initially reference had to be made to data from India (Blasco 1975, 1977), Malesia (Watson 1928, Chai 1975, Chapman 1977, Macnae 1968) and Australia (Saenger *et al.* 1977, Bunt *et al.* 1982, Smith and Duke 1977), cross-referenced with Smitinand (1980) and published sections of *Flora of Thailand* even to compile a reasonably

complete species list. However, a more thorough species list has now been published (Thailand Natural Resources Profile 1987) and Table 4 is based on this.

Watson (1928) noted that mangrove was zoned in relation to the frequency of tidal inundation. His schematic species distribution (botanical names updated) for an estuarine area is illustrated on Fig. 11. The following inundation classes were distinguished:

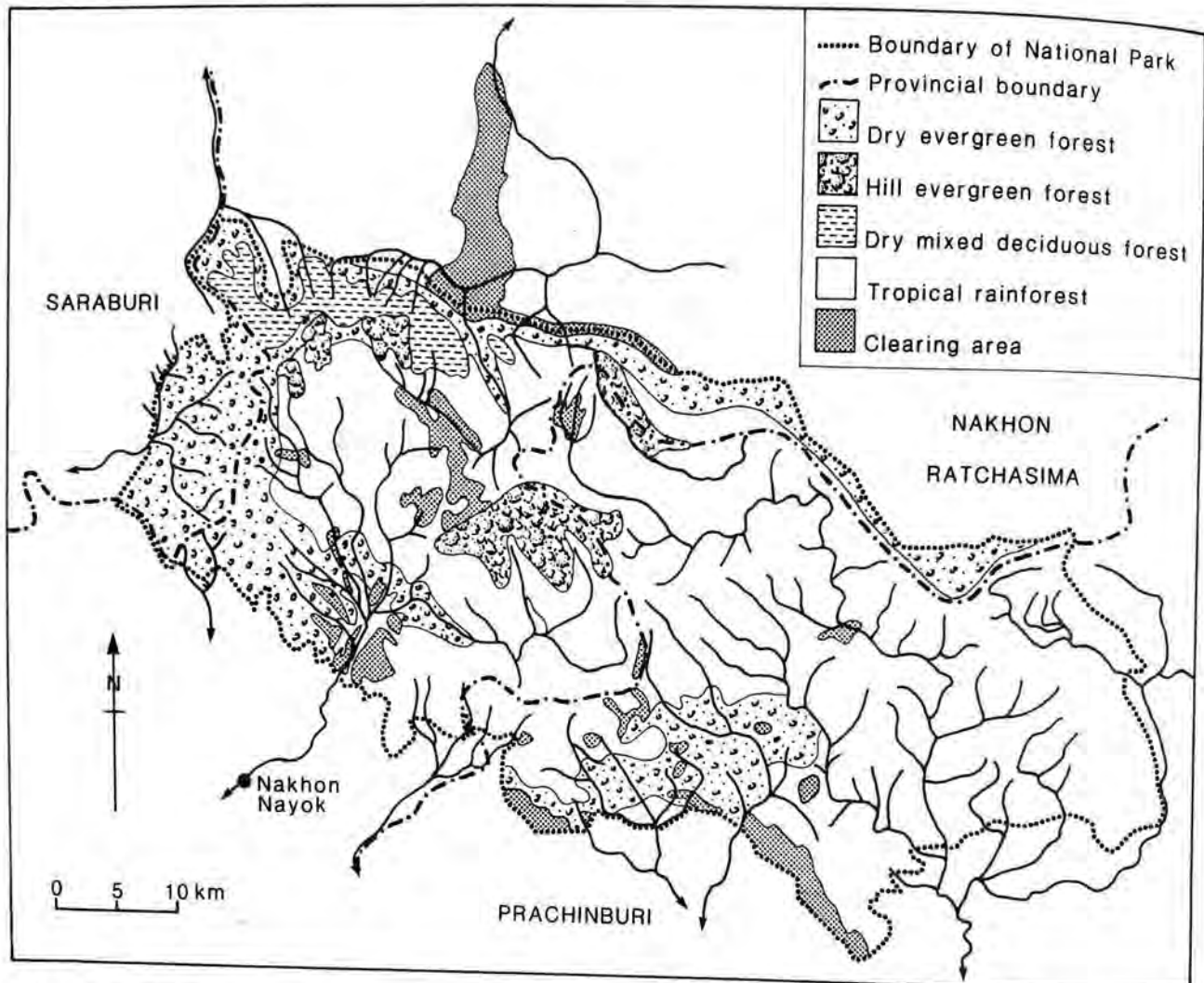


FIG. 10. The distribution of the natural vegetation in the Khao Yai National Park (adapted from Smitinand 1968)

1. Inundated by all high tides (flooded 56-62 times per month)
2. Inundated by medium high tides (flooded 45-59 times per month)
3. Inundated by normal high tides (flooded 20-45 times per month)
4. Inundated by spring tides (flooded 2-20 times per month)
5. Inundated by abnormal or equinoctial tides (flooded up to twice per month)

So mangrove grows in the intertidal zone: the forests are covered by salt water during high tides while mud flats are exposed during ebb tides. Only *Rhizophora mucronata*, exceptionally, will grow on land of Inundation Class 1; *Avicennia alba*, *A. marina* and *Sonneratia griffithii* (*R. mucronata* bordering rivers) can tolerate Inundation Class 2; most mangrove taxa can tolerate Inundation Class 3 (but *Rhizophora* spp. tend to dominate) while *Bruguiera cylindrica* and *B. gymnorhiza* prefer Inundation Class 4, the latter becoming dominant in Inundation Class 5. Obviously the frequency of inundation is unlikely to be the only control on species distribution. Salinity is also likely to be important, for instance, perhaps the main check on distributions (de Haan 1931). Unfortunately no systematic studies of limiting factors have been made in South-East Asian mangroves in more recent times but Bunt *et al.* (1982) found that, in general, *Rhizophora stylosa*, *R. apiculata*, *Sonneratia alba* and *Ceriops tagal* were the most tolerant of sea water in North Queensland, Australia, followed by *Aegiceras corniculatum* and *Bruguiera parviflora*, then *Excoecaria agallocha* and *Rhizophora mucronata*. The least tolerant two groups of species were *Acrostichum* sp., *Heritiera littoralis* and *Nypa fruticans* and finally *Barringtonia* sp., *Bruguiera sexangula* and *Sonneratia caseolaris*. Macnae (1968:131) noted that *Aegiceras corniculatum* was always an indicator of the presence of freshwater and that *Avicennia marina* seems to have the widest range of salinity tolerance of all mangroves as it can grow in almost fresh water or soils with water salinity exceeding 90 per cent. Macnae (1968) also observed that certain species of mangrove, including *Xylocarpus* spp. and *Lumnitzera*, only grow in well-drained soils, that trees of the *Barringtonia* association, described later, prefer well-drained soils, while those of the *Nypa* association grow in water-logged soils.

The landward fringe is the most highly variable of zones: it may have soils which are mainly sandy or muddy, well-drained or water-logged, nutrient rich or poor, depending on the source of the parent material. Additionally, the soil water salinity may be high or low. Where mangrove merges into tropical rainforest an abrupt change in species composition occurs at the level of extreme high water. In peninsular Malaysia, Watson (1928) found *Bruguiera gymnorhiza* as the dominant on heavy, wet soils on the landward fringe and this was accompanied by old trees of *Rhizophora apiculata*, *Xylocarpus moluccensis* and good stands of *Intsia bijuga*. Lianas, other climbers, and various epiphytes (Macnae 1968) are likely to be common in this kind of environment and *Avicennia officinalis* is occasionally abundant at this level throughout South-East Asia. An undergrowth of ferns occurs almost always with *Acrostichum speciosum* in shade and the larger *A. aureum* in clearings where it can form 3m high stands.

In Java a *Lumnitzera littorea* association with a thin tree layer of *Bruguiera gymnorhiza*, *Lumnitzera littorea*, *Xylocarpus granatum*, *Heritiera littoralis*, *Ficus microcarpa*, *Terminalia catappa* and *Barringtonia racemosa* was present as the transition vegetation on firm shallow soils with banks of marl. The undergrowth comprised a dense mass of *Scyphiphora hydrophyllacea* and *Acrostichum* sp. Where the soils had an uneven surface, *Xylocarpus granatum*, *Heritiera littoralis*, *Ficus retusa*, *Intsia bijuga* and *Nypa* occurred in muddy gullies and *Derris heterophylla* and *Acrostichum* sp. formed a thick undergrowth.

Moderately firm soils had a tree layer including *Bruguiera sexangula*, *Dolichandrone spathacea*, *Corypha utan*, *Barringtonia racemosa*, *Terminalia catappa*, *Ficus microcarpa* and *Lagerstroemia speciosa*, with *Xylocarpus granatum* and *Oncosperma filamentosum* along the creeks, and a dense undergrowth of *Acanthus ilicifolius*, *Derris heterophylla*, *Acrostichum* sp. and *Crinum* sp.

These three associations may merge into a *Barringtonia racemosa* association or peat swamp forest. The former contains several species which may also occur in transitional forest: *Terminalia catappa*, *Thespesia populnea* and *Pandanus tectorius*. It occurs locally in southern Java but otherwise may not be widespread in South-East Asia where the *Nypa* association is more typical of the region flooded by the highest spring tides. Where *Nypa* is very dense other plants are shaded out. This certainly seems true of vegetation in a cut off meander of the Bang Pakong River near Ban Pho, c. 7km west of Khok Phanom Di. Occasional trees of *Heritiera littoralis*, *Xylocarpus granatum*, *X. moluccensis*, *Bruguiera sexangula*, *B. gymnorrhiza* or *Lumnitzera littorea* can overtop *Nypa* and *Rhizophora apiculata* can occur as a lower level. *Excoecaria agallocha*, *Bruguiera cylindrica* and *Sonneratia caseolaris* are frequent associates, with *Hibiscus tiliaceus* and *Pandanus* spp. present where water is almost fresh.

The termite *Thalassina anomala* constructs mounds up to 3m high in this association. These often reach heights above high-water mark but levels which are occasionally flooded are colonized by *Acrostichum speciosum* and the lianas *Clerodendrum inerme*, *Cyanachum carnosum*, *Entada schefferi* and rotans such as *Calamus aquatilis*.

Mangroves, including *Avicennia officinalis*, *Kandelia candel*, *Brownlowia tersa*, *Aegiceras corniculatum* and, especially, *Sonneratia caseolaris*, may develop between the nypa-lined creeks and rivers and a narrow, continuous belt of *Oncosperma tigillaria* often marks the ecotone with freshwater swamp forest.

Van Breemen *et al.* (1973) reported a vegetation dominated by *Bruguiera gymnorrhiza*, *Nypa fruticans* and *Xylocarpus granatum*, with some *Excoecaria agallocha*, *Ceriops decandra* and *Rhizophora apiculata*, and an undergrowth consisting mainly of *Derris heterophylla* and *Acrostichum aureum* from inside a convex meander belt of the Bang Pakong River, but did not give a precise location for this.

Macnae (1968) has recognized the following zones on the margins of a large estuary:

1. Zone of *Ceriops* thickets
2. Zone of *Bruguiera* forests
3. Zone of *Rhizophora* forests
4. The seaward *Avicennia* zone
5. The *Sonneratia* zone

The *Ceriops* zone is not pronounced in ever-wet areas. In peninsular Thailand *Ceriops* occurs in association with well-developed, mature virgin forests of *Rhizophora* spp. but where rainfall is intermediate, or soils are well-drained, dense thickets of *C. tagal* occur at levels immersed by all spring tides. Watson (1928) recognized three types of *Bruguiera* forest: that dominated by *B. cylindrica*, present on stiff blue clay soils with a shallow humus layer and well-marked surface drainage, but no creeks; that with *B. parviflora*, frequent on formerly cleared areas; and that with *B. gymnorrhiza*, regarded as a transition to a well-developed landward fringe.

De Haan (1931) also described three variants from Cilacap in southern Java: a *Bruguiera gymnorrhiza* association, *B. cylindrica* association and *Xylocarpus-Heritiera* association. The *B. gymnorrhiza* association was developed on mainly firm, flat soils and both the others on more or less firm clays with irregular surfaces due to the activities of burrowing crustaceans.

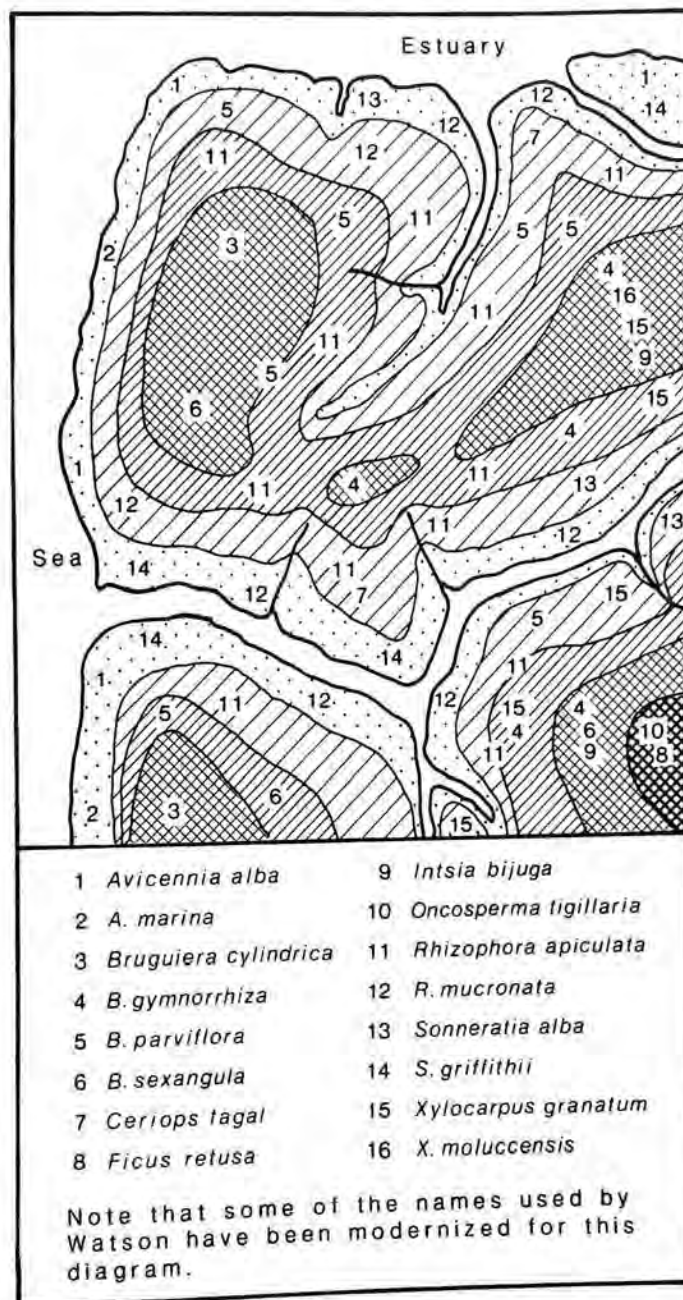


FIG. 11. The typical distribution of mangrove trees species near the mouth of a large river (after Watson 1928)

Rhizophora spp. grow in areas flooded at all high tides upwards to those only occasionally flooded. The majority of South-East Asian virgin *Rhizophora* forests (Macnae 1968) have an undergrowth of *Ceriops tagal* and *Bruguiera parviflora*, especially, but *C. decandra* and *B. cylindrica* also occur. *Rhizophora mucronata* forest occurs in areas dominated by seawater and that of *R. apiculata* in freshwater areas. So *R. mucronata* forest grades upstream to *R. apiculata* forest, yet Bunt *et al.* (1982) found that the latter was the more salt-tolerant of the two species.

One or more shade intolerant *Avicennia* species usually form the most seaward zone of trees. In Sarawak *A. alba* is present on mud flats and *A. marina* more usually on sandy soils (Chai 1975). The two species are rarely associated. *A. marina* tends to be the pioneer in seaward facing locations in South-East Asia and *A. alba* in channels, creeks or rivers (Macnae 1968). The former often gives way inland to a forest of *Bruguiera cylindrica* and the latter to one of *Rhizophora mucronata*. Two species of *Sonneratia*, *S. griffithii* and *S. alba*, hardly ever found together, can grow seaward of *Avicennia* at levels wetted daily or border creek mouths with *A. marina*. *Sonneratia caseolaris*, in contrast, dominates along river banks and other locations where there is abundant fresh water. The *Sonneratia* species are replaced by *Rhizophora* upstream along creeks, interspersed with and then displaced by *Xylocarpus granatum*, *Avicennia alba* and, at the salt-water limit, *Aegiceras corniculatum*, *Pandanus* spp. and other components of the *Barringtonia* and *Nypa* associations.

A complete zonation only occurs where rainfall is high at all seasons, silt in suspension (to raise the soil level enabling mangrove to extend seaward) is available, and there is a considerable tidal range. Mangroves are less extensive where the shoreline is stable and the tidal range small. The shoreline of the Gulf of Siam is not stable but the tidal range is not extreme. The nature of the shore slope and the presence of creeks, gullies, rivers and channels complicate plant distributions: along much of the west coast of peninsular Malaysia the zone of *Bruguiera* forests is widest but further north, between Rayong and Phangnga in Thailand, the *Rhizophora apiculata* zone is most extensive.

The most thorough description of non-mangrove sea front vegetation from South-East Asia appears to be that for Vietnam given in Schmid (1974). There, *Spinifex littoreus* and *Lepturus repens* (both grasses) accompanied *Ipomoea pes-caprae* and *Pentatropis pierrei*. *Scaveola taccada*, *Cerbera manghas*, *Pandanus tectorius* and *Cycas rumphii* occurred behind these. Other tree or small tree species present included *Pleiospermum littorale*, *Euphorbia longana*, *Wikstroemia viridiflora*, *Clerodendrum inerme*, *Vitex trifolia*, *Markhamia pierrei*, *Sindora maritima*, *Caesalpinia godefroyana*, *Hiptage corymbifera* and *Maerua siamensis*. *Wikstroemia* has not been reported from Thailand by Smitinand (1980) but all the other taxa have, at least at the generic level. The following lianas occurred: *Capparis beneolens*, *Abrus precatorius*, *Dalbergia* sp., and *Canavalia rosea*. Additional herbs present included the grasses *Thourea involuta*, *Cenchrus inflexus*, *Chrysopogon orientalis*, *Digitaria barbata* and *Ischaemum muticum*, the sedges *Fimbristylis* sp. and *Bulbostylis barbata*, composites *Launaea pinnatifida*, *Poilania laggeroides*, *Calotis gaudichaudii*, *Grangea* and *Sphaeromorpha* (largely absent from Thailand), *Eriocaulon*, *Asparagus*, *Gloriosa superba*, *Tribulus terrestris*, *Christia* and *Desmodium* spp.

Macnae (1968) stated that the *Ipomoea pes-caprae* association of the coast was dominated by *I. pes-caprae*, but usually accompanied by *Canavalia* sp., shrubs of *Sophora* sp., *Scaveola* sp. and a single row of *Casuarina equisetifolia*.

Schmid (1974) also outlined the vegetation of stabilized and unstabilized sand dunes. Woody taxa found on incompletely fixed dunes included *Vatica tonkinensis* (a dipterocarp not present in Thailand), *Breynia* spp., *Eugenia* sp., *Rhodamnia cinerea*, *Decaspermum fruticosum*, *Ochna* sp., *Gomphia* sp., *Albizia* sp., *Connarus* sp., *Calophyllum* sp., *Canthium* sp., *Vaccinium* cf. *bracteatum*, *Carissa cochinchinensis*, *Pouteria* sp., *Manilkara hexandra*, *Diospyros* sp. and *Hedyotis pinifolia*, various sedges (*Cyperus* sp., *Fimbristylis pauciflora*, other *Fimbristylis* spp. and *Bulbostylis barbata*), and grasses (*Eriachne pallescens* and *Eragrostis alopecuroides* at the summit and *Eremochloa ciliaris*, *Chrysopogon orientalis* and *Germania schmidiana* (not in Thailand) at the base).

The fern *Schizaea dichotoma* and various epiphytes (*Cassytha filiformis*, *Henslowia* sp. and *Scur-rula* sp.) also occurred. *Baeckia frutescens*, *Melaleuca leucandendra* and *Leptocarpus disjunctus* occupied moist depressions as pure or mixed stands. The grasses *Panicum repens* and *Eremochloa ciliaris* and sedges *Fuirena ciliaris* and *Scleria tonkinensis* plus *Xyris complanta* were present in drier areas. Stabilized dunes had forest including *Miliusa*, *Streblus*, *Phyllanthus*, *Breynia*, *Sauropus*, *Securinega*, *Grewia*, *Derris*, *Dalbergia* (liana), *Capparidaceae*, *Hiptage*, *Zizyphus*, *Ebenaceae* and *Jasminium*, but was dominated by trees of *Parinari anamense*, *Stereospermum anamense* and *Lannea*.

TABLE 1: *Plants collected on or immediately around Khok Phanom Di*

Species	Family	Physiognomy
<i>Anacardium occidentale</i> L.	Anacardiaceae	small tree (exotic)
<i>Annona reticulata</i> L.	Annonaceae	small tree (exotic)
<i>Uvaria</i> cf. <i>cordata</i> Alston	Annonaceae	climber
<i>Allemanda cathartica</i> L.	Apocynaceae	climber (exotic)
<i>Carissa</i> cf. <i>cochinchinensis</i> Pierre	Apocynaceae	shrub
<i>Telosma minor</i> Craib.	Asclepiadaceae	climber
<i>Canna indica</i> L.	Cannaceae	herb (exotic)
<i>Epiphyllum hookeri</i> Haw.	Cactaceae	shrub (exotic)
<i>Bauhinia</i> cf. <i>acuminata</i> L.	Caesalpiniaceae	shrub (exotic)
<i>Cassia siamea</i> Benth.	Caesalpiniaceae	tree
<i>C. tora</i> L.	Caesalpiniaceae	under-shrub
<i>Cleome gynandra</i> L.	Capparidaceae	herb
<i>Eupatorium odoratum</i> L.	Compositae	herb (exotic)
<i>Vernonia elliptica</i> D.C.	Compositae	climber
<i>Aniseia martinicensis</i> (Jacq.) Choisy	Convolvulaceae	climber
<i>Ipomoea stolonifera</i> Gmel.	Convolvulaceae	creeping herb
<i>Citrullus lanatus</i> Mats. & Nakai	Cucurbitaceae	herb (exotic)
<i>Bridelia ovata</i> Decne	Euphorbiaceae	small tree
<i>Euphorbia hirta</i> L.	Euphorbiaceae	herb
<i>Manihot esculenta</i> Crantz	Euphorbiaceae	shrub/small tree (exotic)
<i>Ricinus communis</i> L.	Euphorbiaceae	shrub/small tree
<i>Sauropus</i> sp.	Euphorbiaceae	shrub
<i>Castanopsis</i> sp.	Fagaceae	tree
<i>Flacourtia jangomas</i> (Lour.) Rausch.	Flacourtiaceae	tree (exotic)
<i>Bambusa arundinacea</i> (Retz.) Willd.	Gramineae	giant herb
<i>Lophatherum gracile</i> Brongn.	Gramineae	herb
<i>Panicum repens</i> L.	Gramineae	herb
<i>Ocimum basilicum</i> L.	Labiatae	under-shrub (exotic)
<i>Cinnamomum</i> cf. <i>bejolghota</i> Sweet	Lauraceae	tree
<i>Lagerstroemia speciosa</i> Pers.	Lythraceae	tree
<i>Abelmoschus manihot</i> (L.) Medic.	Malvaceae	herb (exotic)
<i>Abutilon hirtum</i> (Lamk.) Sweet	Malvaceae	under-shrub
<i>A. indicum</i> (L.) Sweet	Malvaceae	under-shrub
<i>A. cf. persicum</i> (Burm. f.) Merr.	Malvaceae	under-shrub
<i>Sida acuta</i> Burm. f.	Malvaceae	under-shrub
<i>Azadirachta indica</i> Juss. var. <i>siamensis</i> Valetton	Meliaceae	tree

Plants collected on or immediately around Khok Phanom Di (cont.)

Species	Family	Physiognomy
<i>Acacia farnesiana</i> Willd.	Mimosaceae	shrub/small tree (exotic)
<i>Albizia lebbek</i> L., Benth.	Mimosaceae	tree
<i>Pithecellobium dulce</i> Benth.	Mimosaceae	tree (exotic)
<i>Ficus elastica</i> Nois ex Bl.	Moraceae	tree (exotic)
<i>Ficus</i> cf. <i>nervosa</i> Heyne	Moraceae	epiphytic small tree
<i>Maclura cochinchinensis</i> Lour.	Moraceae	tree
<i>Eucalyptus</i> cf. <i>bicolor</i> A. Cunningh. ex Hook.	Myrtaceae	tree (exotic)
<i>Eugenia</i> cf. <i>caryophyllus</i> Bullock and Harrison	Myrtaceae	small tree (exotic)
<i>Boerhaavia diffusa</i> L.	Nyctaginaceae	herb
<i>Caryota urens</i> L.	Palmae	under-shrub
<i>Pandanus tectorius</i> Soland ex Park.	Pandanaceae	shrub/small tree
<i>Abrus precatorius</i> L.	Papilionaceae	climber
<i>Passiflora foetida</i> L.	Passifloraceae	herbaceous creeper
<i>Zizyphus jujuba</i> Mill.	Rhamnaceae	small tree (exotic)
<i>Hedyotis corymbosa</i> (L.) Lamk.	Rubiaceae	herb
<i>Murraya</i> cf. <i>koenigii</i> (L.) Spreng.	Rutaceae	shrub/small tree
<i>Azima sarmentosa</i> (Bl.) B. & H.	Salvadoraceae	climber
<i>Solanum melongena</i> L.	Solanaceae	under-shrub
<i>Stachytarpheta indica</i> (L.) Vahl	Verbenaceae	under-shrub
<i>Alpinia</i> sp.	Zingiberaceae	herb

TABLE 2: *Littoral plants reported from an Udon Thani ricefield*

Species	Family
<i>Alternanthera philoxeroides</i> (Mart.) Griseb.	Amaranthaceae
<i>A. sessilis</i> Br.	Amaranthaceae
<i>Emilia sonchifolia</i> (L.) D.C. ex Wight.	Compositae
<i>Enydra fluctuans</i> Lour.	Compositae
<i>Cyperus compactus</i> Retz.	Cyperaceae
<i>C. compressus</i> L.	Cyperaceae
<i>C. difformis</i> L.	Cyperaceae
<i>C. halpan</i> L.	Cyperaceae
<i>C. iria</i> L.	Cyperaceae
<i>C. polystachyus</i> Rottb.	Cyperaceae
<i>Fimbristylis dichotoma</i> (L.) Vahl.	Cyperaceae
<i>F. littoralis</i> Gaudich.	Cyperaceae
<i>Eragrostis atrovirens</i> (Desf.) Trin. ex Steud.	Gramineae
<i>E. japonica</i> (Thunb.) Trin.	Gramineae
<i>Eriochloa fatmensis</i> (Hochst.& Steud) W.D. Clayton	Gramineae
<i>Ischaemum rugosum</i> Salisb.	Gramineae
<i>Panicum paludosum</i> Roxb.	Gramineae
<i>P. repens</i> L.	Gramineae
<i>Paspalum scrobiculatum</i> L.	Gramineae
<i>Sporobolus</i> sp.	Gramineae
<i>Hydrolea zeylanica</i> Vahl.	Hydrophyllaceae
<i>Ludwigia octovalis</i> (Jacq.) Raven	Onagraceae
<i>Hedyotis corymbosa</i> (L.) Lamk.	Rubiaceae

TABLE 3: *Freshwater swamp species with Central and South-East Thai names*

Species	Family	Physiognomy
<i>Xylopia malayana</i> Hook. f. & Th.	Annonaceae	small tree
<i>Aglaonema nitidum</i> Kunth.	Araceae	herb
<i>Dischidia hirsuta</i> Decrie	Asclepiadaceae	creeper
<i>D. rafflesiana</i> Wall.	Asclepiadaceae	creeper
<i>Euonymus javanicus</i> Bl.	Celastraceae	small tree
<i>Cnestis palala</i> Merr.	Connaraceae	climber
<i>Connarus semidecandrus</i> Jack	Connaraceae	climber
<i>Fimbristylis pauciflora</i> R. Br.	Cyperaceae	forest edge herb
<i>Shorea gratissima</i> Dyer	Dipterocarpaceae	tree
<i>Diospyros oblonga</i> Miq.	Ebenaceae	tree
<i>Elaeocarpus griffithii</i> Gray	Elaeocarpaceae	tree
<i>Endosporum diadenum</i> Airy Shaw	Euphorbiaceae	tree
<i>Macaranga gigantea</i> Muell. Arg.	Euphorbiaceae	tree
<i>M. griffithiana</i> Muell. Arg.	Euphorbiaceae	tree
<i>M. triloba</i> Muell. Arg.	Euphorbiaceae	tree
<i>Sapium discolor</i> Muell. Arg.	Euphorbiaceae	tree
<i>Flacourtia rukam</i> Zoll. & Mor.	Flacourtiaceae	tree
<i>Garcinia nigrolineata</i> Planch.	Guttiferae	tree
<i>Cratoxylon formosum</i> Dyer	Hypericaceae	tree
<i>Dianella ensifolia</i> Red.	Liliaceae	herb
<i>Fagraea ceilanica</i> Thunb.	Loganiaceae	epiphytic shrub/small tree
<i>F. racemosa</i> Jack	Loganiaceae	shrub/small tree
<i>Parkia speciosa</i> Hassk.	Mimosaceae	tree
<i>Ficus callophylla</i> Bl.	Moraceae	tree
<i>F. consociata</i> Bl.	Moraceae	tree
<i>F. fistulosa</i> Reinw.	Moraceae	small tree
<i>F. microcarpa</i> L.f.	Moraceae	tree
<i>Maesa ramentacea</i> A.D.C.	Myrsinaceae	tree
<i>Myristica iners</i> Bl.	Myristicaceae	tree
<i>Eugenia longiflora</i> F. Vill.	Myrtaceae	small tree
<i>Cyrtostachys lakka</i> Becc.	Palmae	tree
<i>Pandanus odoratissimus</i> L.f.	Pandanaceae	small tree
<i>Hydnophytum formicarum</i> Jack	Rubiaceae	epiphytic shrub
<i>Pavetta indica</i> L.	Rubiaceae	shrub
<i>Lepisanthes fruticosa</i> Leenh.	Sapindaceae	small tree
<i>Pometia pinnata</i> J.R. & G. Forst.	Sapindaceae	tree
<i>Irvingia malayana</i> Oliv. ex A. Benn.	Simaroubaceae	tree of swamp edge
<i>Sterculia coccinea</i> Roxb.	Sterculiaceae	shrub/small tree
<i>Clerodendrum villosum</i> Bl.	Verbenaceae	shrub

Freshwater swamp species with Central and South-East Thai names (cont.)

Species	Family	Physiognomy
<i>Asplenium nidus</i> L.	Aspleniaceae	epiphytic fern
<i>Lycopodium phlegmaria</i> L.	Lycopodiaceae	epiphytic fern
<i>L. squarrosum</i> Forst.	Lycopodiaceae	epiphytic fern
<i>Taenitis blechnoides</i> Sw.	Parkeriaceae	fern
<i>Drynaria quercifolia</i> L.	Polypodiaceae	epiphytic fern
<i>Platyserium coronatum</i>	Polypodiaceae	epiphytic fern
<i>Stenochlaena palustris</i> (Burm.) Bedd.	Polypodiaceae	climbing fern

TABLE 4: *Species to be expected in Thai mangroves and back mangroves*

Species	Family	Physiognomy
<i>Acanthus ebracteatus</i> Vahl.	Acanthaceae	shrub
<i>A. ilicifolius</i> L.	Acanthaceae	shrub
<i>Cerbera manghas</i> L.	Apocynaceae	small tree
<i>C. odollum</i> Gaertn.	Apocynaceae	tree
<i>Avicennia alba</i> Bl.	Avicenniaceae	tree
<i>A. marina</i> Vierh.	Avicenniaceae	tree
<i>A. officinalis</i> L.	Avicenniaceae	tree
<i>Barringtonia acutangula</i> Gaertn. ssp. <i>spicata</i> Payens	Barringtoniaceae	small tree
<i>B. asiatica</i> Kurz	Barringtoniaceae	tree
<i>B. coccinea</i> Kostel	Barringtoniaceae	tree
<i>B. pauciflora</i> King	Barringtoniaceae	tree
<i>B. racemosa</i> Roxb.	Barringtoniaceae	tree
<i>Dolichandrone spathacea</i> Schum.	Bignoniaceae	tree
<i>Cynometra bijuga</i> Span.	Caesalpiniaceae	tree
<i>C. malaccensis</i> Meeuwen	Caesalpiniaceae	tree
<i>Intsia bijuga</i> Ktze	Caesalpiniaceae	tree
<i>Peltophorum pterocarpus</i> Back. ex Heyne	Caesalpiniaceae	tree
<i>Suaeda maritima</i> Dum.	Chenopodiaceae	under-shrub
<i>Lumnitzera littorea</i> (Jack) Voight.	Combretaceae	small tree
<i>L. racemosa</i> Willd.	Combretaceae	small tree
<i>Pluchea indica</i> Less.	Compositae	tree
<i>Cycas rumphii</i> Miq.	Cycadaceae	small tree
<i>Diospyros ferrea</i> Bakh.	Ebenaceae	shrub/small tree

Species to be expected in Thai mangroves and back mangroves (cont.)

Species	Family	Physiognomy
<i>Excoecaria agallocha</i> L.	Euphorbiaceae	shrub/small tree
<i>Glochidion littorale</i> Bl.	Euphorbiaceae	shrub/small tree
<i>Sapium indicum</i> Willd.	Euphorbiaceae	small tree
<i>Scolopia macrophylla</i>	Flacourtiaceae	small tree
<i>Scaveola taccada</i> Roxb.	Goodeniaceae	shrub
<i>Dendrophthoe pentandra</i> Miq.	Loranthaceae	parasitic shrub
<i>Pemphis acidula</i> J.R. & G. Forst.	Lythraceae	shrub
<i>Thespesia populnea</i> Soland ex Correa	Malvaceae	small tree
<i>Hibiscus tiliaceus</i> L.	Malvaceae	shrub/small tree
<i>Schumannianthus dichotomus</i> (Roxb.) Gagnep.	Maranthaceae	herb
<i>Melastoma villosum</i> Lodd.	Melastomataceae	shrub
<i>Xylocarpus gangeticus</i> Parkins.	Meliaceae	tree
<i>X. granatum</i> Koen.	Meliaceae	tree
<i>X. moluccensis</i> Roem.	Meliaceae	tree
<i>Cocculus trilobus</i> (Thunb.) D.C.	Menispermaceae	small tree
<i>Ficus macrocarpa</i> L.f.	Moraceae	tree
<i>Aegiceras corniculatum</i> (L.) Blanco	Myrsinaceae	shrub
<i>Rapanea porteriaia</i> Mez.	Myrsinaceae	tree
<i>Rapanea umbellulata</i>	Myrsinaceae	tree
<i>Horsfieldia irya</i> Warb.	Myristicaceae	tree
<i>Melaleuca leucandendra</i> L.	Myrtaceae	shrub/small tree
<i>Nypa fruticans</i> Wurm.	Palmae	tree
<i>Oncosperma tigillaria</i> Ridl.	Palmae	tree
<i>Phoenix paludosa</i> Roxb.	Palmae	tree
<i>Pandanus odoratissimus</i> L.f.	Pandanaceae	small tree
<i>Dendrolobium umbellatum</i> Benth.	Papilionaceae	shrub
<i>Derris indica</i> Bennet	Papilionaceae	tree
<i>Derris trifoliata</i> Lour.	Papilionaceae	climber
<i>Ceratopteris thalictroides</i> Brongn.	Parkeriaceae	aquatic fern
<i>Aegialites rotundifolia</i> Roxb.	Plumbaginaceae	shrub
<i>Stenochlaena palustris</i> (Burm.) Bedd.	Polypodiaceae	climbing fern
<i>Acrostichum aureum</i> L.	Pteridaceae	aquatic fern
<i>A. speciosum</i> Willd.	Pteridaceae	aquatic fern
<i>Bruguiera cylindrica</i> (L.) Bl.	Rhizophoraceae	small tree/tree
<i>Bruguiera gymnorhiza</i> Lamk.	Rhizophoraceae	tree
<i>Bruguiera hainesii</i> C. G. Rogers	Rhizophoraceae	tree
<i>Bruguiera parviflora</i> Wight. & Arn. ex Griff	Rhizophoraceae	tree
<i>Bruguiera sexangula</i> Poir.	Rhizophoraceae	tree

Species to be expected in Thai mangroves and back mangroves (cont.)

Species	Family	Physiognomy
<i>Ceriops decandra</i> Ding Hou	Rhizophoraceae	shrub/small tree
<i>C. tagal</i> C.B. Robins.	Rhizophoraceae	tree
<i>Kandelia candel</i> Druce	Rhizophoraceae	small tree
<i>Rhizophora apiculata</i> Bl.	Rhizophoraceae	tree
<i>R. mucronata</i> Poir.	Rhizophoraceae	tree
<i>Scyphiphora hydrophyllacea</i> Gaertn. f.	Rubiaceae	shrub
<i>Guettarda speciosa</i> L.	Rubiaceae	small tree
<i>Paramignya longispina</i> Craib.	Rutaceae	climber
<i>Azima sarmentosa</i> Benth. & Hook.	Salvadoraceae	climber
<i>Planchonella obovata</i> Pierre	Sapotaceae	tree
<i>Sonneratia alba</i> Smith	Sonneratiaceae	tree
<i>S. caseolaris</i> (L.) Engler	Sonneratiaceae	tree
<i>S. griffithii</i> Kurz	Sonneratiaceae	tree
<i>S. ovata</i> Back.	Sonneratiaceae	tree
<i>Heritiera fomes</i> Buch.-Ham.	Sterculiaceae	tree
<i>Heritiera littoralis</i> Dry.	Sterculiaceae	tree
<i>Brownlowia helferiana</i> Pierre	Tiliaceae	tree
<i>Brownlowia tersa</i> (L.) Kosterman.	Tiliaceae	tree
<i>Clerodendrum inerme</i> (L.) Gaertn.	Verbenaceae	climber
<i>Premna obtusifolia</i> R. Br.	Verbenaceae	climber

IV. FIELD AND LABORATORY METHODS AND PROBLEMS OF INTERPRETATION

By B. K. Maloney

FIELD METHODS

FIELDWORK took place between January and April 1985. This involved field recording, core boring, an ecological survey of vegetation and collection of modern pollen samples from the near environs of the site and an area of limestone in the Chanthaburi Mountains. Small sections were cut from exposures in a dried-out irrigation canal which runs near the south side of the site and a large monolith was taken from a sidewall of one of three deep fishponds excavated north-east of the site in February 1985. The stratigraphy of the latter will be outlined later.

Eight long cores, and a few shorter ones, were extracted from the near environs of Khok Phanom Di during late March–early April 1985 using the Russian design borer. Core segments were 50cm long and 4.2cm in diameter. In general one hole was used at each coring point due to a shortage of time. Ideally 50cm sections should be derived from two boreholes alternately to avoid contamination by younger sediment falling down the hole. Each core segment was wrapped in polythene, sealed, then labelled at the top and bottom. Some deterioration in transit due to microbial activity probably occurred. This was unavoidable as the cores could not be kept in a frozen state after extraction and during transportation to Britain. However, all cores were placed in a deep freeze as soon as they arrived in Belfast both to render them sterile for health reasons and to prevent any additional destruction of pollen grains.

LABORATORY METHODS

Chemical pre-treatment of all samples to concentrate sufficient pollen for counting and identification proved difficult. My own experience with Indonesian and Irish samples has shown that the use of heavy liquids to float off lighter organic material is messy, time-consuming and not very effective. Many of the samples which Hillen (1983) found to be poor in pollen seem to be similar in nature to those from near Khok Phanom Di which have yielded counts. The methods finally adopted, after some experimentation, were as follows:

1. The outer part of the core sediment was scraped away using a spatula to avoid contamination.
2. A syringe with the end cut off was used to collect c. 1cm³ of the sediment from the centre of the core.
3. The samples were placed in 15ml polystyrene centrifuge tubes and 3 tablets containing an approximately known number of stained *Lycopodium clavatum* spores (the method devised by Stockmarr 1971) were added.

4. Dilute HCl (5 per cent) was added to dissolve the CaCO_3 matrix of the tablets and the samples were washed and centrifuged (at 3,000 rpm for 4 minutes) until the acid was neutralized.
5. The samples were heated for 10-15 minutes using 10 per cent KOH then centrifuged as before and the supernatant liquid was decanted.
6. The samples were washed in distilled water, centrifuged and then treated with a heated 10 per cent solution of sodium pyrophosphate for 20 minutes to deflocculate the clays – a treatment known not to damage pollen (Bates *et al.* 1982).
7. The sodium pyrophosphate was neutralized by repeated washing in distilled water.
8. The samples were treated with heated sodium pyrophosphate for a second time and were fed through a $180\mu\text{m}$ sieve into a second set of test tubes during one of the washing stages.
9. The samples were treated with heated 40-60 per cent HF for up to 30 minutes, then neutralized with HCl and washed.
10. The succeeding stages of preparation followed standard techniques: washing in glacial acetic acid and acetylation as described in Moore and Webb (1978). The final mountant was silicone fluid (AK 2000) and tertiary butyl alcohol was used in the final drying phase. The pollen grains were not stained.

At least four slides from each sample were counted, scanning an equal number of traverses, more closely spaced towards the margins as smaller pollen grains have been reported to drift outwards in a silicone fluid mount (Brooks and Thomas 1967). Identifications were effected using a modern pollen reference collection including some preparations from plants collected in the field, and the literature, especially Huang (1972, 1981). A number of the minor taxa could probably be determined more closely with a larger reference collection (see chapter IX).

The samples were counted on an Olympus BHS 2 system microscope with x10 eyepieces and a x40 objective. Critical identifications were made with a x100 objective under oil immersion. All grass pollen grains and all pollen grains requiring checking were measured and described. The state of preservation of each pollen grain and pteridophyte spore was noted using the following categories: morphologically fresh, corroded, very corroded, extremely corroded, crumpled and torn. These classes are not mutually exclusive in that fresh pollen grains as well as those showing a varied degree of corrosion are included in the crumpled and torn. However, the system was time-consuming and cumbersome enough in use as it was without additional complications, while there was no certainty that the results would be of any value until they were calculated. In fact they did yield important data useful in the selection of samples for radiocarbon dating (chapter V) and interpreting the pollen record (chapter VI).

The following microfossils were counted in addition to pollen and pteridophyte spores: charcoal and monocotyledon leaf fragments of 15 x 15 eyepiece unit ($35 \times 35\mu\text{m}$) in size and above, algae (other than diatoms), radiolaria/silicoflagellates and sponge spicules. The last two groups, some phytoliths and occasional micro-foraminifera survived the harsh chemical pre-treatment. As far as phytoliths are concerned, in general counts were only made of diagnostic grass phytoliths during pollen counting.

The minimum pollen and fern spore count size accepted was 200. This accords with the procedure used by others, e.g. Grindrod (1985). The aim has been to trace local changes in the

vegetation, not to obtain statistically satisfactory figures so that a pollen diagram could be based on counts of the minor taxa excluding Rhizophoraceae or Gramineae. Many samples were, in fact, so poor in pollen that even counting to the 200 total took a considerable time.

Counts of charcoal fragments were made from all slides examined as pollen analysis proceeded but only remains showing clear plant structure were recorded. Swain (1973, 1978) divided the charcoal into size classes, estimated using a graticule grid, and then calculated the total area of charcoal present in each sample. The technique used here is simpler and less time-consuming. As influx rates cannot be reliably calculated using samples from an open-basin depositional environment, a more complicated method would hardly yield results of greater usefulness. Swain (1978) calculated, without indicating what exactly it was designed to show, a charcoal/pollen ratio dividing the total number of pollen grains counted at each sampling level by the total squares of charcoal found on the sampling traverses. Others, e.g. Hope (1983) and Kershaw (1986) have simply presented graphs of charcoal particles per cm^3 .

Winkler (1985) rightly pointed out that microscopic analysis of charcoal carried out after sample pre-treatment with several acids and bases to concentrate pollen and pteridophyte spores cannot yield absolute (reliable charcoal influx) figures but enables useful temporal and spatial comparisons to be made provided that the sediments are always treated in a similar manner.

PROBLEMS OF INTERPRETATION

Soundly based interpretations of pollen diagrams depend upon knowledge of the range of existing vegetations and their floristic composition in an area, and data concerning pollen production, dispersal and preservation from such plant communities. The data are obtained either through trapping over a minimal period of a year or from a study of modern pollen samples derived from clumps of closely growing mosses (moss polsters) or surface soils. The floristic composition of the vegetation on and around Khok Phanom Di has already been described (chapter III), reference has been made to data on the flora of Khao Yai National Park and information on South-East Asian mangrove and other coastal vegetation types. Numerous surface sediments were collected from the vicinity of Khok Phanom Di, and a few from a limestone area of the Chanthaburi Mountains. Those from near the site (Judith Brown, pers. comm.) and all five samples, including that from the surface, of the short BMR 1 core (chapter V) were dominated by grass pollen. The latter is most useful in interpreting the longer term grass pollen record, as will be demonstrated later, since data on pollen grain size, surface patterning and preservation have been recorded for each pollen grain.

No opportunities were available to collect surface sediments from various kinds of mangrove, from *Nypa* groves, or from vegetation types growing up valley. Equally unfortunately, no modern pollen samples from mainland South-East Asian mangrove are available in the literature and reference has to be made to information from Indonesian Kalimantan (Caratini and Tissot 1985), India (Caratini *et al.* 1973, Thanikaimoni 1987) and Australia (Grindrod and Rhodes 1984, Grindrod 1985) to draw conclusions about pollen production, dispersal and preservation. Attention must also be drawn to the literature concerning pollen transport and deposition in estuarine and coastal areas, a somewhat neglected subject worthy of far more research (Muller 1959, Rossignol 1961, Groot 1966, Traverse and Ginsburg 1966, Gallivan and Davis 1981, Moslow and Tye 1985, Sternberg *et al.*, 1986).

Caratini *et al.* (1973) have distinguished between autochthonous pollen types, those belonging to the plant communities from which surface sediments were collected, and allochthonous pollen types derived from plants growing elsewhere. They grouped the former into Rhizophoraceae, *Avicennia*, *Sonneratia*, *Excoecaria*, other trees and shrubs and Chenopodiaceae and acknowledged that *Bruguiera cylindrica* and *Ceriops decandra* could be distinguished from *Rhizophora apiculata* and *R. mucronata* using pollen morphology. Grindrod and Rhodes (1984) and Grindrod (1985) have indicated that *Bruguiera* and *Ceriops* pollen types cannot be separated. *Rhizophora* and *Bruguiera* pollen types have been distinguished in the analysis presented here but a third Rhizophoraceae pollen type nearer to *Bruguiera* than to *Rhizophora* and initially thought perhaps to originate from *Carallia*, a taxon of lowland forest, has been labelled *Bruguiera* comp. 2. Fuller details of this are given in chapter IX. The pollen of *Bruguiera/Ceriops*, referred to as *Bruguiera* comp. 1 hereafter, was not abundant in the Indian sediments and Caratini *et al.* (1973) grouped them with *Rhizophora* claiming that these have the same ecology. This is not entirely true as indicated in chapter VII, and the separation of the two types is useful. Indeed if the pollen of *Bruguiera* and *Ceriops* could be identified and recognized at the species level, far more accurate palaeoecological conclusions could be derived from the data presented in chapter VII.

Caratini *et al.* (1973) reported that Rhizophoraceae were over-represented in the pollen record in relation to the importance of the plants in the vegetation and that both wind and water seemed to play an important role in the distribution of the pollen grains. Grindrod and Rhodes (1984) reported that all samples from closed-canopy Rhizophoraceae-dominated mangrove forests at Missionary Bay, an estuary in North Queensland, Australia, contained at least 90 per cent Rhizophoraceae pollen and, in general, showed a relatively low pollen diversity in relation to the number of species recorded from the parent vegetation. A low-tide mud bank sample was also found to contain little other than *Rhizophora* pollen. *Rhizophora* pollen was recorded nearly 2km upwind from parent sources at Princess Charlotte Bay, also in North Queensland (Grindrod 1985). Hillen (1983) suggested that 85-95 per cent of *Rhizophora* indicated that the trees were actually growing at the site and that it was an intertidal mangrove environment. Where *Rhizophora* only comprised 60-80 per cent of the total pollen content, then deposition was occurring in a shallow offshore environment. A 30-40 per cent representation suggests either a tidal flat or an offshore sample. This generalization, while evocative, must be used with circumspection in interpreting prehistoric pollen spectra from the Khok Phanom Di area, because it was likely to have been a rather different topographic and sedimentary, if not vegetational, environment, when compared with peninsular Malaysia.

Bruguiera comp. dominated two samples from Missionary Bay but none from Princess Charlotte Bay, although it was commoner in a few. Grindrod (1985) stated that the highly localized distribution suggested inefficient wind dispersal of the pollen despite the fact that *Ceriops tagal*, at least, occupies open shrub communities landward of closed-canopy mangrove forests. Floral structures are indicative of animal vector pollination. Caratini *et al.* (1973) reported that *Sonneratia* pollen, probably from *S. apetala*, was over-represented at Pichavaram. *Sonneratia* did not occur in the North Queensland samples at all but Caratini and Tissot (1985) reported *S. alba* and *S. caseolaris* from the Misedor Delta, Kalimantan, and *S. caseolaris* was the more abundant of the two but its highest frequency in the 20 samples considered was only 3.4 per cent. *S. apetala* does not occur in Thailand but the following taxa do: *S. alba*, *S. caseolaris*, *S. griffithii* and *S. ovata*. According to Macnae (1968:131), *S. caseolaris* only grows where salinity is less than 10 per cent.

S. alba and *S. griffithii* hardly ever grow together but, since ecological determinants are unknown, separation of the pollen types is not worthwhile at present.

Caratini *et al.* (1973) found that generic separation of the Chenopodiaceae was impossible but surmised that most came from *Suaeda maritima*, the only species of the family found in abundance in the region. The fact that Chenopodiaceae values are higher in samples from the *Suaeda maritima* zone supports this and normal representation is accepted. Caratini and Tissot (1985) have not reported Chenopodiaceae from the Misedor Delta samples nor have Grindrod and Rhodes (1984) from Missionary Bay, but they dominated several surface spectra from Princess Charlotte Bay (Grindrod 1985), although they were less common in samples derived from pollen traps. Grindrod suggests that most of the pollen was deposited very locally.

Sufficient genera in Amaranthaceae, with two indigenous species of *Amaranthus* recorded from the environs of Khok Phanom Di, occur in Thailand to make separation of Chenopodiaceae from Amaranthaceae impossible. This is unfortunate, as *Suaeda maritima*, a potentially useful indicator of saltmarsh conditions, is the only indigenous taxon in Chenopodiaceae recorded by Smitinand (1980) and the Amaranthaceae are weeds of agriculture and road or tracksides.

Caratini *et al.* (1973) also recorded normal representation for *Lumnitzera littorea*, *Dalbergia spinosa* and *Acanthus ilicifolius*, less common mangrove taxa. *Lumnitzera* has been found sparingly in some samples from the Khok Phanom Di cores, but not the other two pollen types, although *Acanthus ilicifolius* grows with *Nypa* in some creeks at the edge of the Bang Pakong River. Caratini and Tissot (1985) did not find *Lumnitzera* at Misedor Delta at all and it occurred infrequently in the North Queensland samples (Grindrod and Rhodes 1984, Grindrod 1985).

Avicennia officinalis occupied a fairly large area in front of the *Rhizophora* zone at Pichavaram (Caratini *et al.* 1973) but the pollen was greatly under-represented, not exceeding a 2 per cent representation even in regions where it had total dominance, and this was attributed to poor pollen production. *Avicennia* occurred in only two surface samples from Misedor (Caratini and Tissot 1985), with 1.5 as the highest percentage, and never reached more than a few per cent in those from Missionary Bay (Grindrod and Rhodes 1984). Some samples from Princess Charlotte Bay (Grindrod 1985) had more than 10 per cent *Avicennia* pollen, however, and pollen production was suggested to be relatively strong but with highly localized dispersal. So, where even very moderate percentages occur in the pollen record *Avicennia* may be the main component of the vegetation.

Three species of *Avicennia* grow in Thailand: *A. alba*, *A. marina* and *A. officinalis* (Smitinand 1980). *Avicennia marina* seems to have the widest range of salinity tolerance of all mangroves (Macnae 1968:131). It is capable of growth in water which is almost fresh, or has a salinity of 90 per cent. *A. officinalis* is common (Macnae 1968:93) at the landward limit of mangrove, and may also have a wide salinity tolerance, while *A. alba* (Macnae 1968:114) replaces *A. marina* at the entrance to channels where wave action is less and the substratum is very soft. The clear conclusion from this is that without species identification of the pollen it is impossible to use *Avicennia* as a reliable indicator of fore mangrove conditions and it is a surprisingly unreliable guide to salinity.

Caratini *et al.* (1973) also recorded that *Excoecaria agallocha* pollen had only about one third of its expected values in sediments from Pichavaram while *Aegiceras corniculatum*, *Azima tetracantha*, *Clerodendrum inerme* and *Derris trifoliata* were not represented at all. The other reports tend to confirm non or under-representation of taxa such as these, and *Nypa*, *Scyphiphora* and *Xylocarpus* (Grindrod 1985) can be added to the list of poorly represented taxa. Caratini and Tissot (1985) recorded in excess of 24 per cent *Nypa* from one Misedor Delta surface sample, however.

Most of the allochthonous pollen grains found by Caratini *et al.* (1973) seemed to be produced by vegetation from within 5km of the sites studied. They distinguished three groups of such pollens: Gramineae, Cyperaceae and miscellaneous and unidentified pollens. Grasses were absent from the *Rhizophora* zone but a few taxa (*Eragrostis* spp., *Sporobolus* spp., *Aeluropus lagopoides* (especially) and *Zoysia matrella*) occurred in back mangrove and *Spinifex littoreus* on littoral dunes. The pollen was most abundant in samples from a wide channel, the Uppanar River and a lagoon, suggesting that most was brought in by water.

Gramineae pollen was recorded in all the North Queensland surface samples (Grindrod and Rhodes 1984, Grindrod 1985), including pollen trap samples from mangrove sites (Grindrod 1985) located 500-1000m from the nearest source. This is claimed to indicate relatively efficient wind dispersal. It also occurred in 16 of the 20 Misedor Delta surface spectra (Caratini and Tissot, 1985).

Unfortunately, none of the writers has attempted to determine the grass pollens below the family level using pollen grain sizes or surface patternings. One important point does emerge from the analyses, however: the presence of a small percentage of grass pollen in samples from mangrove is normal.

Cyperaceae were widely represented in back mangrove and adjacent vegetation at Pichavaram (Caratini *et al.* 1973), *Bulbostylis barbata* was stated to be very common and *Cyperus arenarius* common. Yet sedge pollen was not abundant in any sample, even those from the waterways. Cyperaceae pollen was consistently represented (Grindrod 1985) in traps but the greater general abundance in surface samples from Princess Charlotte Bay was taken to indicate that the pollen was mainly deposited very locally despite some wind dispersal. The highest percentages recorded from the Misedor Delta samples, where Cyperaceae were also ever present, were from the two prodelta samples, suggesting that water transport can be important.

None of these writers has tried, like Maloney (1979) and Walker and Flenley (1979), to subdivide the Cyperaceae aiming at generic determination. This has been attempted in the Khok Phanom Di analyses and the following pollen types have been distinguished: *Carex* comp., *Cyperus* comp., *Eleocharis*, *Fimbristylis* comp., *Scirpus* comp., *Rhynchospora* sim. and *Cyperaceae* undifferentiated. Heckman (1979) reported various *Cyperus* species and two *Fimbristylis* species as components of the littoral flora in an Udon Thani ricefield. It would be unwise to rely upon the presence of *Cyperus* comp. or *Fimbristylis* comp. as indicators for the occurrence of rice but *Eleocharis* and *Scirpus* appear to prefer rather wetter conditions than the other taxa, locally at least.

The miscellaneous category of Caratini *et al.* (1973) included the following taxa: *Cocos*, *Borassus*, *Phoenix*, *Casuarina*, *Acacia*, *Typha*, *Boerhaavia*, *Tribulus*, *Barleria*, *Justicia*, *Jatropha*, *Barringtonia*, Compositae, Combretaceae, Caryophyllaceae and Myrtaceae. Many of these occur in the Khok Phanom Di samples. The miscellaneous category was, like the grasses, most abundant in the wide channel, lagoon and Uppanar River samples, suggesting that water might have been responsible for pollen dispersal.

The Missionary Bay samples taken along a gradient from brackish swamp through mangrove swamp to low tide muds show a progressive increase of Rhizophoraceae accompanied by a decrease in fresh/brackish swamp and sclerophyll taxa (Grindrod and Rhodes 1984). Although the vegetation inland of the mangrove is rather different, one might expect a similar generalization to hold true for the Bang Pakong estuary: that samples from immediately landward of the Rhizophoraceae-dominated forest will contain less Rhizophoraceae pollen but the figure may still be as high as 60 per cent. Samples with 80-90 per cent plus *Rhizophora* pollen are most likely to derive from

sites within *Rhizophora* forest. Where Rhizophoraceae percentages are less than 60 per cent, and upper intertidal taxa such as *Scyphiphora*, *Lumnitzera* and *Excoecaria* are represented, a freshwater/dryland forest – mangrove ecotone was probably nearby. The modern pollen literature cannot provide a useful guide concerning taxa which might be found in Thai freshwater/dryland forest or any data on pollen production, dispersal and preservation. Reliance has to be placed on the data extracted from Corner (1978) and Smitinand (1968) referred to in chapter III.

Grindrod (1985) detected a small percentage of long-distance pollen dispersal from the Princess Charlotte Bay samples, recording *Casuarina*, *Podocarpus* and *Callitris*. The account of the montane vegetation of Khao Yai National Park (Smitinand 1968) gives some clues as to which taxa in the pollen cores from Khok Phanom Di are of long-distance origin.

The interpretation of the pollen spectra from the environs of Khok Phanom Di depends not only on information about pollen production, dispersal and preservation but also the mechanics of pollen dispersal and deposition. This has been best studied not in the papers already reviewed but those of Muller (1959) and Germeraad *et al.* (1968). Extensive research in oil palynology has revealed that individual pollen grains may be transported, mixed and sorted according to size and possibly redeposited once or several times in deltaic-marine silts and clays. Muller (1959) demonstrated that all pollen taxa are initially transported through the air, although this process can take the form simply of a straight fall from the tree canopy and incorporation in peat swamp deposits (Muller 1972, Anderson and Muller 1975). At the opposite extreme, wind may transport pollen down from montane vegetation growing many, if not hundreds, of kilometres away. Such pollen grains are deposited as wind strength declines or when rainfall clears the atmosphere and are either destroyed on the ground or transported further by water. Rivers transport a small proportion of pollen from the entire drainage area and deposit this in alluvial plain and coastal deltaic sediments. Apparently most is concentrated at the river mouth and discharged into the sea with the sedimentary load (Germeraad *et al.* 1968). In this instance, size sorting is scarcely noticeable as tidal currents and turbulence usually efficiently mix the final suspension entering the sea. Such fluvio-marine sediments tend to contain a large pollen flora.

Sea currents act as slow transporting agents and the pollen settles gradually, with smaller pollen grains being deposited first. A wind transported component can be added and may considerably affect the pollen composition of areas far offshore. Selective corrosion of pollen and fern spores may occur during seaborne transport, but little is known of this.

Rossignol (1961) found pollen and fern spores transported by the Nile and subsequently by shore currents in sediments off the coast of Israel. So if pollen was not brought down from northern Thailand directly by the Chao Phraya floods, it may have reached the Bang Pakong area through longshore drift, although longshore drift along the Trat-Chanthaburi coast is rather more likely.

As far as more local movement is concerned, Groot (1966) discovered that the number of pollen and spores per gallon of water varied greatly from high in the upper reaches of the estuary and during ebb tides to low at the mouth of the Delaware Bay and during flood tides. Pollen grains were derived from the whole river basin with minimal local influence. They were found to be transported with fine-grained clastic sediments and in the same manner Brown (1985) reported that pollen and spore concentrations in a New Forest stream varied quasi-independently with discharge and suspended sediment load from 1 grain/ml-1 at base flow to 230 grains/ml-1 at flood peak.

Sternberg *et al.* (1986) reported that fine bottom sediment is eroded and transported as suspended sediment in shallow marine environments and that inorganic, and presumably organic,

particles undergo numerous cycles of erosion and deposition before reaching a permanent resting place. Much research on the processes involved in redeposition is necessary, as time-series measurement of suspended sediment and velocity profiles in San Francisco Bay, California, have revealed errors of 25-50 per cent from predictive equations. Germeraad *et al.* (1968) reported that meandering rivers (such as the Bang Pakong) may erode sediments deposited only a short time before, so this process need not always delay final incorporation into sediment unduly. Difficulties in interpreting pollen spectra occur when the time-lag between deposition and recycling is not so rapid. Reworked assemblages may not always be readily distinguishable and the initial promise offered by fluorescence microscopy (van Gijzel 1967, Phillips 1972) as a means of detection appears, through lack of recent publications, not to have been fulfilled. Pollen is unlikely to be preserved in the marginal fan deposits of the Bang Pakong Valley, and, as the plain is of Holocene origin, any reworked pollen present in sediments from near Khok Phanom Di is likely to be of recent origin. Allochthonous pollen can be distinguished from that of local origin (Faegri and Iversen 1975), using its state of preservation. Pollen from taxa growing near the site of sample collection is likely to be both fresh and undamaged. As the pollen spectra from close proximity to Khok Phanom Di derive from what is now a deltaic flat, but which might have been variously a shallow-water sea or lagoon accumulating pollen from inland sources, the mound on which the archaeological site stands, and through longshore drift, it was decided to record the preservation status of every pollen grain and pteridophyte spore counted on a taxon by taxon basis, using the methods already outlined, in an attempt to assess which palynomorphs were being redeposited and how frequently. It is well-known (Macnae 1968) that bioturbation occurs in mangrove swamp and monitoring of pollen preservation status, the resulting smoothing of pollen curves and comparison of several pollen diagrams from a small area should indicate how important this has been.

V. SEDIMENTARY STRATIGRAPHY AND DATING

By B. K. Maloney

INTRODUCTION

THE stratigraphic sections of the pollen cores and fishpond monolith are shown in Figs. 12, 13, 14 and 15. All depths relate to ricefield level, taken as 3m above sea level. Their relationship to the site is seen in Fig. 16. All cores were poor in organic content, apart from a few small pieces of possibly inwashed wood, and all had sedimentary banding throughout. Insufficient time was available in the field to collect duplicate cores to provide sufficient material for bulking to obtain conventional radiocarbon dates. The Oxford University Research Laboratory for Archaeology and the History of Art, however, has processed nine samples from cores KL 2 and BMR 2 using accelerator techniques, the results of which are presented and discussed below.

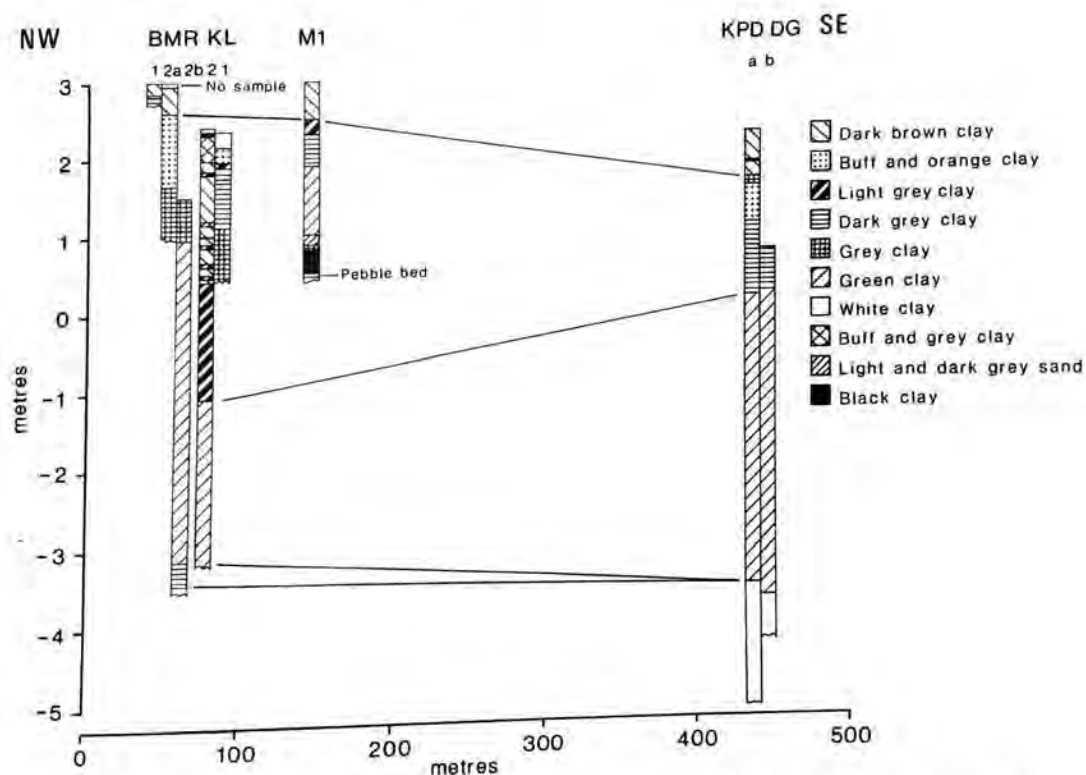


FIG. 12. The correlation between boring locations BMR, KL, M1 and KPD

EXCAVATION OF KHOK PHANOM DI

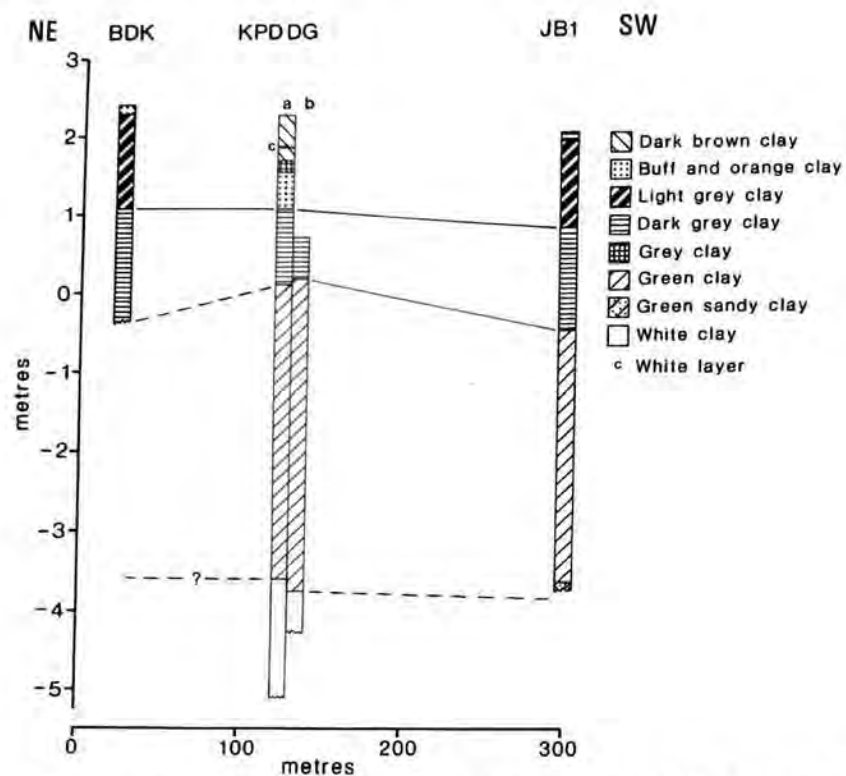


FIG. 13. The correlation between boring locations BDK, KPD DG and JB 1

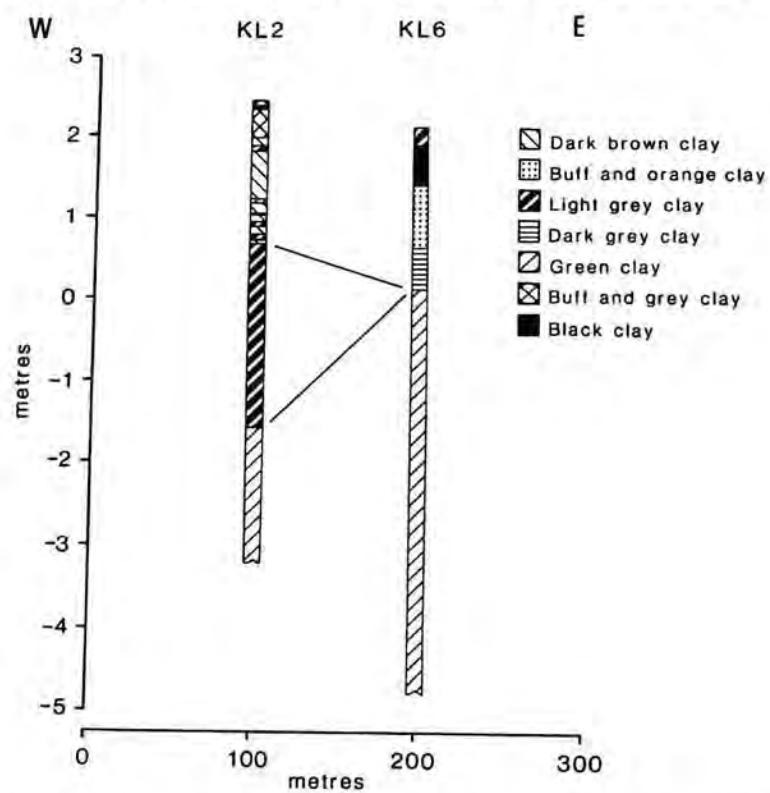


FIG. 14. The correlation between boring locations KL 2 and KL 6

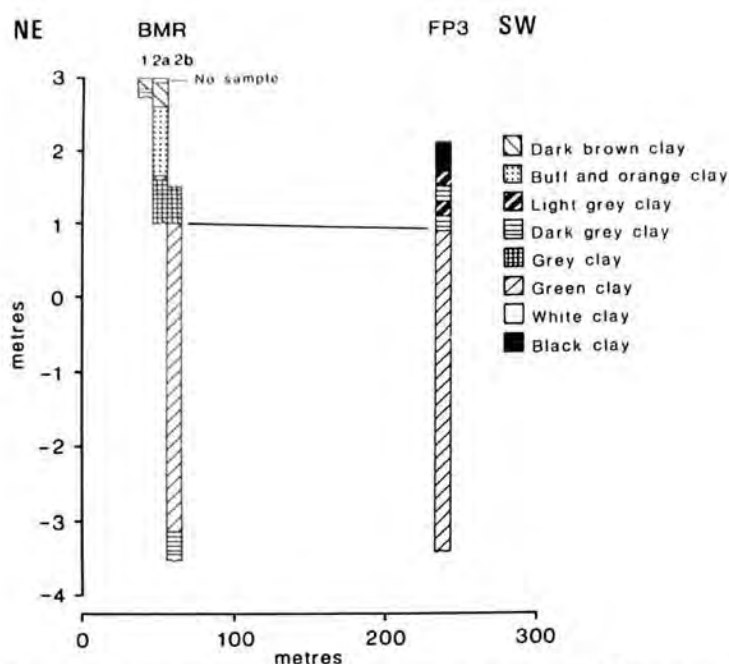


FIG. 15. The correlation between boring locations BMR and FP 3

THE SEDIMENTARY STRATIGRAPHY

The sedimentary stratigraphy of coastal deposits is rarely simple and those from the environs of Khok Phanom Di are no exception. The area is a deltaic flat, as defined by Takaya (1971), and can therefore be expected to show dominance by brackish water sediments in which iron sulphides become concentrated. Takaya (1972) and Hattori (1972) described sections in several parts of the Bang Pakong Valley and the latter investigated many samples chemically and mineralogically but made no attempt to trace the course of landform development. The valley floor sediments were stated to consist of either dark brownish-grey clay with mottles of varied colours or dark greenish-grey clay with brown mottles, the former supposedly of brackish origin and the latter of marine origin (Hattori 1972:326). Van der Kevie (1971) recognized a similar division, but neither author expanded upon what was meant by 'marine': it is very relevant to the palaeoecological reconstruction of the near environs of Khok Phanom Di to know if these are nearshore or deep water deposits. The clayey nature of the green sediment, however, suggests quiet water, possibly lagoonal depositional conditions (cf. Takaya 1969), while the dark grey brackish-water clays are presumably estuarine deposits.

Hattori (1972:326) stated that the so-called acid sulphate soil was supposed to have developed from brackish-water sediments and usually has red and yellow (occasionally pale yellow) mottles. The reconnaissance soil map, however, noted acid sulphate soils developed from green marine clays (Fig. 9). Indeed, the zone of younger acid sulphate soils distinguished by van der Kevie (1971) is probably largely, if not entirely, underlain by such deposits. X-ray diffraction of the mottles (Hattori 1972) indicated that the red ones probably comprise haematite and goethite, the yellow ones goethite and the pale yellow ones jarosite. Some brackish sediments in the Prachinburi-

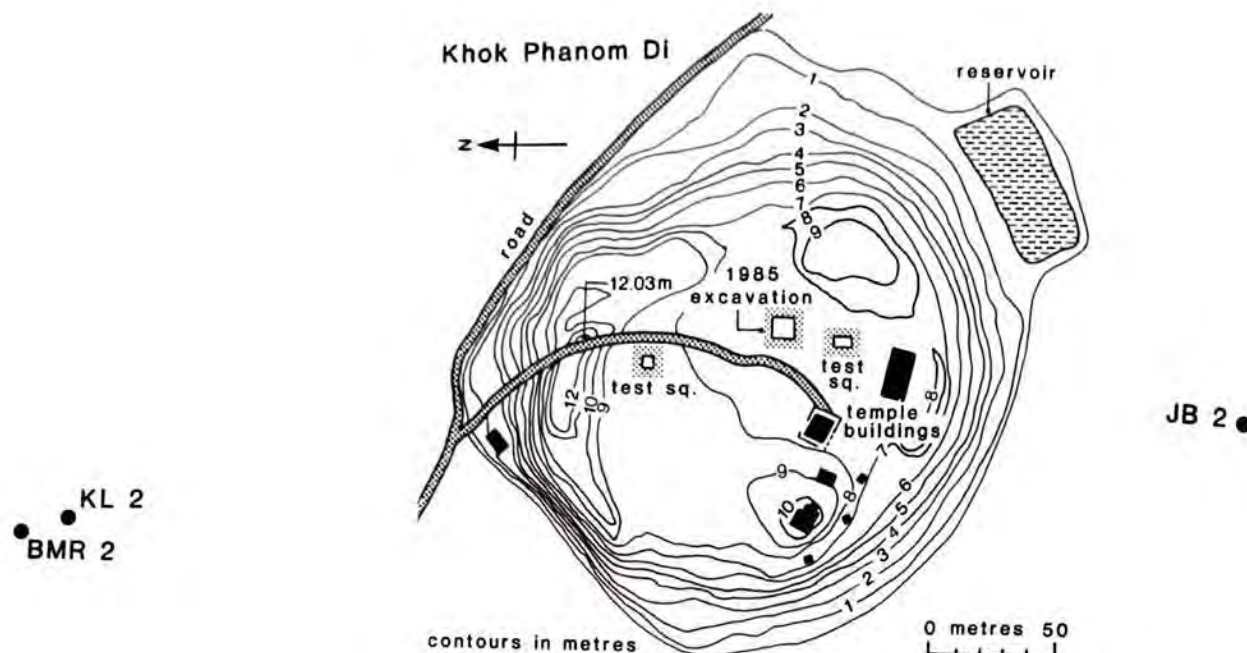


FIG. 16. The location of cores relative to the site of Khok Phanom Di

Kabinburi area were reported to contain iron nodules (pisolithic laterite) and/or plinthitic (lateritic) mottles, which was not unexpected given the present seasonally dry climatic regime.

Four profiles were examined in the Chonburi–Phanom Sarakhan area. The deepest (No. 163) comprised 3m of brackish-water sediment over a lateritic layer. The upper 20cm or so consisted of a black clay and the dark grey clay below this contained red mottles down to *c.* 2.20m and had yellow mottles, then red mottles again, below this. A radiocarbon age of *c.* 5400 BC (7440 ± 150 BP), from *c.* 2.50m depth (no laboratory number given) was presented in Takaya (1972). This profile falls in the zone of older acid sulphate soils, without gypsum, delineated in van der Kevie (1971). Another much shallower, undated, profile (No. 166), from closer to Chonburi, comprised a thinner black clay over *c.* 80cm of dark grey clay containing red mottles down to *c.* 80cm depth and yellow mottles below this. This is from the zone of younger acid sulphate soils recognized by van der Kevie (1971). A radiocarbon date of *c.* 2000 BC (3945 ± 65 BP) was obtained from the sub-soil (2m depth) of a younger acid sulphate profile located west of the Bang Pakong (no laboratory number was given, but all of van der Kevie's dating was conducted at Groningen University). Shallow profiles developed on fresh and brackish-water deposits were also examined in the Ban Na-Ongkharak area in the north of the valley in van der Kevie's zone of older acid sulphate soils. Four of those are of particular interest: No. 146, which consisted of over 1.50m of sediment, of

freshwater origin, and containing brown mottles, No. 150, which had c. 80cm of black clay over a shallow red and yellow mottled brackish-water clay, No. 147 which was similar, but with a shallower black clay, and No. 152 which had c. 20cm of black clay beneath a similar thickness of brown mottled clay and over c. 50cm of red mottled dark grey clay and a similar depth of brown mottled freshwater clay. Unfortunately, none of these profiles has been radiocarbon dated, but the 4m level of van der Kevie's C 1 collected from the same region as No. 152 was only c. 3100 years old. The sequence from the upper Bang Pakong Valley (Prachinburi–Kabinburi) is also interesting especially as radiocarbon dates are available (Takaya 1972) from two of the exposures: Nos. 157 and 158.

The latter has c. 1.20m of brown mottled freshwater clay over c. 80cm of black clay, then a shallower red mottled sediment underlain by yellow mottled brackish-water clay, another metre of black clay, a few centimetres of red mottled clay and finally c. 50cm of yellow mottled clay: a complicated profile with a radiocarbon date of c. 4700 BC from 3.5m depth (6730 ± 145 BP). Profile No. 156 contained a thinner black clay which could correlate with the upper one from No. 158 but only red and yellow mottled clays below this to 4m depth. In contrast, profile No. 157 had a black clay at c. 50cm of yellow mottled clay above this, red and yellow mottled clays, red mottled clays and (1.50–3.50m) brown mottled clay. The lower part of the brown mottled clay yielded a radiocarbon date of c. 2000 BC (4030 ± 120 BP). About 50cm of brown mottled clay with iron manganese nodules separated the lower clay from an upper brown mottled clay. The locations of the sample sites are shown in Fig. 17 and the stratigraphic sections are illustrated in Fig. 18. It is clear from the literature (Moorman 1963, van der Kevie 1971, Hattori 1972, Ismangun and Dreissen 1974) that there is confusion over the definition of acid sulphate soils. This seems to have arisen because some people include potential acid sulphate soils, what Moorman (1963) calls mud-clays (nondrained, unoxidized soils with high potential acidity) and Ismangun and Dreissen (1974) refer to as unripe acid sulphate soils, in the definition whereas others, including Hattori (1972), appear to regard only drained, aerated soils with severely oxidized sulphides as acid sulphate soils. As intermediate forms between mud-clay and cat-clay (acid sulphate soil *sensu stricto*) occur, with the upper parts of profiles oxidized and acidic (Moorman 1963) and the lower reduced and near-neutral, precise definition is impossible. The *sensu lato* interpretation, following Ismangun and Dreissen (1974), has been followed in Maloney (1985b) and will also be adhered to here. Under this, all the dark grey brackish-water clays are regarded as acid sulphate soils whether mottling is present or not, because they are potentially so.

The deposits of three main sedimentary environments occur in the vicinity of Khok Phanom Di: brackish-water clays, green 'marine' clays and white, possibly kaolinitic, clays of probable subaerial origin. Hattori (1972) has considered the chemistry and mineralogy of sediment from brackish water and green marine clays but not the white clays described from some profiles in the Bang Pakong Valley by Takaya (1972).

White, banded, clays occur at the base of cores KPD DG a and b and BMR 2 (Fig. 12). These are probably of fluvial origin and either represent pre-Holocene deposition or Holocene deposition preceding a Holocene transgression, which seems to be represented by the green clays. The upper surface of these deposits is almost level over a distance of c. 500 m apart. This, and the lack of a weathering horizon, could suggest that they have been planed off by a rising sea.

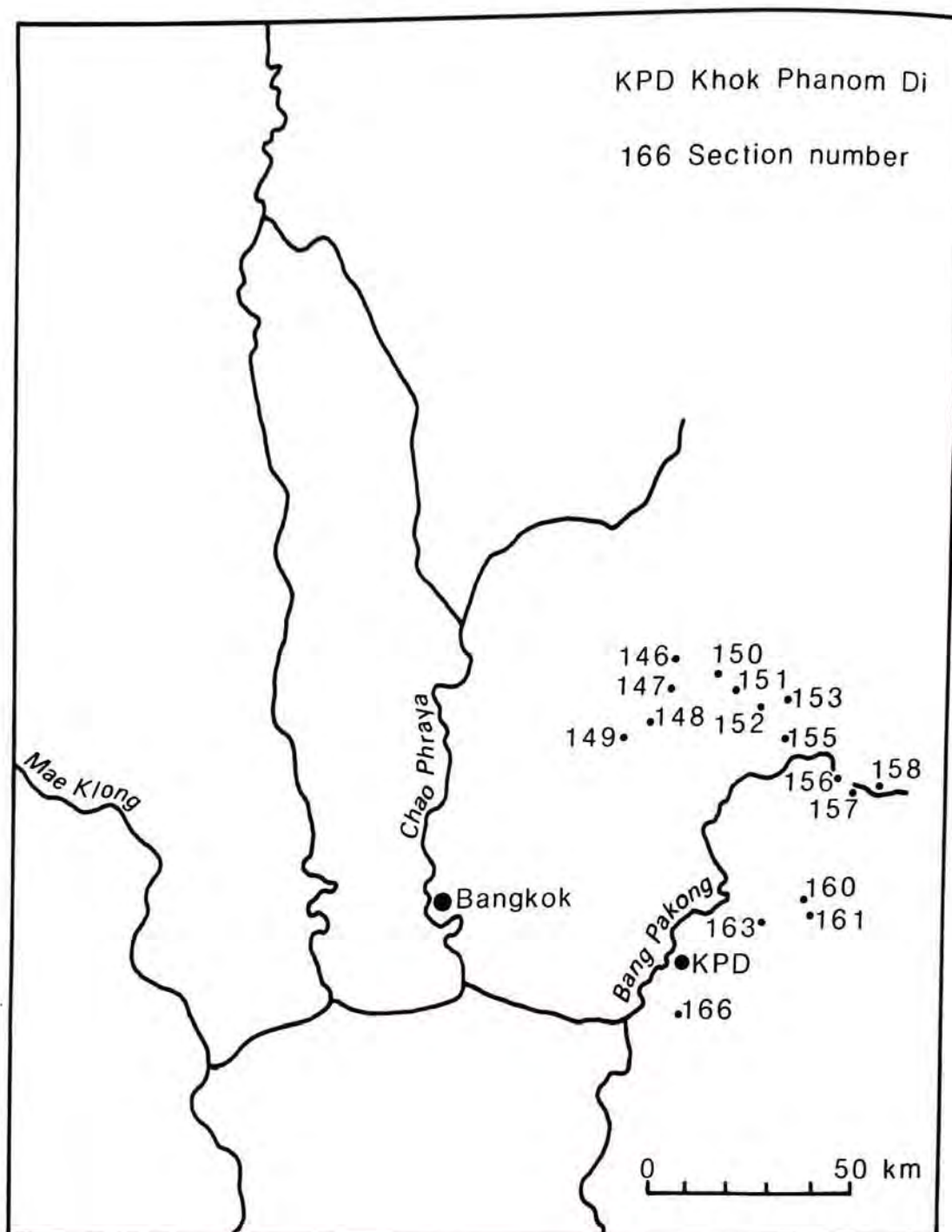


FIG. 17. The location of Quaternary outcrops in the eastern Bangkok Plain, adapted from Takaya (1972)

BMR 2 has dark grey clay, possibly indicating the presence of brackish-water conditions, above the white clay but beneath the green clays. This indicates that a hiatus in deposition certainly occurs at KPD DG but the possibility that another occurs above the dark grey clay cannot be excluded. The fact that it survived at all suggests that the erosive power of the transgressing sea was not strong. If Takaya (1969) is correct in his theory that barrier islands developed, Khok Phanom Di

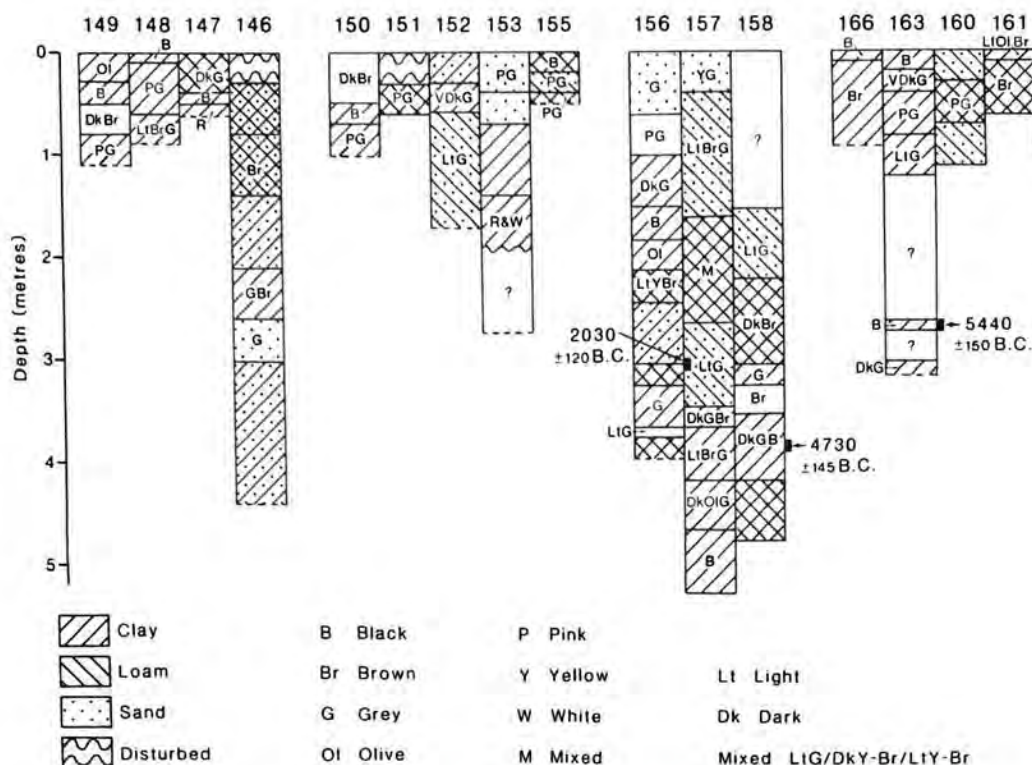


FIG. 18. The stratigraphy of the Quaternary outcrops in the eastern Bangkok Plain, compiled from Hattori (1972)

may have originated as an offshore bar in a shallow sea, and the brackish clays might have partly infilled a protected lagoon. This would account for their presence north and not south of the site.

The fact that green clays are absent from the surface anywhere in the region indicates, if colour is accepted as a valid guide, that they are not of recent origin. It can, however, be argued that those upper profiles which do not consist of made ground are so chemically altered that it is impossible to establish their original colour. Near Khok Phanom Di, the green clays range from 2.00–4.50m in thickness but at least 6m are present near Ban Pho, about 7km west of the site, and over 6.5m at Ban Bang Hak, *c.* 7km south of Ban Pho. Both these coring locations border the Bang Pakong River. The green 'clays' are by no means clayey throughout but sometimes contain shell bands, wood fragments and minor inclusions of coarse sand visible on X-rays if not always apparent from the surface of core segments.

Unlike the white clays, the upper surface of the green marine clays is not a fairly uniform depth. Core KL 2 and the fishpond monolith are especially anomalous. In general the upper limit is between approximately 1m above sea level and 0.5m below it but at KL 2 it first occurs at *c.* 1.10m below sea level and in M 1 almost 90cm of marine clay is present between 1.00 and 1.90m above sea level. In the latter case the presence of a thin (3 cm) green band over the grey clay and additional green layers in the predominantly dark grey clays of KL 1 from 1.35–1.95m above sea level and KL 2 between 1.15–1.20m ASL suggest correlatives (similar material is notably absent from KPD DG and JB 1), and a second sea-level transgression may be indicated (Fig. 13). It is important, however, to note the proviso given above concerning the indicativeness

of colour. The KL 2 anomaly can be explained quite simply: the 1.5m of light grey sediment overlying the green marine clay may represent drying out and oxidation to form a ripe acid sulphate soil horizon. The lack of correlatives is not puzzling. What may have happened is that a creek dried out, allowing oxidation to occur in the dry season. Digging of a drainage or irrigation canal would produce a similar effect. The other cores extracted from irrigation canals, BDK, JB1 and KL 6 all have dark grey (brackish-water) clays, unripe acid sulphate horizons, above the marine clay.

KL 2 has light grey clays between 0.40 and 1.85m ASL, along with the single band of green clay, intercalated with dark brown clay. Where present at all, dark brown clays, possible freshwater deposits judging by Hattori (1972) but likely soil horizons (van der Kevie 1971), only occur elsewhere in the upper 15–50cm of cores. The upper part of the KL 2 core consists of a buff (jarosite?) and grey clay with a thin black peaty clay band. This is certainly an acid sulphate soil *sensu* Hattori (1972). Jarosite sometimes forms by the reaction of ferric hydroxide with sulphuric acid due to slow oxidation (Ismangun and Dreissen 1974) as the level of the water-table declines and may result from careful drainage by man or natural changes associated with a gradually falling sea level.

This acid sulphate soil could be a correlative of the orange and buff-coloured clays which underlie the dark brown clays in cores BMR 2a, KL 1 and KPD DGa and might represent the younger acid sulphate soil of van der Kevie (1971). Correlation with core KL 6 (Fig. 14) is more difficult as the apparent younger acid sulphate soil is overlain there by about 50cm of black organic mud. This material is very incoherent and probably represents recent fill. A very similar, but thinner, black mud was present in the upper parts of two short cores (not diagrammed) extracted nearby (KL 4 and KL 5) and the upper part of FP 3 (Fig. 15).

Core to core correlation indicates very clearly how variable the sedimentary sequence is over short distances. Part of this variability can, almost certainly, be accounted for by natural or anthropogenic disturbance to sections, involving erosion or removal of sediment and redeposition elsewhere and part of it due to pedogenesis. It is also clear that van der Kevie's division of acid sulphate soils into older and younger, while true in outline, may not be sustainable on detailed consideration because soil profile development has probably occurred intermittently due to vagaries of what, as Takaya (1969, 1971) indicated, is a highly unstable depositional environment. Most cores from around Khok Phanom Di do exhibit one, quite variable acid sulphate soil profile. However, KL 2 shows what may be two, with development of the first possibly curtailed and perhaps even truncated by a second marine transgression. The thickness of marine clay in the M 1 monolith provides the best lithostratigraphic evidence for a second transgression (the pollen evidence will be considered later). The stratigraphic sequence consists of dark grey (brackish-water) clay below a pebble bed (the pebbles were all small and angular) with a peaty layer incorporating unrooted wood and shells, a thin sandy horizon, the green marine clay, more (42cm) dark grey brackish-water clay, a thin light grey (? ripe acid sulphate soil) and 50cm of dark brown clay. The dark brown, light grey and dark grey clays had orange iron mottlings, replacing root channels in the case of the dark grey clay, and appear to represent the younger acid sulphate soil. The sediments from beneath the green clay may represent an older acid sulphate soil. It does appear as if the Khok Phanom Di mound may have formed a barrier protecting sedimentary sequences behind it in later prehistory, but was fronted by a more active erosional environment.

RADIOCARBON DATING

The samples sent for radiocarbon dating were derived from the centre of each core segment and from contexts with little redeposited pollen, and were re-bagged and double wrapped before being sent to Oxford. Accelerator radiocarbon dating has been described in Hedges (1979), Hedges *et al.* (1980), Kutschera (1983), etc. Its main advantage is in the fact that useful results can be obtained from milligram samples, indeed samples up to one thousand times smaller than those required for conventional dating may be processed (Beukens 1979). Other advantages to the counter as much as

TABLE 5: Radiocarbon dates from pollen cores from the vicinity of Khok Phanom Di. All are based on a 5570 year half life, calibrated according to Klein *et al.* (1981) and expressed at the 2σ range

CONTEXT	SOURCE	LAB. NO.	yrs. BP (uncal.)	yrs. BC (calib.)
KL 2	0.87-0.91m	OxA 1354	3360 $\pm$ 120	1910-1435
KL 2	1.46-1.50m	OxA 1355	560 $\pm$ 150	AD 1235-1595
KL 2	2.25-2.29m	OxA 1356	5560 $\pm$ 160	4710-3960
KL 2	3.50-3.54m	OxA 1357	6060 $\pm$ 200	5330-4555
KL 2	4.82-4.86m	OxA 1358	6280 $\pm$ 130	5530-4935
KL 2	4.91-4.95m	OxA 1359	6400 $\pm$ 300	5800-4755
BMR 2	0.88-0.92m	OxA 1449	3960 $\pm$ 100	2855-2185
BMR 2	3.96-4.00m	OxA 1360	6560 $\pm$ 100	5767-5230
BMR 2	6.60-6.64m	OxA 1361	6610 $\pm$ 140	5855-5230

the user are that counting times can be considerably reduced, therefore multiple measurements can be made, but sought after improvements in accuracy over conventional counting have not yet been achieved and may not materialize. The main difficulties experienced with the technique revolve round making sure that only ions of the right mass enter the counter, that stripping of other interfering ions of similar mass has been carried out efficiently and that ion source operation is stable (Kutschera 1983).

Dates from the Oxford AMS system (Gillespie *et al.* 1985) are measured as $^{14}\text{C}/^{13}\text{C}$ ratios in comparison with the new NBS oxalic standard and are expressed in years BP. No independent measurement of ^{13}C is made, rather it is assumed that wood has a ^{13}C of -25 per cent and bone of -19 per cent. Allowance is made for c. 0.5 per cent contamination with modern ^{14}C during the preparation process and errors are quoted as one standard deviation. The type of accelerator used is a General Ionex 3 MV Tandatron (Hedges *et al.* 1980). This has a higher current capability than the Van de Graaf accelerator used formerly, ensuring that the transmission of ion beams is more stable. Most samples from Khok Phanom Di were prepared as CO_2 and a CO_2 ion source was used. However, more recently the laboratory has reverted to using iron/graphite and OxA 1449 was processed in this way.

The samples proved to be far from ideal due to the suspected presence of high quantities of silica dioxide (Housley, pers. comm.). They all gave low beams in the accelerator and this has

resulted in unusually high standard deviations (Table 5). As standards run at the same time all gave acceptable results, the age measurements are probably not suspect, although OxA 1355 is difficult to explain. The upper samples from BMR 2 were especially poor and needed to be re-prepared and run a second time. Even then, only one yielded a date.

In general, apart from the KL 2 inversion, the results are not unexpected. Dates from both cores confirm that deposition was particularly rapid initially but stabilized later. It is clear that the marine transgression reached the Khok Phanom Di area before *c.* 5500 BC and that the basal deposits of BMR 2, which have indications of a freshwater flora, are older than this. The uppermost date from BMR 2 appears to confirm that OxA 1354 is correct and that the inversion in KL 2 is an error. Examination of X-rays of the KL 2 core revealed no traces of modern root penetration. It is not unlikely that the undated FP 3, KL 6 and JB 2 core deposits also accumulated rapidly.

VI. POLLEN ANALYSIS: RESULTS AND DISCUSSION

By B. K. Maloney

INTRODUCTION

SAMPLES from five cores (KL 2, BMR 1, BMR 2, FP 3 and KL 6) extracted north of Khok Phanom Di have been subjected to pollen analysis. Judith Brown has analysed an additional 59 samples from core JB 2 derived from south of the site (Maloney and Brown 1987). The main features of each pollen diagram will be outlined and discussed here and the state of preservation of the microfossils in the cores analysed will be considered in relation to the pollen and pteridophyte spore content and lithostratigraphies of samples. A large number of pollen taxa and a few pteridophyte spore types occurred only once or occasionally. Most of these are fairly securely determined, but little palaeoecological information of value can be obtained from many of them because they cannot be readily assigned to ecological groups to be discussed one by one. They have been tabulated (Tables 7, 8 and 9), and notes on each taxon are available in chapter VIII, but only the possible cultivars will be alluded to in any detail.

A handful of isolated and indeterminate pollen grains, all tricolporates, was encountered. As these are a statistically insignificant percentage of the total pollen and pteridophyte spores counted in any single sample, and even more so when the data are evaluated as a whole, they do not merit any further attention. Of far more importance is consideration of the microfossil charcoal concentrations (Figs. 20, 25, 30 and 34) of each core, the pollen concentrations of the main taxa, the records of monocotyledon leaf and alga concentrations (Figs. 22, 27, and 31-34) and, not least, the detailed information on the grass pollen grains (Figs. 23, 28, 33 and 35).

THE POLLEN CORES

Pollen core KL 2

Core KL 2, extracted closest to the northern edge of Khok Phanom Di (Fig. 16), was derived from an irrigation canal. Below 5m depth, the lithostratigraphy consisted of green marine clay while the biostratigraphy (Fig. 19) was dominated by extremely corroded and probably redeposited pollen of Rhizophoraceae (*Rhizophora* and *Bruguiera* comp. 1 especially). The percentage of fresh pollen grains, mainly but not exclusively from mangrove taxa, showed an overall increase upward from the base of the core rising from less than 10 per cent in the lowest level to c. 25 per cent by 5.10m. The core consisted of light grey clay, suggested to be a ripe (oxidized) acid sulphate soil horizon in chapter V, between 3 and 5m in depth. The variable preservation of the pollen might

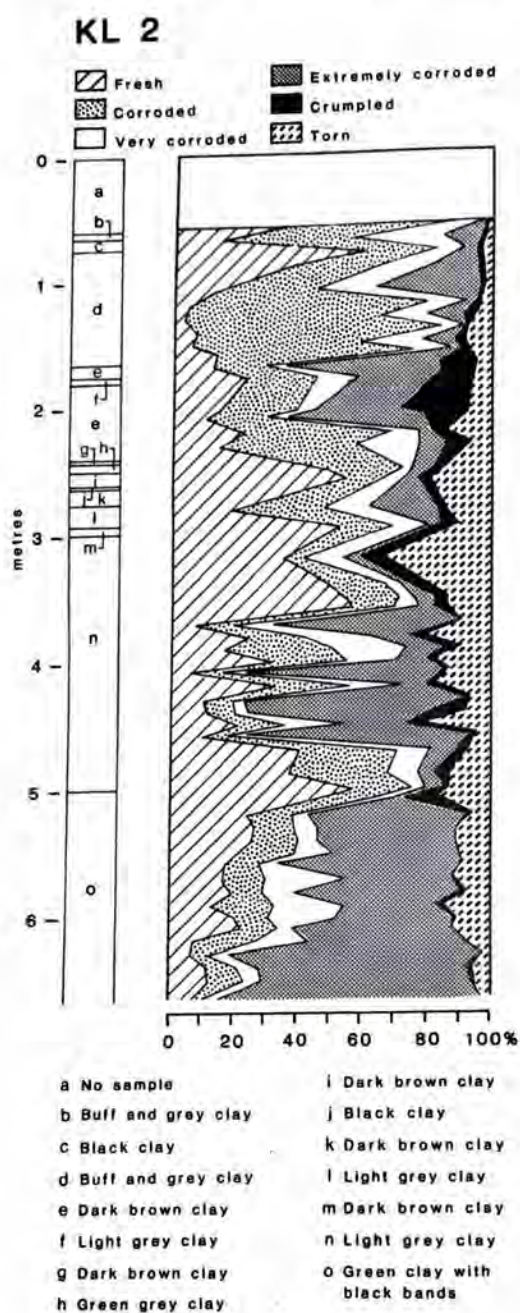


FIG. 19. The lithostratigraphy and pollen and fern spore preservation from core KL 2

be considered to support this hypothesis, but fresh pollen, again mainly of *Rhizophoraceae*, reached 30 per cent or above in samples from the 3–3.5 and 4.7–5.1m sections of the core.

In the former case, an oscillation between fresh *Rhizophora* and *Bruguiera* comp. 1 pollen grains took place but in the latter, *Bruguiera* comp. 1 was dominant. Five of the intervening samples did have very high percentages of extremely corroded pollen grains and this lends credence to the

oxidation theory. In all these levels, more badly preserved *Rhizophora* than *Bruguiera* comp. 1 pollen grains occurred, considerably so in the 4.42 and 4.11m samples (Table 7).

TABLE 6: *Extremely corroded pollen grains of Rhizophora and Bruguiera comp. 1. Percentages are of total pollen and pteridophyte spores*

Depth (m)	RHIZOPHORA		BRUGUIERA		comp. 1
	Number of pollen grains	%	Number of pollen grains	%	
3.72	132	31.3	107		25.4
4.11	196	55.2	69		19.4
4.32	188	42.9	121		27.6
4.42	202	45.7	99		22.3
4.61	216	41.6	151		29.1

Rather than oxidation, this sequence is suggestive of relatively stable pollen deposition at the base and top of the light clay with an interesting period of instability resulting in redeposition of *Rhizophora* pollen especially. The overall high percentages of Rhizophoraceae pollen (Fig. 20) in this section of the diagram and lower down seems to indicate (cf. Hillen 1983, Grindrod 1985) that mangrove, probably a *Bruguiera/Ceriops* forest, was growing at the coring site and the redistribution of the *Rhizophora* pollen is explicable in terms of higher than usual tides. The longer pollen diagram (Fig. 21) and table of minor taxa (Table 7) offers no evidence to refute this view and the pollen concentration figures (Fig. 22) tend to confirm the importance of *Bruguiera* comp. 1, a taxon apparently less prone to over-representation than *Rhizophora*. The monocotyledon leaf concentrations showed interesting changes, tending to be lower, often quite considerably so, when *Rhizophora* concentrations were highest. The most likely sources of monocotyledon leaves are grasses and sedges growing in slightly brackish to freshwater herbaceous swamp conditions inland of the coring site. So, before c. 4300 BC, a *Bruguiera/Ceriops* forest with *Rhizophora* on the seaward margin and under the influence of both tidal and riverine conditions seems to have been in the vicinity of the coring site. While apparently representing stable mangrove forest conditions, the 3.0–3.5m section of the core was characterized by an increase of torn palynomorphs, mainly of mangrove taxa and smooth (psilate) spores which seem to be from *Lygodium*, a climbing fern characteristic of freshwater conditions. Monocotyledon leaf concentrations, although remaining high, did not show the same excessive peaks found lower down. The degree of mechanical fracturing of pollen and fern spores, which declined above 3.0m and reached low levels above 1.4m depth, suggests that the environment was not particularly stable. The *Lygodium* curve is of especial interest and will be discussed in more detail later.

The sedimentary sequence between c. 1.7 and 3.0m, particularly between 2.5 and 3.0m, is complicated. Given the data in Hattori (1972) and Takaya (1972), the dark brown clay (Fig. 19) which overlies the thin layer of green (? marine) clay, may be of freshwater origin. The green layer has another dark brown clay, with a thin black horizon, and a light grey clay, over another thin brown band beneath it. The state of pollen and fern spore preservation shows significant changes in this

EXCAVATION OF KHOK PHANOM DI

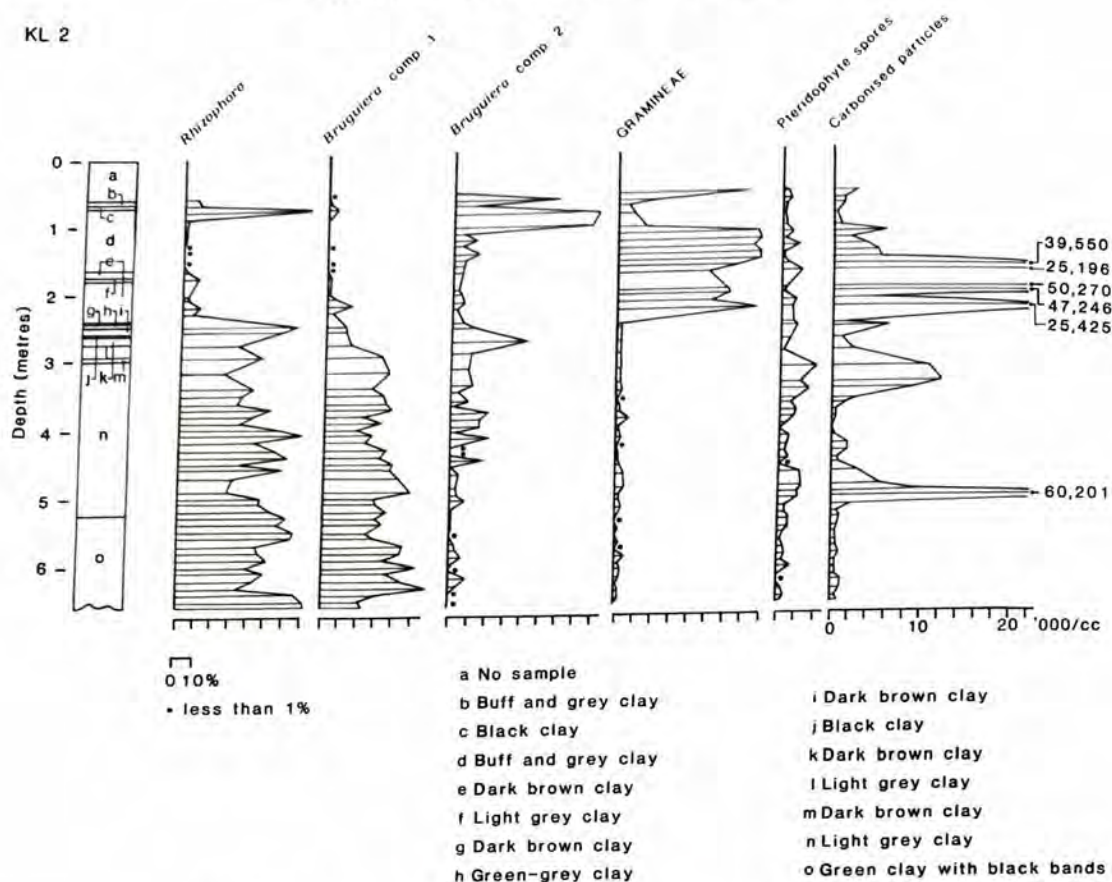


FIG. 20. The summary pollen diagram from KL 2

section of the diagram but without the extremes evident between 3.5 and 4.7m depth. Fresh pollen, largely of *Rhizophora*, attained a peak of 54 per cent at 2.61m but was replaced by corroded pollen, almost entirely of grass, at 2.32m and extremely corroded, and probably redeposited, grass pollen from 2.11 to 1.69m. This sequence of changes would not be inconsistent with a phase of agricultural activity involving some turning over of the soil by hoeing, but there may be other explanations, and the possibility of hiatuses in the stratigraphy must be considered. The sudden decline in mangrove elements around 2.5m depth and equally abrupt, and massive, increase in grass pollen percentages (Figs. 20 and 21) is, without consideration of the pollen and spore concentration data (Fig. 22) and the microfossil charcoal curve (Fig. 20), suggestive of a depositional hiatus. Taking microfossil charcoal first, this initially rose above background level around 5.0m depth and the large peak there may represent burning of natural or human origin long before Khok Phanom Di itself was occupied.

The charcoal curve declined thereafter but only returned to background level in samples from c. 3.5 to 4.3m depth. A renewed rise to a lower peak at c. 3.2m occurred and a decline ensued again. Both phases of higher than usual charcoal concentration are associated with peaks in the aggregated pteridophyte spore curve (Fig. 20), which comprises *Lygodium psilate* mainly, and this suggests that burning may have kept the vegetation on Khok Phanom Di rather open. So, a pattern of firing seems to have been established before the peaks associated with the large rise of the grass

pollen and it is likely that the increase in open vegetation gradually extended out, northwards, from the site as sea level declined and the environment became increasingly marginal for mangrove growth. The pollen and fern spore concentration figures (Fig. 22) support the view that mangrove vegetation gave way to a grass-dominated vegetation gradually, rather than suddenly, but those for *Lygodium* psilate are not strong. The decline in the monocotyledon leaf concentrations with the increase in grass pollen is apparently anomalous but can be explained by oxidation as a result of burning and of drying out of the land. The rise in *Bruguiera* comp. 2 pollen in percentage and concentration figures before the massive increase of grass pollen indicates clearly how important it is to attempt a closer determination of this taxon as a possible ecological indicator, especially so since it became significant before the rise of *Rhizophora* as grass declined at 0.9m depth. While a hiatus cannot be ruled out with certainty, the aggregate changes in the microfossil record shows such a high degree of consistency that alteration of the environment due to natural variations, aided and abetted by man, gives a satisfactory explanation without invoking a period of increased erosion. The increased concentration of algae other than diatoms (only the extremely rare desmid occurred), deriving from taxa such as *Spirogyra*, is suggestive of a change to damp non-marine conditions.

Returning to Fig. 19, most of the corroded pollen dominating the 1.11m sample consisted not of grass but *Bruguiera* comp. 2, although c. 33 per cent was from grass. The lithostratigraphy of the core from 0.7 to 1.7m depth consists of buff and grey clay, a likely oxidized acid sulphate soil. Oxidation may account for the poor state of the pollen and the dominant taxa could have survived while less resistant pollen and fern spores were destroyed by microbial activity. However, the 0.92m sample was dominated by fresh pollen of *Bruguiera* comp. 2 and that from 0.82m by fresh *Rhizophora* pollen. The black clay band evident in the lithostratigraphy may correlate with a similar thin (10–25cm) layer present in irrigation channel exposures south of the site and throughout much of the eastern half of the plain. The colour, peaty consistency and vegetation changes suggest that a short-lived marine transgression is indicated followed by a change to the present-day open grassland vegetation of a widely farmed landscape. Corroded grass pollen dominated the uppermost (0.62m) sample from the core with corroded or very corroded *Bruguiera* comp. 2 pollen and a significant percentage of grass pollen in that (0.72m) below it.

The longer pollen diagram (Fig. 21) indicates that fore mangrove taxa (*Avicennia*, *Sonneratia* spp.) were never of any importance and that pollen of less saline or more probably freshwater conditions, e.g. *Pandanus*, *Scirpus* comp. and *Typha angustifolia*, occurred sporadically, as indeed did a quite consistent, but low, percentage of grass pollen. Some of the changes in the lesser pollen and fern spore curves associated with the great phase of grass pollen dominance are worthy of comment. *Licuala* (see chapter IX) was of minor importance in three of the lower samples from the phase. *Licuala* is grown as an ornamental on Khok Phanom Di today and Pookajorn (1990) has reported macrofossil remains from prehistoric contexts elsewhere in Thailand. Chenopodiaceae/Amaranthaceae, likely ruderals, became slightly more important briefly, but more interesting are the weeds which are associated with wet rice cultivation (although they all can and do occur in other wet-land locations in the wild): *Scirpus* comp., Commeliniaceae, *Ludwigia*, *Monochoria*, *Nymphoides* and the fern, *Ceratopteris thalictroides*. Urticaceae/Moraceae pollen, again possibly from weeds in the nettle family, is rather more important in the lower part of the phase. The consistency in occurrence of all these palynomorphs offers circumstantial evidence, but not definite proof, of an agricultural landscape with the probability of rice cultivation. Pollen from a range of possible upland taxa occurs sporadically (Table 8), e.g. the gymnosperms *Dacrycarpus imbricatus*,

Dacrydium elatum, *Pinus* spp., *Podocarpus* spp.). Additionally there is some pollen from trees, small trees and shrubs which would have occurred naturally in the lowlands, on Khok Phanom Di itself, or in other dryland locations, viz. *Cassia* id. *siamea* comp., *Quercus*, *Shorea* comp., *Grewia* comp., *Ardisia* comp., etc. Some pollen from genera which include cultivated fruit trees occurs: *Citrus* comp., *Eugenia* comp., *Decaspermum*, *Zizyphus* comp., and an isolated pollen grain from *Passiflora* id. (resembling *P. foetidum*) at 2.05m depth, but nothing which can be attributed with certainty to a cultivar.

The grass pollen grains have been graphed in Fig. 23, which shows the number in each μm class found during the counting of each sample. No attempt has been made to count samples until a statistically reliable number of grass pollen grains has been encountered, but obviously the data pertaining to those samples which contain a lot of grass pollen are more useful for further discussion than those which only contain little. Additionally, the records from the longer cores are best interpreted by comparison with those from the short (25cm) BMR 1 (Fig. 34) size distributions and those from KL 2, except that some KL 2 samples have rather more pollen in the likely size range of rice (c. 31–40 μm). The number of very small grass pollen grains (14–15 μm in size) is somewhat surprising. These may be immature pollen grains from taxa with a higher modal diameter, but most Sumatran taxa studied produced larger pollen grains (Maloney 1990). Exceptions were *Eragrostis elongata* and *E. unioloides*, although even their modes were at 22 and 20 μm respectively. *Leersia hexandra*, a wild grass in the same sub-group as rice (*Oryzae*), had a mode at 23 μm but ranged from 19 to 24 μm in diameter. A number of grasses, including *Imperata cylindrica*, had modal values of 26 or 28 μm , but that of rice was at 36 μm and *Lophatherum gracile*, a forest grass present at Khok Phanom Di, at 33 μm , although a lesser peak occurred at 28 μm . A Sumatran specimen of the other forest grass present at Khok Phanom Di, (*Oplismenus compositus*) had a mode at 37 μm .

Below 2.5m depth most KL 2 grass pollen grains were 18 μm in diameter and the pollen was almost certainly derived from weed species such as *Eragrostis* with very little contribution from the 26–28 μm group. This changed considerably between 1.2 and 2.5m: the 18 μm group became more important than ever before but smaller, 14–15 μm , and larger likely weed grass pollen was also much more abundant. At the end of the phase the 18 μm group remained the most significant while almost all the others declined. The second phase of grass pollen domination in the uppermost part of the core was characterized by a return to the grass pollen grain size distribution pattern of the 1.2–2.5m section.

While pollen grains at the lower end of the size range were not infrequent and occurred more or less throughout the core, those from the opposite extreme were far less plentiful and were only present during the two phases of grass pollen domination. The 42.5–47.5 μm pollen grains are in the upper extreme of the rice range but, on Sumatran experience, are more typical of *Themeda* although pollen at the lower end of the *Coix* range or a wild tetraploid rice are other possibilities. A specimen of Sumatran *Oryza rufipogon* had a mode at 37 μm and a range from 34 to 42 μm . It is unlikely that, even with more detailed study, firmer conclusions can be reached about which grasses produced the pollen grains of different sizes but some of that of 25.5 μm and over had the more coarsely scabrate surface patterning which is typical of *Paspalum* and does not occur in the other taxa mentioned. The preparatory treatment involving use of hydrofluoric acid in most cases has undoubtedly led to some reduction in grass pollen size, but this is unlikely to have been so great as to affect the general conclusions.

Pollen core BMR 2

This core was derived from the edge of a ricefield which was a virtual *Eleocharis* back-swamp until a few days before the core was extracted when the water was drawn off the land. Indeed, the uppermost sediment was still too fluid to be retained in the borer and the top few centimetres had to be obtained by coring on slightly firmer ground nearby. The latter core has been labelled BMR 1. The lowest sediment from BMR 2 (Fig. 24) comprised a stiff white clay overlain by a few centimetres of grey, orange and white banded clay. The 2.0–6.5m section of the core consisted of green clay-sands with some shell bands and dark, more organic, bands. There were few dramatic changes in pollen and pteridophyte spore preservation status and a minimum of 30–40 per cent fresh palynomorphs occurred except in two samples from around 5m depth and another from 3.1m. So, there is a marked contrast with core KL 2. *Rhizophora* was the main contributor of corroded pollen grains in the former case and both *Rhizophora* and *Bruguiera* comp. 1 in the latter. *Rhizophora* dominated the pollen spectra of this part of the diagram (Fig. 25) but the aggregate pteridophyte spore curve was also quite strong, with a peak just above 4m in depth which seems to correlate with the first major peak in the KL 2 core. Unlike core KL 2, however, the charcoal concentration curve never rose beyond background level. The *Rhizophora* dominance seemed to be real (Fig. 26) as it consistently had the highest concentration figures. Therefore, while *Bruguiera/Ceriops* forest appears to have been present at the KL 2 coring site, BMR 2, slightly further out from Khok Phanom Di, was very probably under *Rhizophora* forest. Neither the percentage nor concentration curves were so smooth as to indicate that bioturbation by burrowing organisms had been of major importance, but it would be foolhardy to ignore this possibility in interpreting the pollen diagram.

As at KL 2, *Bruguiera* comp. 2 became important in both percentage (Figs. 25 and 26) and concentration terms (Fig. 27) before the increase in the grasses, but *Rhizophora* remained of importance. An earlier rise of *Bruguiera* comp. 2 between c. 4.5 and 5.0m depth also appears to have been real and suggests that bioturbation has not been significant. *Bruguiera* comp. 1 was never as important as in core KL 2 but, again, the monocotyledon leaf concentrations showed a general inverse relationship with the figures for *Rhizophora*. If extreme tides were responsible for the redeposition of *Rhizophora* pollen at KL 2, one might expect similar evidence from BMR 2. The fact that this does not seem to occur is rather puzzling. This may be a result of the wide sampling interval but is readily explainable if *Rhizophora* was growing at the northern edge of Khok Phanom Di and the pollen was eroded out and redeposited during periods of disturbance of the vegetation on the mound. Intuitively, this explanation is unsatisfactory. It does not accord with the assumed temporal relationship between the cultural and natural stratigraphies under consideration. Moreover, the correlation of the c. 5m depth and, possibly, the 3.1m sample, with their increase of corroded pollen and the 3.72–4.61m samples from KL 2 with their own more heavily corroded *Rhizophora* pollen is more satisfactory and suggests that the initial interpretation may be correct after all. The fact that later changes are reflected but not with mirror-like veracity in both cores indicates that one might expect the earlier ones to be evident also, especially since the cores do not come from that far apart (Fig. 16). The further finding that the peaks for torn palynomorphs are generally consistent between the cores, if this correlation is accepted, argues for it being correct. *Lygodium* psilate fairly consistently has a high percentage of torn spores and *Rhizophora* is the main pollen contributor of mechanically damaged grains. This is similar to findings from KL 2.

The upper part of the BMR 2 core (Fig. 24) was more varied lithostratigraphically and pollen and fern spore preservation status exhibited changes more readily correlated with those from KL 2. Grey clay, with some inwashed wood, occurred below about 1.3m depth and this may represent an acid sulphate soil horizon. Both the 1.99 and 1.93m samples had major increases in extremely corroded pollen grains, mainly of *Rhizophora*, but the percentages of such badly preserved pollen rapidly decreased upwards, with fresh mangrove pollen regaining dominance. The peaks of redeposited pollen seem to correlate with those from similar depths at KL 2 except that grass is not the dominant pollen type involved.

The pollen diagrams (Figs. 25 and 26) showed that *Rhizophora* was the dominant taxon but that it was replaced by *Bruguiera* comp. 2 above 1.3m depth. The large percentage peaks of grass pollen present in core KL 2 became very much smaller ones at BMR 2 and this suggests that the interpretation of vegetation disturbance on the mound, with pteridophytes replaced by grass, but possibly without cultivation, may have at least partial validity. Perhaps the most likely explanation is that disturbance of this kind, together with some small-scale agricultural activity associated with measures for water control, probably not very sophisticated, took place immediately north of the site. The pollen concentration data (Fig. 27) suggest that *Rhizophora* most definitely grew at the BMR 2 coring site and that it was replaced by *Bruguiera* comp. 2. However, the increase in microfossil charcoal associated with the rise of grass pollen at KL 2 is also most emphatically present at BMR 2 (Fig. 25). The lack of algae indicates that if KL 2 was under wet rice agriculture, BMR 2 was almost certainly not, and that what grass pollen is there was derived from outside the coring locality. The 0.3–1.3m section of the core comprised what is definitely an acid sulphate soil horizon consisting of buff and orange clay separated from the grey clay by a thin band of the green, marine clay. Percentages of fresh pollen decreased from 60–70 per cent to less than 10 per cent and the 0.99m sample contained over 20 per cent corroded pollen, almost all of *Bruguiera* comp. 2. This gave way upwards to an increase in extremely corroded pollen, mainly of grass. The top few centimetres of the core was composed of dark brown clay probably formed under freshwater conditions. Fresh pollen increased, consisting mainly of *Scirpus* comp. and Urticaceae/Moraceae psilate in the uppermost sample. The fuller pollen diagram (Fig. 26) revealed evidence for vegetation changes of note not apparent from that simply showing the main taxa. The lowermost sample had a significant peak of *Pandanus* pollen and this, with the presence of other elements which could grow in freshwater swamp forest, suggests that the landward margin of mangrove forest may be represented. As in the KL 2 core, *Lygodium* psilate comprised the bulk of the pteridophyte spores in the diagram preceding the increase of grass pollen. The phase where grass pollen began to increase showed other changes of note, with minor peaks of *Elaeocarpus*, *Excoecaria*, *Cycas*, *Pandanus* and *Scirpus* comp. Unfortunately it has not been possible to identify the *Avicennia* pollen to the species, but if it is from *A. officinalis*, the landward margin of mangrove forest is indicated (cf. Macnae 1968:93). The increase in percentage of *Excoecaria*, which (Caratini *et al.* 1973) may be under-represented in relation to its importance in the vegetation, like *Avicennia* itself, and *Cycas*, is consistent with a drier back mangrove vegetation and *Elaeocarpus*, *Pandanus* and *Scirpus* comp. with a freshwater environment. The figures for monocotyledon leaf concentrations decreased markedly at this stage but an explanation of this has been given in relation to KL 2.

The grass pollen curve is not as simple as that from KL 2, but the concentration data confirm that the minor peaks and the changes are real and not an artefact of the percentage method (Fig. 27). The two extreme peaks in the concentrations of *Bruguiera* comp. 2 are not likely to be genuine. So much

of this pollen type was present in relation to the number of fossilized, stained, *Lycopodium clavatum* spores added that the estimated concentration figures for the samples concerned are unreliable. Nevertheless, *Bruguiera* comp. 2 was obviously an important component of the vegetation in the 0.75 to 1.5m section of the diagram, much more than at KL 2, where the isolated peak is an artefact. The lack of algae except in the uppermost grass-dominated samples is another important difference in the records of the two cores.

The minor taxa in the pollen diagram (Fig. 26) included *Eugenia* comp. and, once only, *Garcinia* 3 and *Citrus* comp. The only other pollen represented which could conceivably be from a cultivar is that of *Piper* but this was not abundant. The taxa showing a less than 1 per cent presence (Table 8) had some significant inclusions, however: *Areca* at 2.21m, just before the grass rise, and in two upper samples, and *Cocos nucifera*, almost certainly cultivated, in the upper four levels. *Bombax* (kapok) occurred at 5.2m depth but it would not be safe to conclude that it too was from a cultivated tree. Two additional types of *Garcinia* pollen were present in isolated samples (*Garcinia* 1 at 2.21m depth and 4.99m and *Garcinia* 2 at 3.49m). Examination of reference material and the literature suggests that the pollen grains of this genus fall into a number of morphological groups but not enough types have been examined to draw any conclusions about the possible distinctiveness of *Garcinia mangostana* (mangosteen) pollen. A detailed study may reward both the plant taxonomist and the pollen analyst.

The pollen of *Licuala* comp. recurred at BMR 2 and was present at 0.3m, 1.75–1.87m, 1.99m and 3.99m depths. Its persistence during the phase of increased grass pollen might be significant but no firm conclusions concerning the status of this taxon can be drawn. Rather, a large number of minor taxa occurred in total and the list, like that from KL 2, contained small percentages of pollen which could be derived from forests growing at a range of altitudes. The herbs *Ludwigia* and *Nymphoides* were not as well represented as in the KL 2 core, with most finds in the uppermost four samples.

The fern spores included *Asplenium* sp. (? spp.), epiphytes more typical of freshwater environments than mangrove forest, and possibly growing in the vicinity of the core (one would expect the spores to be very locally dispersed) at 4.1–4.2m depth.

The distribution of grass pollen grain sizes (Fig. 28) compares quite well with data from the KL 2 core. The spreads in the uppermost four samples, which included most of the grass pollen in the size range of rice, closely paralleled some of those from the great phase of grass pollen domination evident at KL 2. Pollen of rice size was, not unexpectedly, far less frequent in association with the section exhibiting minor grass peaks. As at KL 2, some pollen in the rice size range occurred in lower samples with less abundant grass pollen. The bulk of the pollen in every sample containing grass is also likely to be from wild species. The presence of some very small (14–15 μ m) grass pollen was, again, noteworthy but this core had less at the other extreme of the range. The conclusion, based on pollen grain sizes and the occurrence of appropriate weeds, that rice was cultivated during the later part of the record is reinforced but still cannot be proven.

Pollen core FP 3

This core (Fig. 16) was extracted from an irrigation canal located north-west of the site and, unfortunately, the upper 0.9m of the record to ricefield level is missing. The lithostratigraphy (Fig. 29) was dominated by green marine clay but two dark grey clay horizons occurred in the upper part of the core. The top 0.35m comprised a soft, black mud of likely recent origin. Apart from the 0.9

and 1.1m samples, which came from this black mud, the core was massively dominated throughout by extremely corroded Rhizophoraceae pollen. The 0.9m level, however, contained 51 per cent fresh pollen, mostly from *Albizia procera* comp. The taxon which produced this must have been growing nearby as *Albizia* is not wind pollinated. Gramineae pollen, mainly corroded (Fig. 30), replaced *Albizia*, at 1.1 m depth. *Rhizophora* dominated the rest of the core, although c. 10–20 per cent *Bruguiera* comp. 1, more in a few samples, was present throughout. *Bruguiera* comp. 2 had an isolated but important peak of 18 per cent at 1.3m. depth and most of its pollen too was extremely corroded. The Rhizophoraceae percentages were so high that, if the conclusions of Hillen (1983) and Grindrod (1985) are to be accepted, mangrove forest was almost certainly growing at the coring location for almost all the record extracted. However, the strong and consistent degree of corrosion of pollen could be used to argue a case for deposition in shallow marine conditions. Microfossil charcoal did not make an important contribution to this core, nor did pteridophyte spores. The pollen concentration data (Fig. 31) more or less confirm the percentage record with *Bruguiera* comp. 1 as a significant contributor almost throughout. *Bruguiera* comp. 2 and Gramineae were not as prominent in the upper part of the diagram in concentration terms as in percentages. As in cores KL 2 and BMR 2, the monocotyledon leaf concentration curve showed a general inverse correlation with the *Rhizophora* curve but the number of particles present was less and the peak values were not generally as extreme (Fig. 31). Algae were absent. The longer pollen diagram (Fig. 32) adds little to the story. *Pandanus*, present on the margins of Khok Phanom Di and on wider ricefield bunds locally, had an isolated minor peak at 1.1m and *Licuala* comp. at 0.9m depth, while possible weed pollen (Chenopodiaceae/Amaranthaceae, *Cyperus* comp., *Scirpus* comp., Commeliniaceae, Urticaceae/Moraceae psilate) was commonest in these two samples.

Lygodium psilate was, again, the most frequent fern spore type throughout. The table of minor taxa (Table 9) was far less diverse than for cores KL 2 and BMR 2 although not dissimilar in the presence of some gymnosperm pollen and a low pollen content of other dry land taxa. *Eugenia* comp. pollen occurred sporadically, but, more importantly, *Artocarpus* comp. and *Cocos nucifera* were present in the 1.1m sample, and *Ricinus* comp. (but this pollen could be from *Homonoia*, see chapter IX) at 2.2m depth. *Ricinus communis* is cultivated in gardens on the slopes of Khok Phanom Di today. The *Momordica* pollen type (0.9m depth) could be from the cultivated *M. charantia* but Suvatti (1978) made no mention of cultivation of *Melothria* (1.1m depth) in Thailand. Possible ricefield weeds were confined almost entirely to the upper two samples and it was these (Fig. 32) which contained most grass pollen. A small number of grains in the size range of rice occurred but the general distribution resembled that of the top four samples from BMR 2.

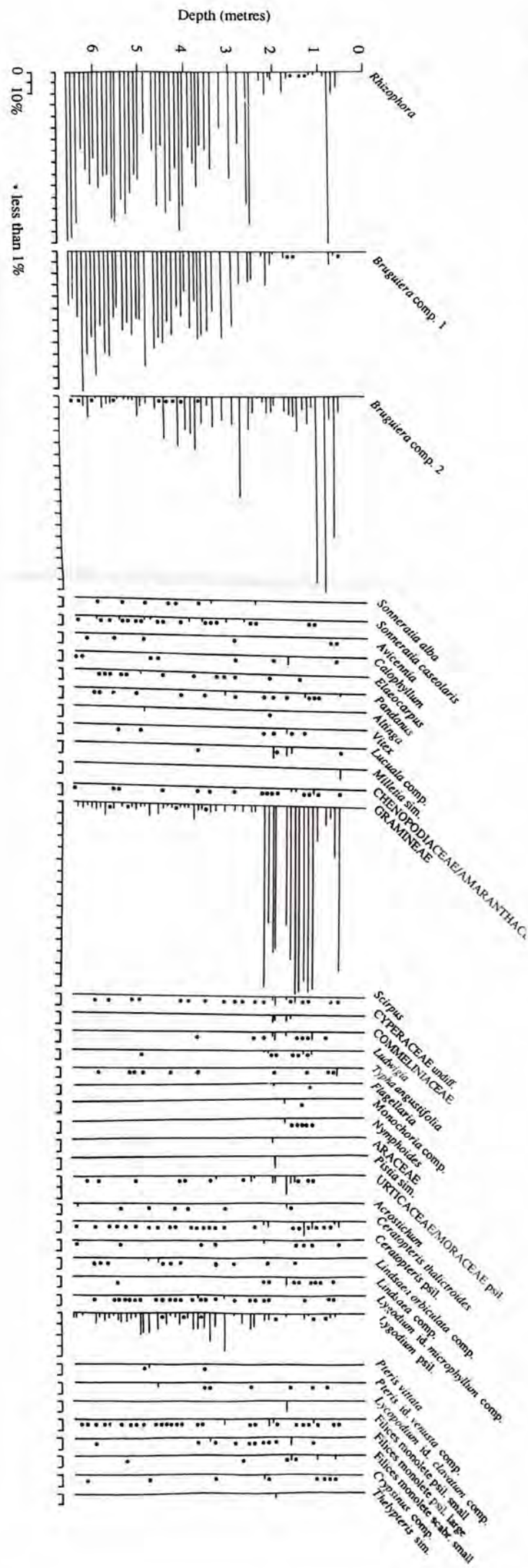
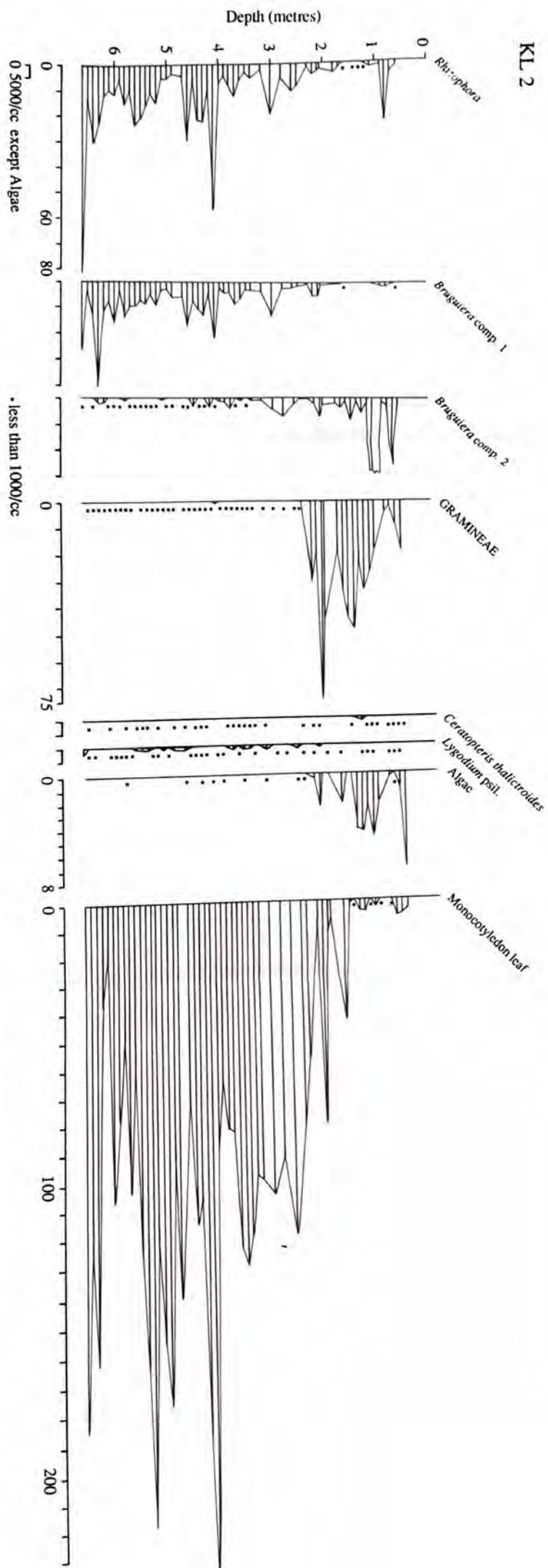


FIG. 21. The complete pollen diagram from KL 2



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FIG. 22. The pollen concentration diagram from KL 2 including monocotyledon leaf fragments and algae

KL 2

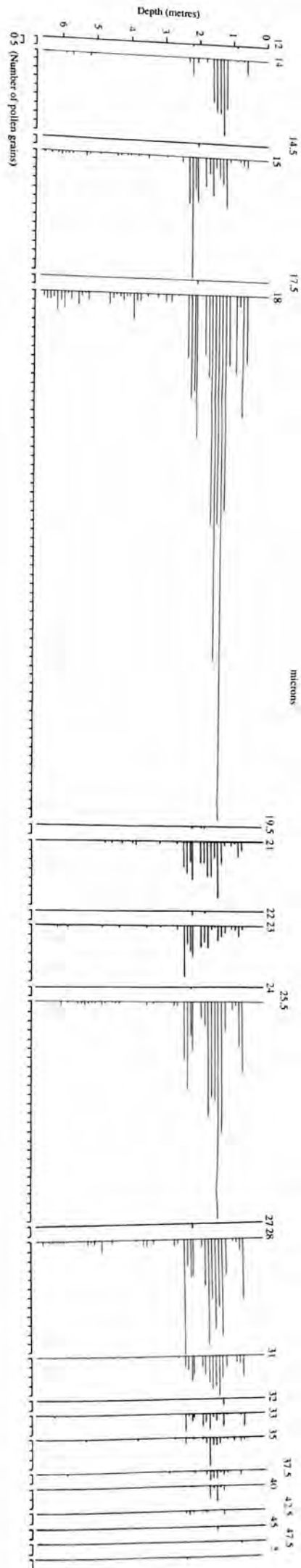


FIG. 23 The sizes of the grass pollen from KL 2

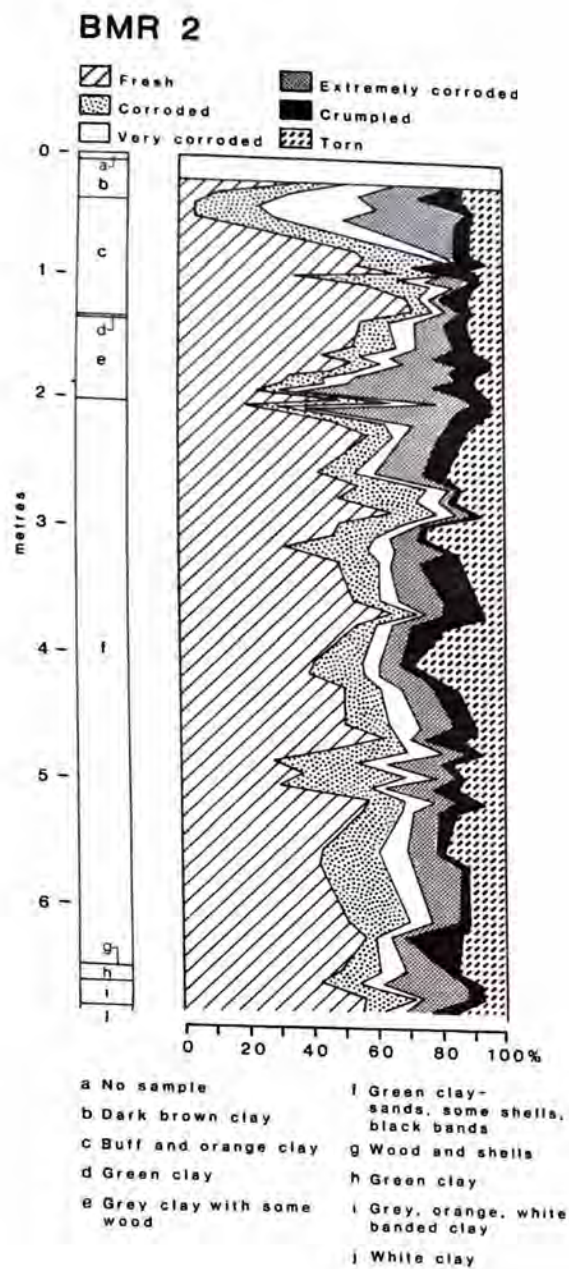


FIG. 24. The lithostratigraphy and pollen and fern spore preservation from core BMR 2

BMR 2

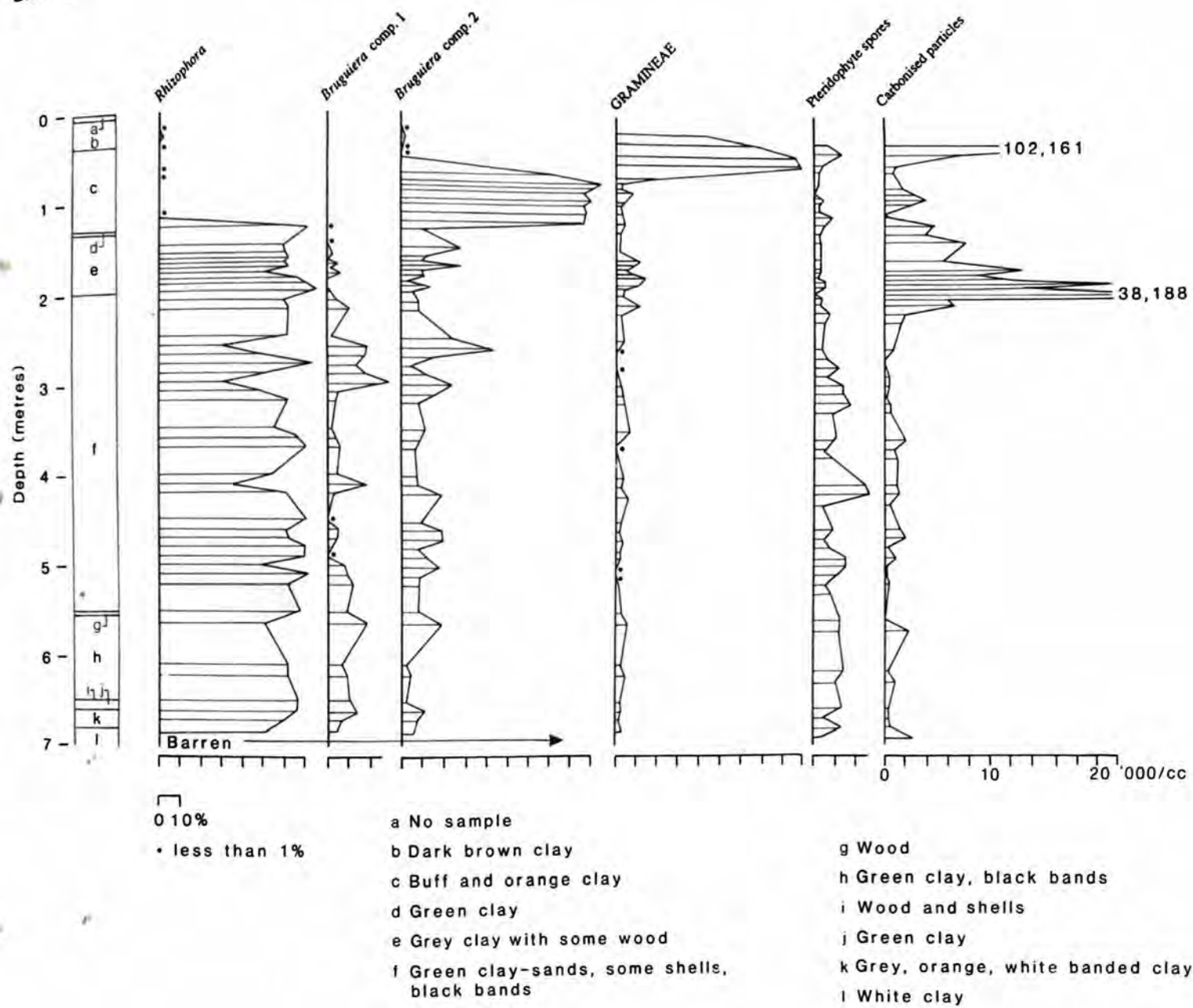


FIG. 25. The abbreviated pollen diagram from BMR 2

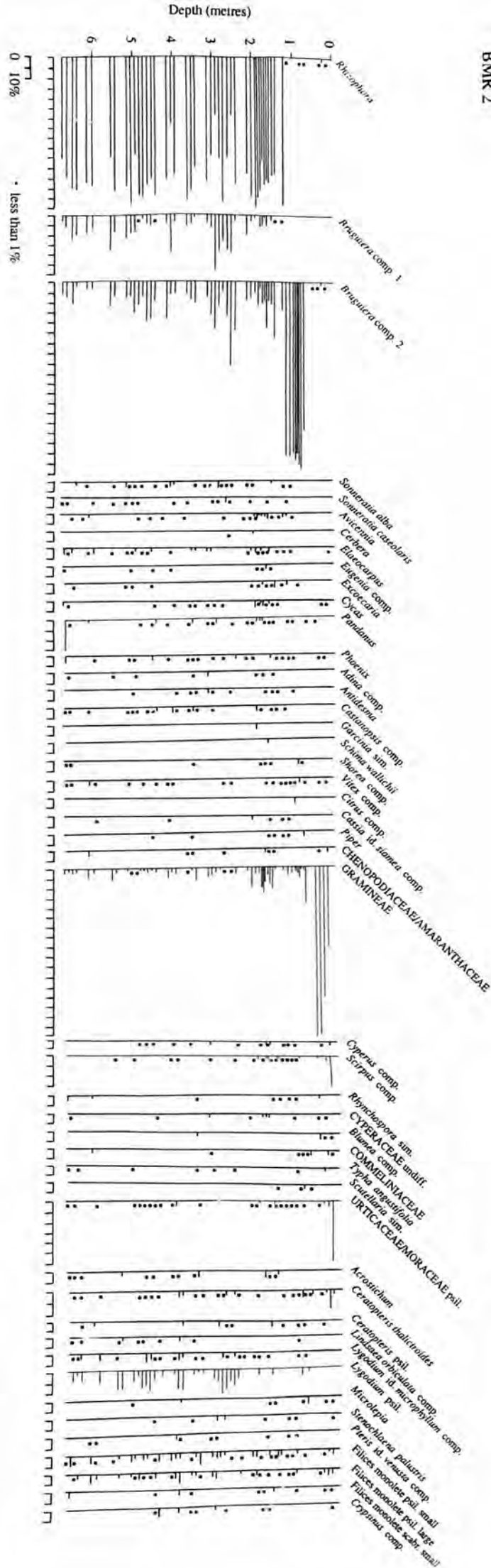


FIG. 26. The complete pollen diagram from BMR 2

BMR 2

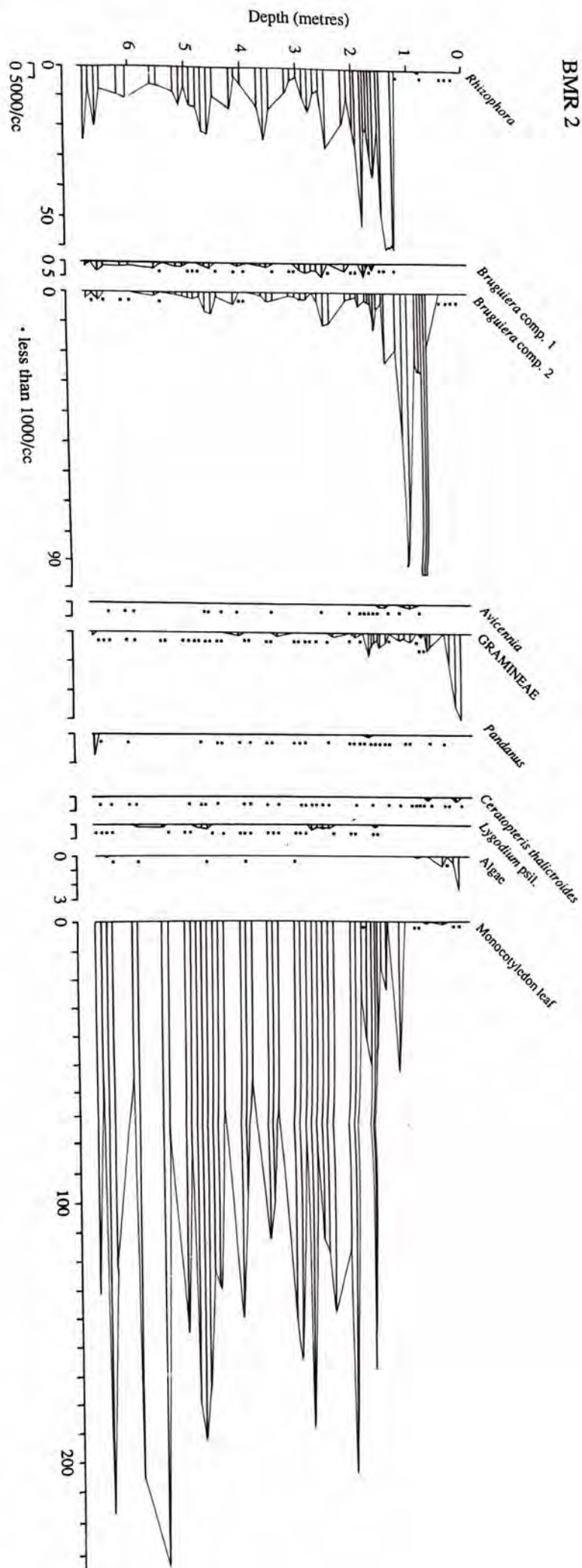


FIG. 27. The pollen concentration diagram from BMR 2 including monocotyledon leaf fragments and algae

BMR 2

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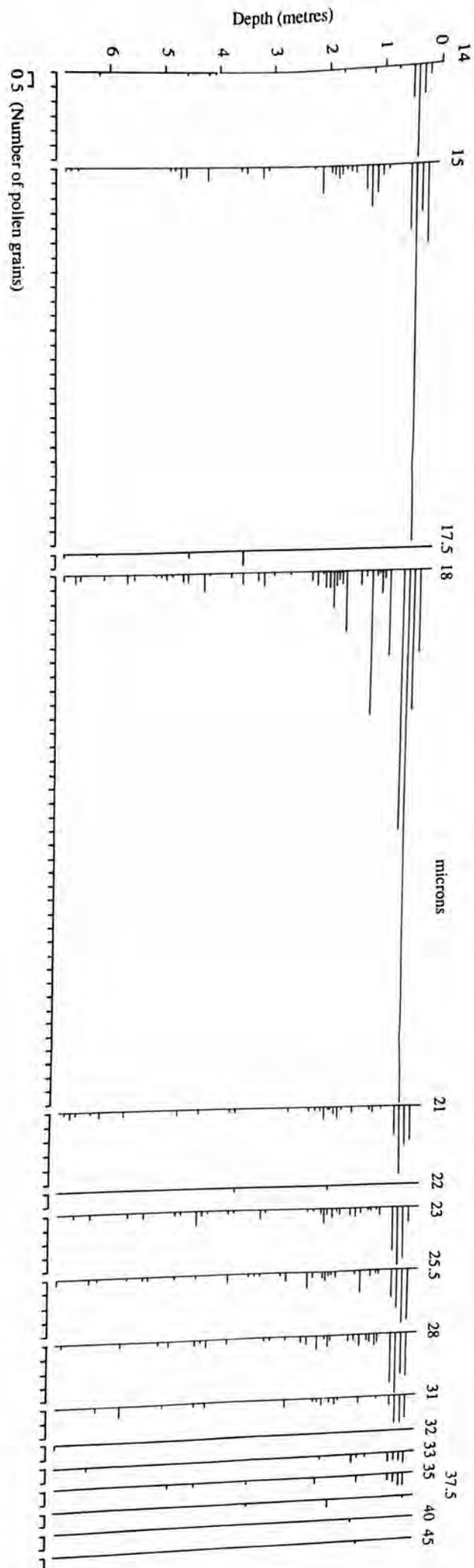


Fig. 28. The size of the grass pollen grains from BMR 2

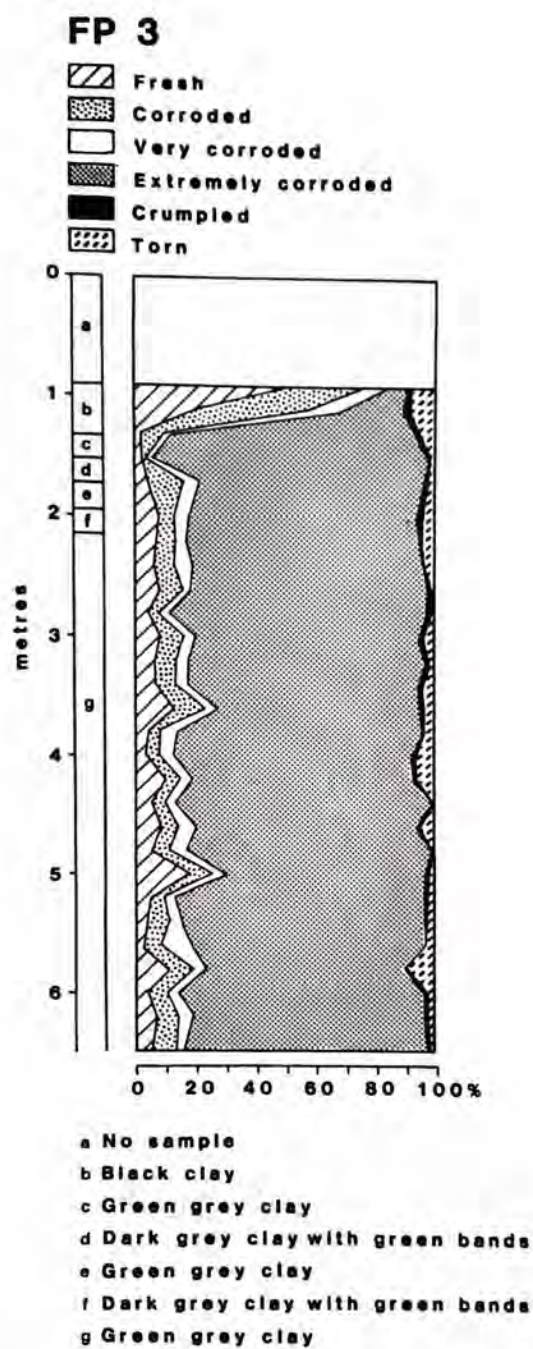


FIG. 29. The lithostratigraphy and condition of the pollen from FP 3

FP 3

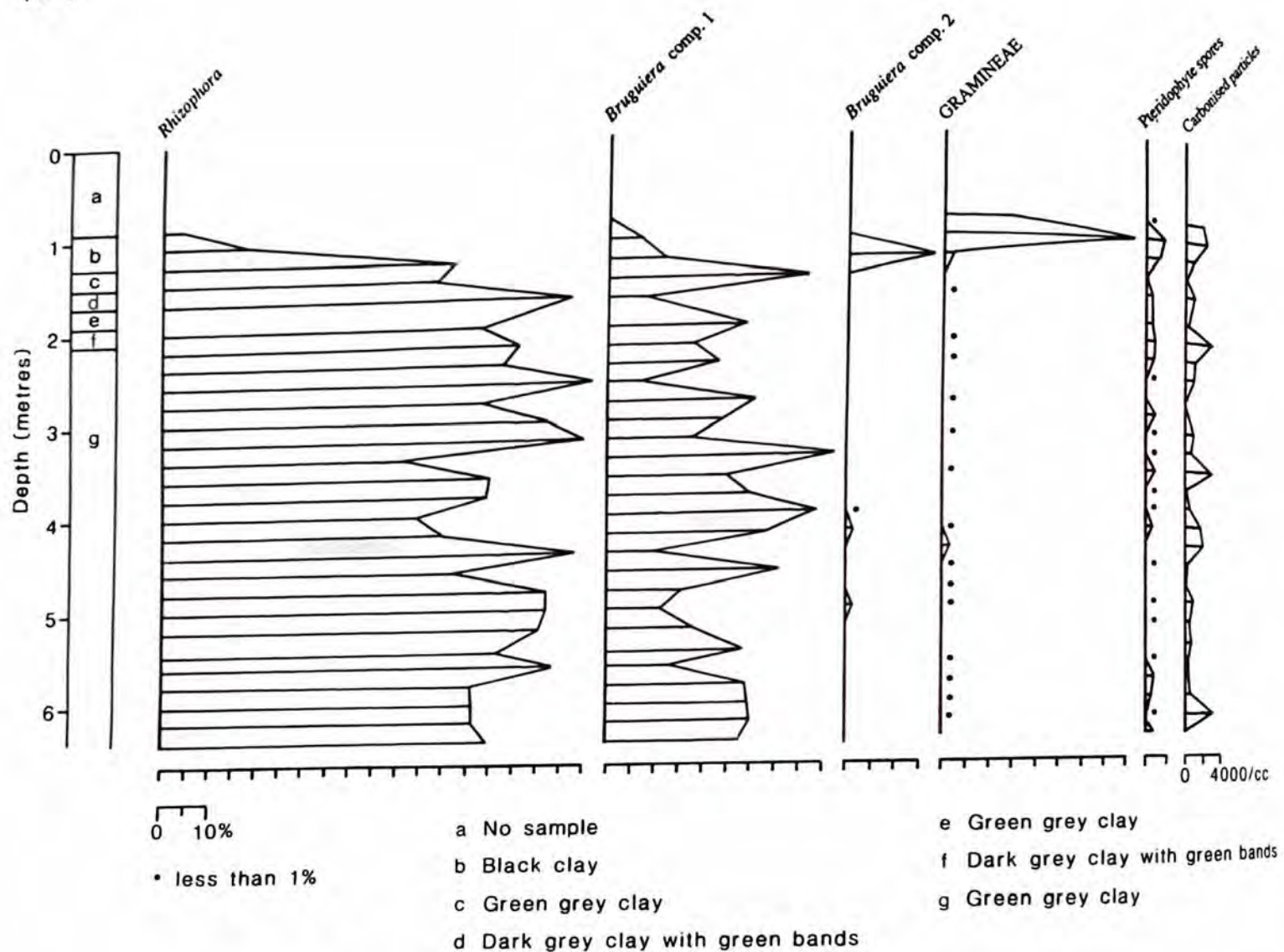


FIG. 30. The abbreviated pollen diagram from FP 3

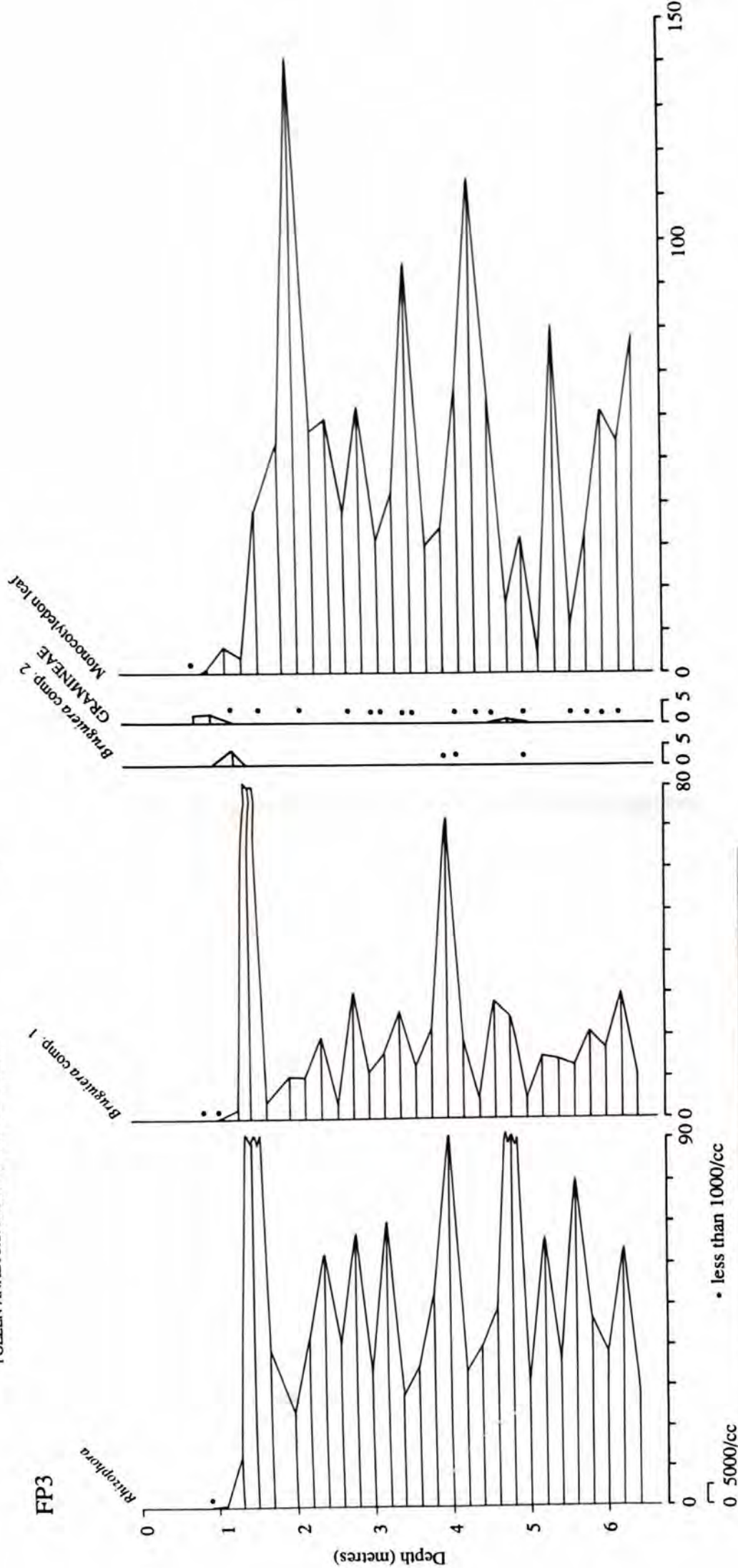


FIG. 31. The pollen concentration diagram from FP 3 including monocotyledon leaf fragments

FP3

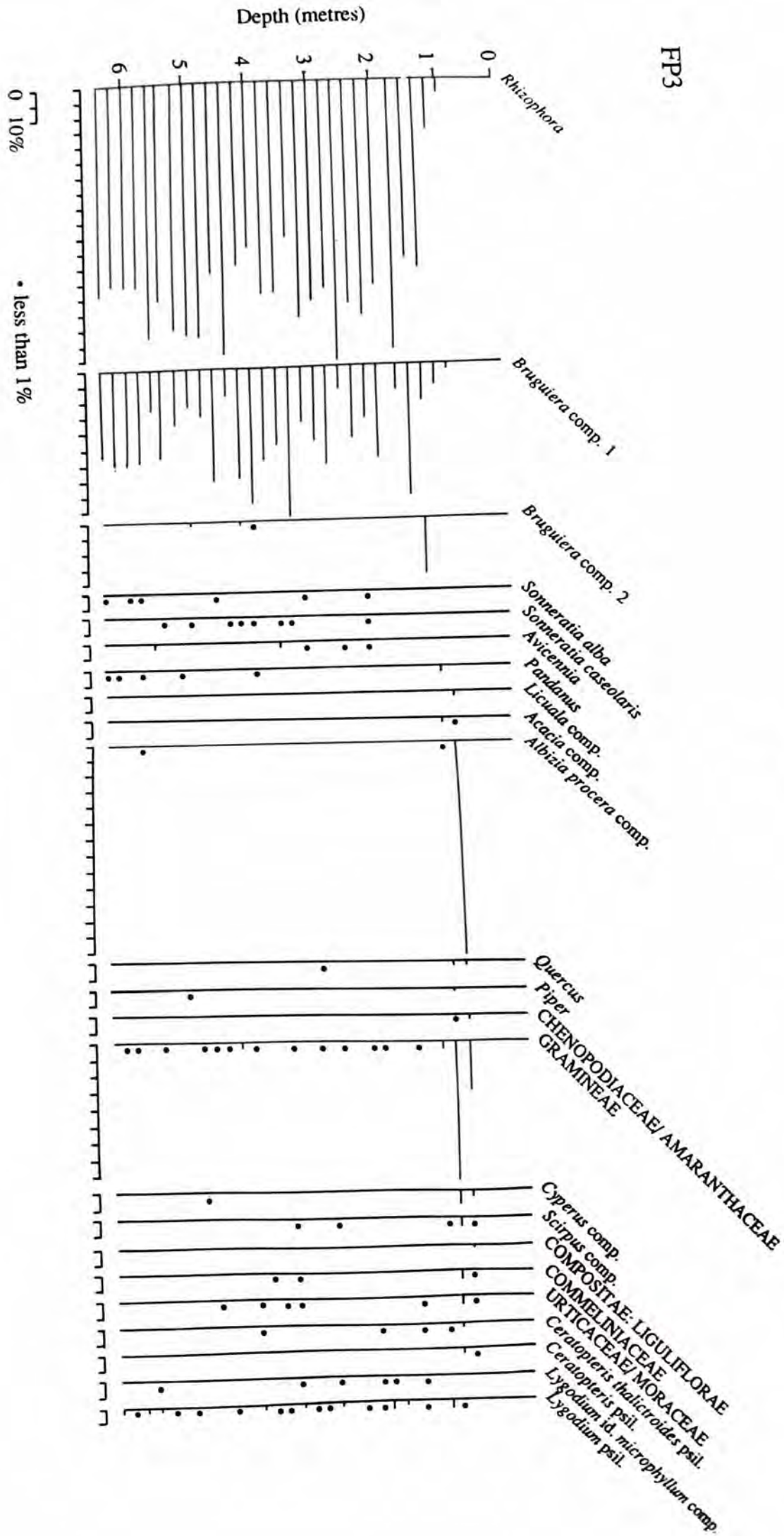


FIG. 32. The complete pollen diagram from FP 3

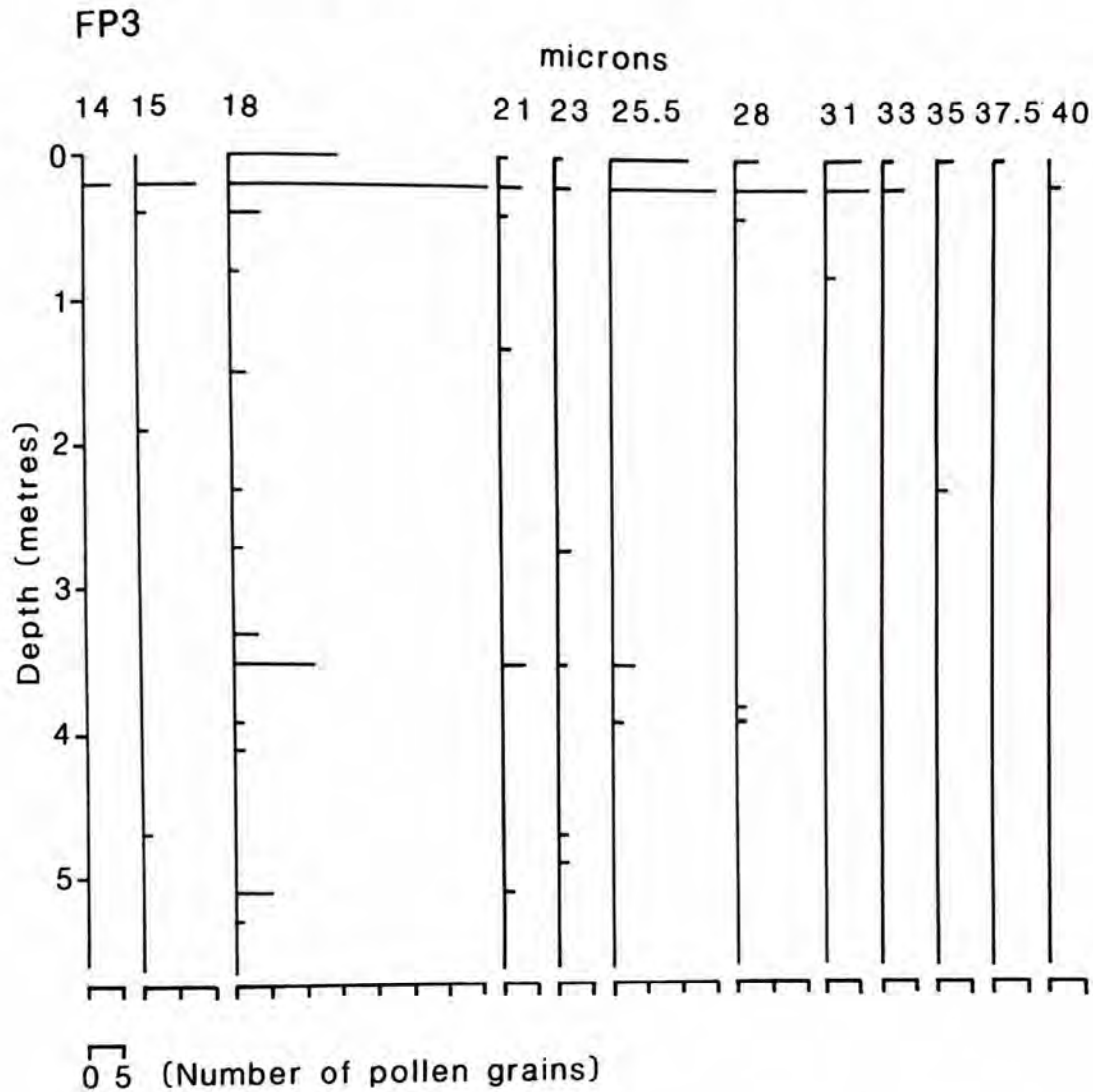


FIG. 33. The size of the grass pollen grains from FP 3

Pollen core BMR 1

As mentioned previously, this was extracted from the same field as BMR 2, as close to it as possible, and comprised 0.25m of sediment. Five samples were analysed and all were found to be massively dominated by grass pollen although pollen concentrations (Fig. 34) only ranged from 15 to 34,000 per cc of deposit, gradually increasing downwards. Corroded pollen occurred most frequently in the surface sample and very corroded pollen in that from 0.22m depth, otherwise corroded pollen had marginally the largest percentages, and large-scale redeposition did not appear to be evident. *Ceratopteris thalictroides* was the most important pteridophyte spore type and its highest percentage occurred in the surface sample, although concentration figures were low at all levels.

BMR 1

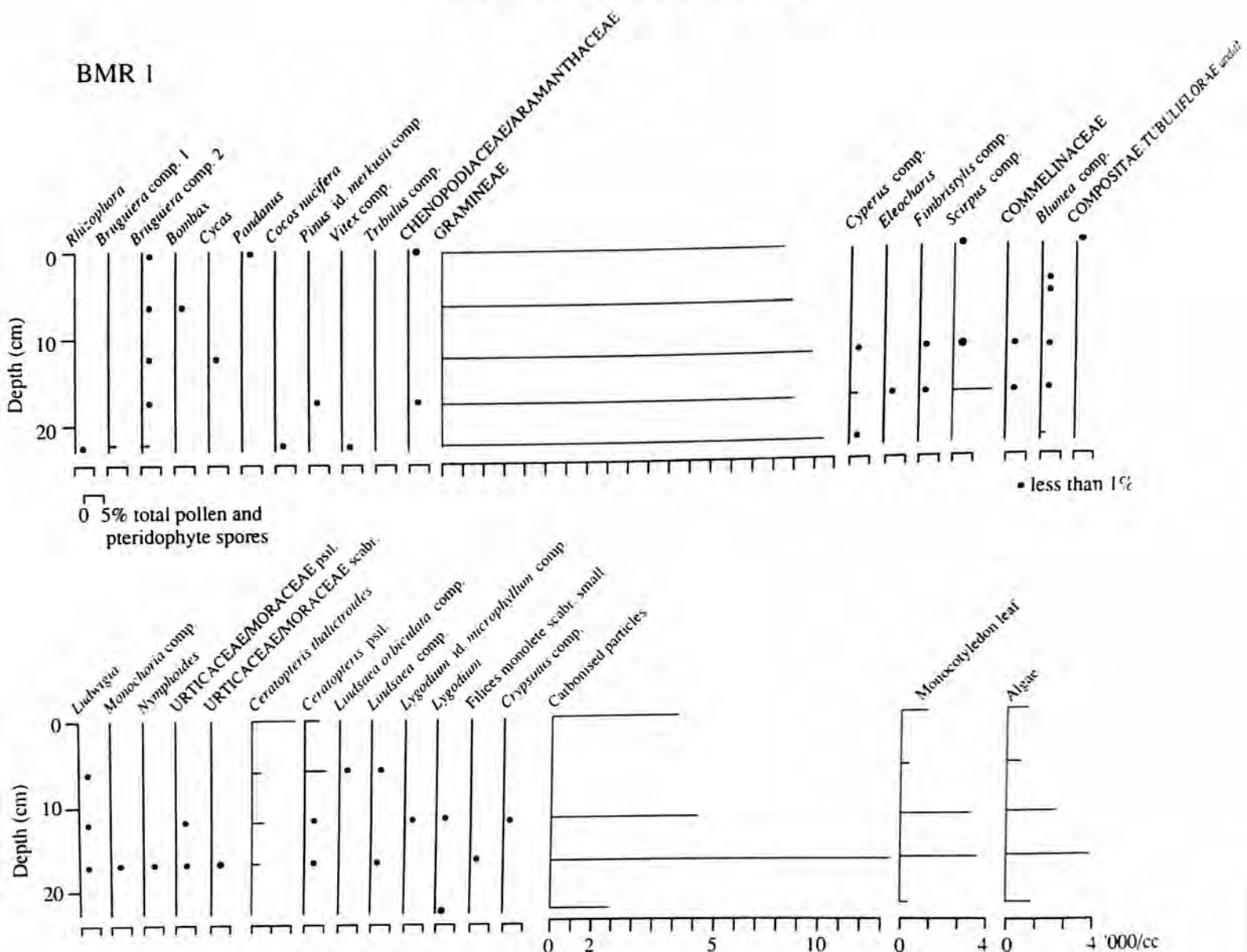


FIG. 34. The pollen diagram from BMR 1

Cyperus comp. and, especially, *Scirpus* comp. were rather commoner in the 0.17m sample and Chenopodiaceae/Amaranthaceae in the two samples above this, while *Bruguiera* comp. 1 and *Bruguiera* comp. 2 contributed more than 1 per cent to the basal (0.22m) level. *Bruguiera* comp. 1 was present in all the samples, however, suggesting that some redeposition of pollen from older to younger materials had taken place. Pollen of likely ricefield weeds was most frequent, but not abundant, at a depth of 0.17m. The intuitive impression, supported by the data on grass pollen grain sizes, is of a phase of rice cultivation followed by abandonment, with *Ceratopteris*, weed grasses and Chenopodiaceae/Amaranthaceae (possibly) taking over, and, perhaps, despite

BMRI

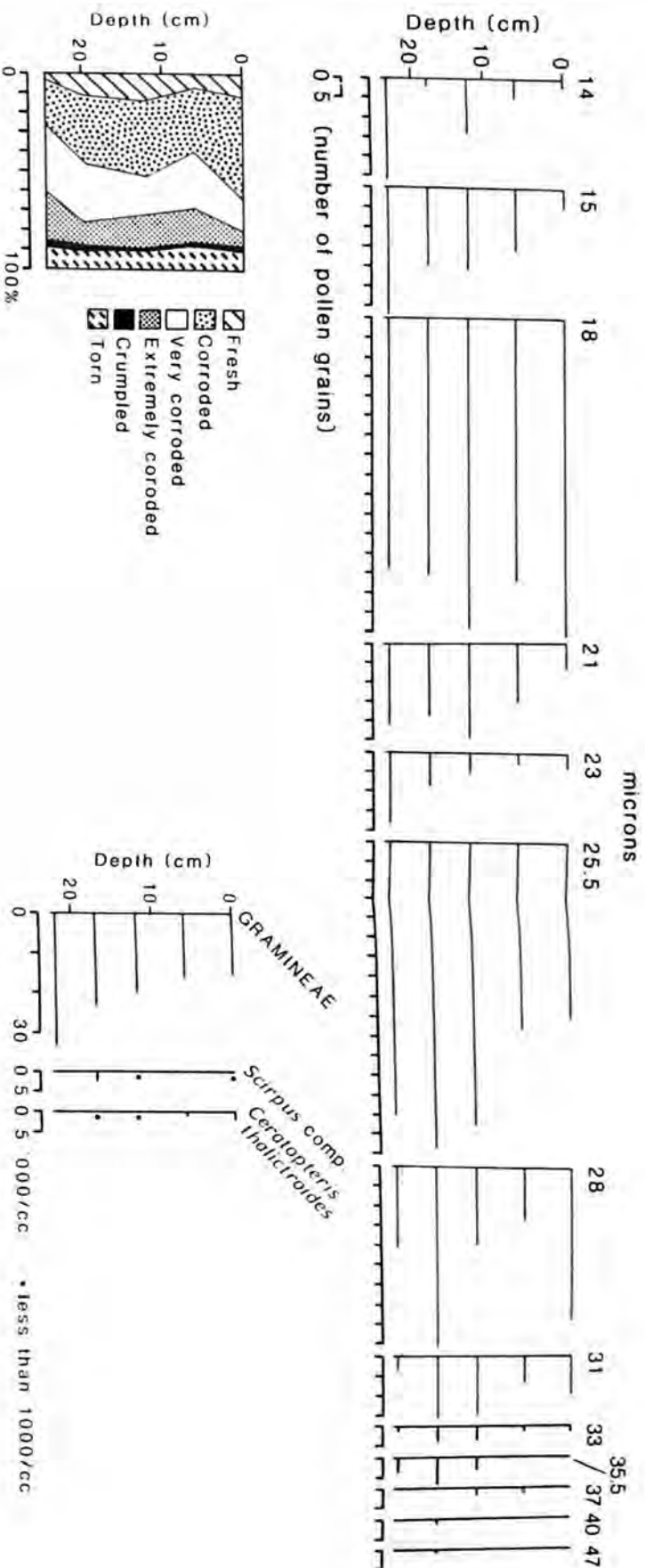


FIG. 35. The size of the grass pollen grains from BMRI

the fact that the field was under water for most of the time that the writer was at Khok Phanom Di, a change to generally drier conditions (Fig. 35). Unfortunately the length of time over which these alterations have taken place cannot be established without radiocarbon dating. The highest microfossil charcoal concentration occurred in the 0.17m sample and may represent burning of stubble after a phase of cropping. Monocotyledon leaf, although never abundant, was commonest

in this sample and the one above it, as were the algae. Pollen of two likely cultivars was present, *Cocos nucifera* at 0.22m and *Bombax* at 0.06m.

The size distribution of the grass pollen grains was not noticeably different from that of the upper parts of other cores and some very small grass pollen grains occurred again.

Pollen core KL 6

This was derived from an irrigation canal located north of the site but further out than BMR 2 and the top 0.95m of deposit to ricefield level is missing. Only six samples have been analysed and diagrams are not presented here, although the lithostratigraphy has been evaluated in chapter V. As at FP 3, the upper few centimetres consisted mainly of fluid black mud. This was underlain by buff and orange clay, an acid sulphate soil horizon, from c. 1.2–2.2m depth, with about 0.5 m of dark grey clay above almost 5m of green marine clay. Two of the samples analysed were from the buff and orange clay while the others were from the green marine clay. All had almost identical pollen spectra, dominated by *Rhizophora* (55–70 per cent representation) and *Bruguiera* comp. 1 (25–35 per cent representation), and most of the pollen was extremely corroded, suggesting that redeposition had occurred. Pollen concentrations were low in the upper two samples and the lowest one (from 7.4m depth). In each case, however, the dominance of *Rhizophora* and *Bruguiera* comp. 1 in the vegetation, indicated by the percentage data, was real. Grass pollen was only of any importance in the uppermost sample (1.3m depth) and even there it was not of great significance. Microfossil charcoal concentrations never increased above background level and monocotyledon leaf was most abundant in the 5.05m level. Insufficient samples have been counted to demonstrate if the inverse relationship with *Rhizophora* applies to this core too. As at FP 3, only a small number of pollen and fern spores making a minor contribution to the record occurred.

Pollen core JB 2

This core was extracted from an irrigation canal south of the site. A full diagram is not available and Fig. 36 is a slightly redrawn version of the summary diagram published in Maloney and Brown (1987). The core was 5.8m long and the lithostratigraphy comprised green marine clay below 2.5m, with wood and shell inclusions present from 3.9–5.6m depth. The basal 0.2m was sandy, indicating likely deposition in a nearshore environment. Dark grey clays occurred above 2.5m (2.5–1.4m), then c. 0.5m of dark grey and orange clay and 0.8m of buff and orange clay.

Rhizophora dominated most of the core, with small percentages of *Bruguiera* comp. 1 and 2 and Gramineae, until c. 0.9m from the top. As *Rhizophora* percentages were usually above 70 per cent, the presence of mangrove forest at the coring site is virtually certain. Unlike the cores from north of Khok Phanom Di, pteridophyte spores never exceeded 1 per cent in representation and the spore curve was not continuous. The decline of *Rhizophora* was accompanied by a large increase in frequency of *Bruguiera* comp. 2 and a lithostratigraphic change from dark grey and orange clay (a partly ripe acid sulphate soil) to a buff and orange (ripe) clay. *Rhizophora* increased again in one sample from c. 0.5m depth, rising to c. 30 per cent of total pollen and fern spores, but *Bruguiera* comp. 2 remained important. The uppermost sample from c. 0.1m below the bed of the irrigation canal was dominated by grass pollen but *Bruguiera* comp. 2 still had a 20 per cent frequency. Information on pollen and pteridophyte spore concentrations are unavailable and counts of algae and monocotyledon leaf were not made. The microfossil charcoal data were based on counting of all particles, regardless of size, on one microscope slide only. While the constancy

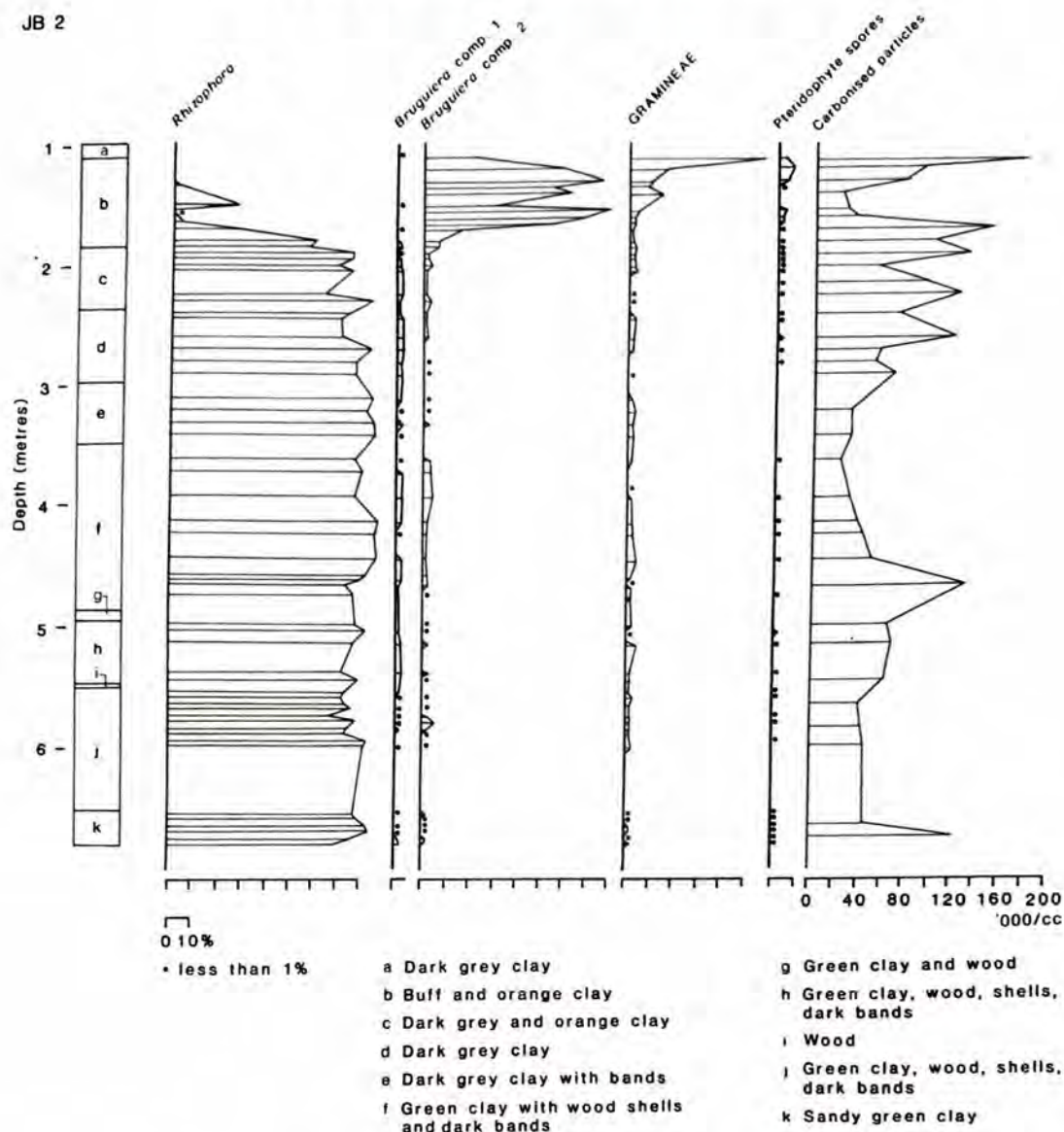


FIG. 36. The pollen diagram from JB 2

of the *Rhizophora* curve is suggestive of bioturbation, the varying nature of the charcoal curve indicates that this may not have been as important as might have been thought at first sight. The series of peaks above c. 1.4m depth in the core appear to be correlatives of the major peaks in cores BMR 2 and KL 2. The vegetation at the JB 2 and BMR 2 coring sites consisted of mangrove forest at this time while core KL 2 was dominated by grass pollen. The charcoal peak at the base of the core may correlate with that from c. 5m depth and that at c. 3.6m with the 3.2–3.4m peak at KL 2. The increases in *Bruguiera* comp. 2 at the tops of each major core and the uppermost phases of grass pollen dominance also seem to correlate with each other, but radiocarbon dating of cores FP 3 and JB 2 is necessary to support this view.

VII. THE POLLEN, PTERIDOPHYTE SPORE AND MICROSCOPIC CHARCOAL: CONCLUSIONS

By B. K. Maloney

INTRODUCTION

THIS section of the monograph has traced changes in the palaeoenvironment in close proximity to Khok Phanom Di during prehistory. It has revealed that the use of pollen core stratigraphies, pollen analysis, microfossil monocotyledon leaf and microfossil charcoal concentrations can illuminate gross three-dimensional vegetation changes as well as variations in relative sea level, and human impact on the environment. It also provides the analytical procedure for further studies of archaeological sites located in former wet-land areas. It was not anticipated that these techniques would yield information on agricultural origins, since it was not thought that pollen grains of cultivated plants could be recognized. With hindsight, this view requires modification in that the size distributions of the grass pollen grains from spectra as old as 4300 BC parallels those from a modern ricefield context, while the presence of likely, although not obligate, ricefield weeds adds further support to the opinion that rice may have been cultivated rather earlier than had been suspected. Indeed, additional excavations at Khok Phanom Di and in its vicinity could well reveal that rice exploitation was occurring among coastal-estuarine communities from the fifth and possibly sixth millennium BC, dates as old as those recently obtained from sites in the Yangtzi valley (Liu Jun 1985). It also, but less importantly, has to be amended because pollen of *Cocos nucifera* occurred in the upper two samples from BMR 2. Pollen of *Areca* was present at 2.21m depth in the same core and this too might well have been cultivated, but there is continuous curve as at Narathiwat.

Yet, as with the pollen grains of other genera which include cultivars, no firm conclusions can be advanced without species identification. This may be possible for some taxa, but seems unlikely in the case of *Areca*.

Time and funds have been limited. As always, the purist might have hoped for more radiocarbon dating of the lowest sediments and others spanning major lithostratigraphic changes, collection of more cores to resolve doubts concerning whether stratigraphic hiatuses have occurred and objective core to core correlation using volume magnetic susceptibility, densitometry or image analysis of what may well prove to be rhythmities (seasonally deposited sedimentary bands differing in organic matter and possibly texture) visible in the cores during fieldwork and revealed again later by X-ray analysis. These remain possibilities for the future, to be conducted in conjunction with additional excavation at Khok Phanom Di and in its environs.

Palynological evidence for human impact on the vegetation of South-East Asia is lamentably thin, and that from the lowlands and in association with archaeological sites is virtually non-existent. Information on natural vegetation changes *per se* and in mangroves, although not extensive by Western European and North American standards, is considerably more abundant. Yet

this is the first time that many cores from such a small area have been subjected to analysis and with such a high resolution. Palynologists have scarcely contributed to the assessment of the course of Holocene sea level change in South-East Asia, a difficult problem in any part of the world. Geomorphologists have suggested that the Holocene transgression was at its maximum 4-5000 years ago. The evidence advanced here lends tenuous support for this although that from core KL 2 in particular suggests that the sea level did not rise constantly, as indicated in Streif (1979), but followed a more oscillating course as accepted by Tjia *et al.* (1983) and, more recently, by Somboon (1988). Layers 11-5 of the 1985 Khok Phanom Di excavation stratigraphy correlates with a period of high sea level as indicated certainly by the radiocarbon dated cores and very probably by Brown's valuable but unfortunately undated JB 2 core. However, the site was then only an island in the sense that it was in the intertidal zone and possibly surrounded by very shallow brackish water for much of each day. One can make more definitive statements about climatic change than sea-level variation, which can be complicated by tectonic events, simply because there is very little evidence for such change: all the diagrams are most readily interpreted in terms of natural variations in vegetation, possibly relating to plant succession, altering soil types, fluctuations in sea level, and human impact on the environment. Undoubtedly, minor, local changes in humidity and precipitation occurred with the advances and retreats of the sea but these relate more to hydrological variation than to significantly alternating temperature although at a world scale the lowering of sea level from its Holocene maximum has connotations of temperature change.

NATURAL VEGETATION CHANGE AND ALTERING SEA LEVELS

The oldest sample analysed from the area was from the base of core BMR 2. Both lithologically and biostratigraphically, this provided evidence for a sea level lower than present. Despite the high *Rhizophora* pollen frequency, the sediment appeared to be of riverine origin and contained indications, especially in the *Pandanus* percentage, for the likely presence of a freshwater environment nearby. There may be an erosion gap between this deposit and the overlying green clays, the thickest lithological unit present in the main cores, which were dominated by *Rhizophora* in cores BMR 2, FP 3, KL 6 and JB 2, especially the last. *Rhizophora* species are most frequent in tidal inundation classes 1-3 (Watson 1982), areas flooded by all high tides to those flooded by normal high tides. So the pollen data suggest that the Khok Phanom Di area was either largely covered by a shallow sea, or in the intertidal zone from c. 6000-4300 BC. If there was a shallow sea, the archaeological site or sites which the charcoal and fern spore curves provide evidence for during this period may have been small islands.

Extremely corroded pollen grains dominated cores FP 3 and KL 6 and these either indicate reworking due to more frequent inundation than in the BMR 2 area or alternatively oxidation and partial destruction due to the sequence of wetting and drying cycles. The monocotyledon leaf influx data from the BMR 2 and FP 3 cores show that the area was subject to incursion from inland probably fresh to slightly brackish-water sources as well as sea water. The monocotyledon leaf concentrations do, indeed, exhibit a general inverse relationship with the *Rhizophora* concentrations. The high, virtually unchanging percentages of *Rhizophora* in core JB 2 suggest that influence from inland may have been minimal at that coring location while the pattern shown in BMR 2 and FP 3 is indicative of estuarine conditions. The seaward side may have been inundated almost permanently,

whether or not the mound was in existence, and the landward side subjected to a varying degree of incursion, with forest under salt water at high tides and exposures of mudflats at low tides. The annual flood cycle associated with the wet season was undoubtedly superimposed on this.

While cores KL 2 and FP 3 had strong similarities, JB 2 was dominated by *Rhizophora* and BMR 2 exhibited a lesser *Rhizophora* dominance, but *Bruguiera* comp. 2 was important in the main mangrove phase of KL 2 and FP 3. *Bruguiera* prefers less frequently inundated environments than *Rhizophora*, so a *Bruguiera* forest may have been present behind the *Rhizophora* zone. *Bruguiera* comp. 2 increased in all the main cores from north of the site as *Rhizophora* declined at JB 2 and BMR 2 while *Bruguiera* comp. 1 increased, especially at KL 2 and FP 3. As KL 2 and FP 3 seemed to have been on the drier side of the mangrove, this change may indicate a decreasing frequency of inundation. Grass pollen increased dramatically only at KL 2 after 4300 BC. It is difficult to attribute this to natural vegetation dynamics or to a falling sea level. Indeed, one might expect that the vegetation at this stage to be rather similar to that from Narathiwat. Its significance has already been touched upon in the introduction to this chapter and it will be discussed in more detail later.

Bruguiera comp. 2 became dominant as grass declined at KL 2, then *Rhizophora* had a strong, isolated, peak. Thereafter *Bruguiera* comp. 2, then Gramineae, recovered. JB 2 had a less pronounced peak of *Rhizophora* followed by a similar pattern of change. Cores BMR 2 and FP 3 showed no recovery of *Rhizophora* at all. This difference may relate to sampling frequency or the occurrence of hiatuses in the stratigraphy. The changes are important because they date to the period of site occupancy revealed by the 1985 excavation.

While undated, the pattern of changes in vegetation seemed to fit the idea of a sea level declining from a Holocene maximum. However, the variations in the upper part where the *Rhizophora* peaks occurred suggested a short-lived recovery. The dating, in contrast, indicates, as mentioned earlier, that oscillations in sea level took place.

HUMAN IMPACT ON THE VEGETATION AND EVIDENCE FOR AGRICULTURE

Strong evidence for human impact on the vegetation occurred in the upper parts of all cores. These coincide with the known occupation of the Khok Phanom Di site and are strongly indicative, when the palynological and archaeological data are viewed in conjunction, of rice cultivation. Since rice occurs even in the basal layers of the site, it may have had an established place in the cultural history of the occupants of the area by 2000 BC. The earlier phase of grass pollen dominance at KL 2, and the lesser peaks at BMR 2, combined with the data on grass pollen sizes from more recent samples and the weed flora are suggestive of rice usage, if not cultivation, from at least as early as c. 4300 BC and possibly even earlier still.

Core KL 2 has a massive increase in microfossil charcoal concentration and an associated increase in pteridophyte (mainly *Lygodium*) spores dated to before 5300 BC. Core JB 2 also has a large increase in charcoal influx, which should also correlate, and core BMR 2 a rise of pteridophyte spores which definitely correlates with that at KL 2. KL 2 also has a pteridophyte spore and charcoal peak post-dating c. 5200 BC. This may correlate with the second increase of charcoal at JB 2 and a rise of pteridophyte spores at c. 3m depth in BMR 2. These data are indicative of minor vegetation disturbances of likely human origin considerably earlier than the base of the 1985 excavation stratigraphy. The *Lygodium* spores are large and although most are mechanically damaged,

they have probably only been moved locally. At present they are best interpreted as indicating that an earlier site, possibly at Khok Phanom Di, was being subjected to forest clearance. The likelihood that rice-using or cultivating peoples lived in the area before the Holocene rise in sea level cannot, however, be discounted. What evidence we have at present indicates that clearing extended northward as sea level declined and that burning was of initially very local extent but later became more widespread.

If rice was either cultivated or harvested wild around 2000 BC it occurred at some place inland of Khok Phanom Di since the site was then in the intertidal zone. Initial evidence for disturbance of the vegetation evidenced by the rise of *Lygodium* and microfossil charcoal began before 5300 BC. A decline in sea level at c. 4300 BC was accompanied by intensified clearance, possibly associated with rice cultivation. The possibility that rice usage or cultivation preceded 4300 BC in the area cannot be sustained on the basis of present evidence but is worthy of further investigation. All research on a site as large and as complex as Khok Phanom Di must be regarded as incomplete and the correlation of archaeological and palynological data offers the promise of greater finds to be made in the future. It is especially important palynologically to recover a sequence of deposits preceding the Holocene rise in sea level.

VIII. TABLES SHOWING TAXA WITH LESS THAN 1% REPRESENTATION

By B. K. Maloney

TABLE 7: *Taxa with less than 1% representation from core KL 2*

Taxon	0.62	0.72	0.82	0.92	1.11	1.22	1.32	1.42	1.52	1.61	1.69
Trees											
<i>Cassia</i> id. <i>siamea</i> comp.	-	0.2	-	0.7	0.3	-	-	0.2	-	-	-
<i>Phoenix</i>	-	-	-	-	-	-	-	0.2	-	-	-
<i>Pinus merkusii</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Podocarpus</i> id. <i>wallichianus</i> comp.	-	-	-	0.1	-	-	-	-	-	-	-
<i>Quercus</i>	-	0.2	-	-	-	0.2	-	-	-	0.2	-
<i>Schima wallichii</i>	-	-	-	-	-	0.2	-	-	-	-	-
<i>Shorea</i> comp.	-	-	-	-	-	-	-	0.4	-	-	-
<i>Xylocarpus</i>	-	0.2	-	-	-	-	-	-	-	-	-
Small trees											
<i>Citrus</i> comp.	-	-	-	-	-	-	-	-	0.1	-	-
<i>Euodia</i> comp.	-	-	-	-	-	-	-	-	-	-	0.5
Shrubs/trees											
<i>Excoecaria</i>	0.5	-	0.9	-	-	0.5	-	-	-	-	-
<i>Mallotus</i> comp.	-	-	-	-	-	-	-	-	-	0.2	-
<i>Styrax</i> sim.	-	0.3	-	-	-	-	-	-	-	-	-
<i>Symplocos</i> id. <i>pendula</i> comp.	-	-	-	-	-	-	-	0.2	-	-	-
Shrubs/small trees											
<i>Cycas</i>	-	-	-	-	-	-	0.1	0.2	-	-	0.9
Taxon	1.81	2.05	2.11	2.22	2.32	2.52	2.61	2.82	2.97	3.22	3.42
Trees											
<i>Acer</i>	-	-	-	0.2	-	-	-	-	-	-	-
<i>Adina</i> comp.	-	-	-	-	-	-	-	-	0.3	-	-
<i>Cassia</i> id. <i>siamea</i> comp.	0.5	-	-	0.4	-	0.2	-	-	-	-	-
<i>Castanopsis</i> comp.	0.5	0.3	-	-	-	-	0.3	-	-	-	-
<i>Celtis</i> comp.	-	-	-	-	0.3	-	-	-	-	-	-
<i>Dacrydium elatum</i>	0.5	-	-	-	-	-	-	-	-	-	-
<i>Phoenix</i>	-	0.3	-	0.4	-	-	-	-	-	-	0.4
<i>Pinus merkusii</i>	-	-	-	-	-	-	-	-	-	0.5	-
<i>Podocarpus</i> id. <i>neriifolius</i> comp.	-	0.3	-	-	-	-	-	-	-	-	-

id. identical to; comp. comparable to; sim. similar to; undiff. undifferentiated

Taxa with less than 1% representation from core KL 2 (cont.)

[illegible]

Taxa with less than 1% representation from core KL 2 (cont.)

[illegible]

EXCAVATION OF KHOK PHANOM DI

Taxa with less than 1% representation from core KL 2 (cont.)

Taxon	0.62	0.72	0.82	0.92	1.11	1.22	1.32	1.42	1.52	1.61	1.69
Climbers	-	-	-	-	-	-	-	-	-	-	0.5
<i>Pothos</i> comp.	-	-	-	-	-	-	-	-	-	-	-
<i>Stephania</i>	0.5	-	-	-	-	-	-	-	-	-	0.5
<i>Smilax</i> comp.	-	-	-	-	-	-	-	-	-	-	-
Shrubs	0.5	-	-	-	-	-	-	-	-	-	-
<i>Caryota</i>	-	-	-	-	-	-	-	-	0.1	-	-
Violaceae comp.	-	-	-	-	-	-	-	-	-	-	-
Taxon	1.81	2.05	2.11	2.22	2.32	2.52	2.61	2.82	2.97	3.22	3.42
Herbs/shrubs/under-shrubs	-	-	-	-	-	-	-	-	0.1	-	-
<i>Crotalaria</i> comp.	-	-	-	-	-	-	-	-	-	-	-
Climbers/trees	-	-	-	-	-	-	-	-	-	0.3	-
<i>Derris</i>	-	-	-	-	-	-	-	-	-	-	-
Climbers/shrubs	-	0.3	-	-	0.3	-	-	-	-	-	-
<i>Piper</i>	-	0.3	-	-	0.3	-	-	-	-	-	-
Small trees	-	-	-	-	-	-	0.3	-	-	-	-
Rutaceae	-	-	-	-	-	-	0.3	-	-	-	-
Shrubs	-	-	-	-	-	-	-	-	0.3	-	-
<i>Aegiceras corniculatum</i>	-	-	-	-	-	-	-	-	0.6	-	-
<i>Caryota</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Scyphiphora hydrophyllacea</i>	-	-	-	-	-	-	-	0.4	0.3	-	-
Under-shrubs	-	0.3	-	-	-	-	-	-	-	-	-
<i>Mimosa pudica</i>	-	0.3	-	-	-	-	-	-	-	-	-
Herbs/shrubs/under-shrubs	-	-	0.4	-	-	-	-	-	-	-	-
<i>Crotalaria</i> comp.	-	-	0.4	-	-	-	-	-	-	-	-
Trailing herbs/climbers/shrubs/under-shrubs	-	0.3	-	-	-	-	-	-	-	-	-
<i>Desmodium</i>	-	0.3	-	-	-	-	-	-	-	-	-
Herbaceous under-shrubs	-	0.6	-	-	-	-	-	-	-	-	-
<i>Donax</i> comp.	-	0.6	-	-	-	-	-	-	-	-	-
Herbaceous creeper	-	0.3	-	-	-	-	-	-	-	-	-
<i>Passiflora</i> id.	-	0.3	-	-	-	-	-	-	-	-	-
Taxon	3.52	3.61	3.72	3.82	3.92	4.02	4.11	4.22	4.32	4.42	4.52
Climbers/small trees	-	0.3	-	-	-	-	-	-	-	-	-
<i>Zizyphus</i> comp.	-	0.3	-	-	-	-	-	-	-	-	-
Climbers/shrubs/small trees	-	0.3	-	-	-	-	-	-	-	-	-
<i>Capparis</i> comp.	-	0.3	-	-	-	-	-	-	-	-	-
Shrubs	0.5	-	-	-	-	-	-	-	-	-	-
<i>Allophyllus</i>	0.5	-	-	-	-	-	-	-	-	-	-
<i>Scyphiphora hydrophyllacea</i>	0.5	-	-	-	-	-	-	-	-	-	-
Herbs/shrubs/small trees	-	-	-	-	-	-	-	-	-	-	-
<i>Acalypha</i>	-	-	-	-	-	-	-	0.2	-	-	-

Taxa with less than 1% representation from core KL 2 (cont.)

Taxon	4.61	4.72	4.92	5.02	5.11	5.22	5.32	5.42	5.52	5.61	
Climbers											
<i>Stephania</i>	-	-	-	0.5	-	-	-	-	-	-	
<i>Calamus</i> comp. 1	-	-	-	-	-	-	-	-	-	0.2	
<i>Calamus</i> comp. 2	-	-	-	0.5	-	-	-	-	-	-	
<i>Calamus</i> comp. 3	-	-	-	0.5	-	-	-	-	-	-	
Shrubs											
<i>Scyphiphora hydrophyllacea</i>	-	-	-	-	-	-	-	0.3	-	-	
Herbs/shrubs/under-shrubs											
<i>Crotalaria</i> comp.	-	-	-	0.5	-	-	-	-	-	-	
Taxon	5.72	5.82	5.92	6.02	6.11	6.22	6.32	6.42	6.52	6.61	
Climbers/trees											
<i>Derris</i>	0.2	-	-	-	-	-	-	-	-	-	
Palmae rugulate	-	-	-	-	0.2	-	-	-	-	-	
Shrubs											
<i>Caryota</i>	-	0.1	-	-	-	-	-	-	-	-	
Taxon	0.62	0.72	0.82	0.92	1.11	1.22	1.32	1.42	1.52	1.61	1.69
Herbs											
<i>Amorphophallus</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Blumea</i> comp.	-	-	-	-	-	0.5	-	-	-	0.2	-
Compositae/Tubuliflorae undiff.											
<i>Cyperus</i> comp.	0.3	-	-	-	0.2	0.7	-	0.2	0.1	-	-
<i>Eriocaulon</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Fimbristylis</i> comp.	-	0.2	-	-	-	-	-	-	-	-	-
Urticaceae/ Moraceae scabrate	-	-	-	-	-	0.2	-	-	-	-	-
Aquatic herbs											
<i>Potamogeton</i> comp.	-	-	-	-	-	-	-	0.2	0.1	-	-
<i>Utricularia</i> id. <i>bifida</i> comp.	-	-	-	-	-	-	-	-	-	-	0.5
Ferns											
<i>Microlepia</i>	-	-	-	-	-	0.2	-	-	-	-	-
<i>Taenitis</i> sim.	-	-	-	-	-	0.2	0.1	0.2	-	-	-
Taxon	1.81	2.05	2.11	2.22	2.32	2.52	2.61	2.82	2.97	3.22	3.42
Creeping herb											
<i>Ipomoea</i> id. <i>aquatica</i> comp.	-	-	-	-	0.3	-	-	-	-	-	-

Taxa with less than 1% representation from core KL 2 (cont.)

Taxon	3.52	3.61	3.72	3.82	3.92	4.02	4.11	4.22	4.32	4.42	4.52
Ferns											
<i>Diplazium</i>	-	-	-	-	-	0.4	-	-	-	-	-
<i>Lycopodium cernuum</i>	0.5	-	-	-	-	-	-	-	-	-	-
<i>Microlepia</i>	-	0.3	-	-	-	-	-	-	-	-	-
Climbers/epiphytes											
<i>Nephrolepis</i>	-	-	0.2	-	-	-	-	-	-	-	-
Climbers											
<i>Stenochlaena palustris</i>	-	-	-	0.2	-	-	-	-	-	-	-
Epiphytic ferns											
<i>Polypodium verrucate</i>	-	-	-	-	-	-	-	0.2	-	-	-
Various											
Filices monolete											
scabrate large	-	-	-	-	-	0.4	-	-	-	-	-
Taxon	4.61	4.72	4.92	5.02	5.11	5.22	5.32	5.42	5.52	5.61	
Compositae/Tubuliflorae undiff.											
<i>Cyperus</i> comp.	0.2	-	-	-	-	0.2	-	-	-	-	
<i>Rhynchospora</i> sim.	-	-	-	-	0.4	-	-	-	-	-	
Various											
<i>Croton</i> comp.	-	0.5	-	-	-	-	-	-	-	-	
<i>Ficus</i> comp. small	-	-	-	-	-	-	-	-	-	0.2	
Urticaceae/											
Moraceae scabrate	-	-	-	-	-	0.2	-	-	-	-	
Aquatic herbs											
<i>Potamogeton</i> comp.	-	-	-	-	-	-	-	-	0.3	-	
Climbers											
<i>Stenochlaena palustris</i>	-	-	-	0.5	-	-	-	-	-	-	
Epiphytic ferns											
<i>Polypodium</i> blocky	-	-	-	0.5	-	-	-	-	-	-	
Taxon	5.72	5.82	5.92	6.02	6.11	6.22	6.32	6.42	6.52	6.61	
Herbs											
<i>Blumea</i> comp.	-	0.1	-	-	-	-	-	-	-	-	
Compositae:											
Tubuliflorae undiff.	0.2	-	0.4	-	-	-	-	-	-	-	
Various											
<i>Croton</i> comp.	-	-	-	-	0.2	-	-	-	-	-	
<i>Ficus</i> comp. small	-	-	-	-	-	0.4	-	-	-	-	
Aquatic herbs											
<i>Nymphaea</i>	-	-	-	-	0.2	-	-	-	-	-	
Climbers/epiphytes											
<i>Nephrolepis</i>	-	0.2	0.4	-	-	-	-	-	-	-	
Climbers											
<i>Dicranopteris</i>	-	-	-	0.2	-	-	-	-	-	-	

Taxa with less than 1% representation from core BMR 2 (cont.)

Taxon	2.10	2.21	2.49	2.60	2.70	2.80	2.90	2.99	3.10	3.20	3.49
Trees											
<i>Altingia</i>	-	0.4	-	-	-	-	-	-	0.5	-	-
<i>Areca</i>	-	0.4	-	-	-	-	-	-	-	-	-
<i>Oncosperma</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Pinus merkusii</i>	-	-	0.4	-	-	-	-	-	-	-	0.4
<i>Pinus</i> 1	-	-	-	-	-	-	-	0.5	-	-	-
<i>Prunus</i> sim.	-	-	-	-	-	-	-	-	-	-	-
<i>Salix</i> comp.	-	-	-	-	-	-	-	-	-	-	0.4
<i>Santiria</i> sim.	-	-	-	-	-	-	-	-	-	0.5	-
<i>Xylocarpus</i>	-	-	-	-	-	-	-	-	-	-	0.4
Small trees/trees											
<i>Diospyros</i>	-	-	-	-	-	-	-	-	0.5	0.5	0.8
<i>Garcinia</i> 1	-	0.4	-	-	-	-	-	-	-	-	-
<i>Garcinia</i> 2	-	-	-	-	-	-	-	-	-	-	0.4
<i>Macaranga</i> comp.	-	-	0.4	-	-	-	-	-	-	-	-
Shrubs/trees											
Flacourtiaceae	-	-	-	-	-	0.4	-	-	-	-	-
Taxon	3.61	3.71	3.99	4.10	4.20	4.49	4.60	4.70	4.80	4.90	4.99
Trees											
<i>Acer</i>	-	-	-	0.5	-	-	-	-	-	-	-
<i>Altingia</i>	0.2	-	-	0.5	0.2	-	0.1	-	-	-	-
<i>Borassodendron</i> comp.	-	-	0.5	-	-	-	-	-	-	-	-
<i>Calophyllum</i>	-	-	-	-	-	0.4	0.1	-	-	-	-
<i>Celtis</i> comp.	-	-	-	-	-	0.4	-	-	-	-	-
<i>Dacrycarpus imbricatus</i>	-	0.2	-	-	-	-	-	-	-	-	-
<i>Dacrydium elatum</i>	-	-	-	-	-	-	0.1	-	-	-	-
<i>Pinus merkusii</i>	0.2	-	-	-	-	0.4	-	-	-	-	-
<i>Pinus</i> 1	-	0.5	-	-	-	-	-	-	-	-	-
<i>Podocarpus</i> id. <i>neriifolius</i> comp.	-	-	-	-	-	-	-	-	-	-	0.5
<i>Podocarpus</i> id. <i>wallichianus</i> comp.	-	-	-	-	-	-	0.1	-	-	-	-
<i>Quercus</i>	-	0.7	-	-	-	-	-	-	-	-	-
<i>Salix</i> comp.	-	-	-	-	-	-	0.1	0.5	-	-	-
<i>Santiria</i> sim.	-	0.5	-	-	-	-	-	-	-	-	-
Small trees/trees											
<i>Diospyros</i>	0.6	0.2	0.5	0.5	-	-	0.1	-	-	-	0.5
<i>Garcinia</i> 1	-	-	-	-	-	-	-	-	-	-	0.5
Shrubs/trees											
<i>Canthium</i>	-	-	-	-	-	-	0.1	-	-	-	-
Taxon	5.10	5.20	5.49	5.62	6.07	6.20	6.47	6.57	6.69	6.80	
Trees											
<i>Albizia procera</i> comp.	-	-	-	-	0.9	-	-	-	-	-	-
<i>Altingia</i>	-	-	-	-	-	0.5	-	0.4	-	-	-

Taxa with less than 1% representation from core BMR 2 (cont.)

Taxon	5.10	5.20	5.49	5.62	6.07	6.20	6.47	6.57	6.69	6.80
<i>Artocarpus</i> comp.	-	-	-	0.5	-	-	-	-	-	-
<i>Bombax</i>	0.4	-	-	-	-	-	-	-	-	-
<i>Calophyllum</i>	-	-	-	-	0.9	-	0.4	-	-	-
<i>Celtis</i> comp.	-	-	-	-	-	-	-	-	-	0.3
<i>Dipterocarpus</i>	-	-	-	-	-	-	0.4	-	-	-
<i>Pinus merkusii</i>	-	-	-	-	-	-	0.4	-	0.9	-
<i>Pinus</i> 1	-	-	-	-	0.5	-	-	-	-	-
<i>Quercus</i>	-	-	0.5	-	-	0.5	0.4	-	-	-
<i>Salix</i> comp.	-	-	-	-	-	-	0.9	-	-	-
<i>Xylocarpus</i>	-	-	-	-	-	0.5	-	-	-	-
Small trees/trees										
<i>Diospyros</i>	0.2	0.4	-	0.9	-	-	-	0.8	0.9	-
<i>Macaranga</i> comp.	-	-	-	-	-	-	-	-	-	0.3
Small trees										
<i>Lumnitzera</i>	-	-	-	-	-	0.5	-	-	-	-

Taxon	0.20	0.30	0.40	0.49	0.75	0.79	0.85	0.89	0.95	0.99	1.10
Trees											
<i>Ilex</i> small	-	-	-	-	-	-	-	-	-	-	0.04
<i>Licuala</i> comp.	-	0.4	-	-	-	-	-	-	-	-	-
Palmae: bacculate/rugulate	-	-	0.6	-	-	-	-	-	-	-	-
Climbers/shrubs/trees											
<i>Randia</i> comp.	-	-	0.2	-	-	-	-	-	-	-	-
Small trees											
Melastomataceae	0.3	-	-	-	-	-	-	-	-	-	-
Climbers/creepers											
Asclepiadaceae	-	0.4	-	-	-	-	-	-	-	-	-
Shrubs											
<i>Hyptis</i> comp.	-	-	-	-	-	-	-	-	-	-	0.04

Taxon	1.20	1.30	1.49	1.57	1.63	1.69	1.75	1.81	1.87	1.93	1.99
Shrubs/small trees											
<i>Ardisia</i> comp.	-	0.05	-	0.3	-	-	-	-	-	-	-
<i>Licuala</i> comp.	-	-	-	-	-	-	0.4	0.5	0.5	-	0.5
<i>Rauvolfia</i> comp.	-	-	-	-	-	-	0.4	-	-	-	-
<i>Saurauia</i>	-	0.1	0.2	-	-	-	-	-	-	-	-
Climbers/trees											
<i>Acacia</i> comp.	-	-	-	-	-	-	-	-	-	0.7	-
Climbers/shrubs/trees											
Annonaceae	-	0.05	-	-	-	-	-	-	-	-	-
Small trees											
Combretaceae/ Melastomataceae	-	-	-	0.3	-	-	-	-	-	-	-

Taxa with less than 1% representation from core BMR 2 (cont.)

Taxon	1.20	1.30	1.49	1.57	1.63	1.69	1.75	1.81	1.87	1.93	1.99
Climbers											
<i>Alyxia</i> comp.	-	-	-	-	-	-	-	0.5	-	-	-
<i>Azima sarmentosa</i>	0.1	-	-	-	-	-	-	-	0.5	-	-
<i>Calamus</i> comp. 1	-	-	-	-	-	-	0.4	-	-	-	-
Shrubs											
<i>Caryota</i>	-	0.05	-	-	-	-	-	-	-	-	-
<i>Itea</i> comp.	-	-	-	-	-	-	0.4	-	-	-	-
Taxon	2.10	2.21	2.49	2.60	2.70	2.80	2.90	2.99	3.10	3.20	3.49
Shrubs/small trees											
<i>Ardisia</i> comp.	-	-	-	-	-	-	-	-	-	0.5	-
<i>Saurauia</i>	-	0.4	-	-	-	-	-	-	-	-	-
Climbers/trees											
<i>Acacia</i> comp.	-	-	-	-	-	-	-	-	-	-	0.8
<i>Derris</i>	-	-	-	0.3	-	-	-	-	-	-	-
Climbers/shrubs/small trees											
<i>Capparis</i> comp.	-	-	-	-	-	-	-	-	-	-	0.4
Combretaceae/ Melastomataceae	-	-	-	0.3	-	-	-	-	-	-	-
Climbers/shrubs											
<i>Mussaenda</i> sim.	0.4	-	-	-	-	-	-	-	-	-	-
<i>Solanum</i>	-	-	-	-	0.5	-	-	-	-	-	-
Shrubs											
<i>Lasianthus</i> comp.	-	-	0.4	-	-	-	-	-	-	-	-
Taxon	3.61	3.71	3.99	4.10	4.20	4.49	4.60	4.70	4.80	4.90	4.99
Trees											
Magnoliaceae	-	-	-	-	-	-	-	-	-	-	0.5
<i>Symplocos</i> id. <i>pendula</i> comp.	0.2	-	-	-	-	-	-	-	-	-	-
Shrubs/small trees											
<i>Ardisia</i> comp.	0.2	0.5	-	-	0.2	-	-	-	-	-	-
<i>Baeckia</i>	-	0.5	-	-	-	-	-	-	-	-	-
<i>Licuala</i> comp.	-	-	0.5	-	-	-	-	-	-	-	-
Shrubs/small trees											
<i>Saurauia</i>	-	-	-	-	0.2	-	0.1	-	-	-	-
<i>Tristania</i> comp.	-	-	-	-	0.2	-	-	-	-	-	-
Climbers/trees											
<i>Derris</i>	-	-	-	-	-	-	0.1	-	-	-	-
Small trees											
<i>Capparis</i> comp.	-	-	-	-	-	-	0.2	-	-	-	0.5
Combretaceae/ Melastomataceae	-	-	0.5	-	-	-	-	-	-	-	-

Taxa with less than 1% representation from core BMR 2 (cont.)

Taxon	3.61	3.71	3.99	4.10	4.20	4.49	4.60	4.70	4.80	4.90	4.99
Climbers											
<i>Aerva</i>	0.2	-	-	-	-	-	-	-	-	-	-
<i>Calamus</i> comp. 2	-	-	-	-	0.2	-	-	-	-	-	-
<i>Calamus</i> comp. 3	-	-	0.5	-	-	-	-	-	0.5	-	-
Palmae scabrate	-	0.5	-	-	-	-	-	-	-	-	-
Shrubs											
<i>Aegiceras corniculatum</i>	-	-	-	-	-	-	0.1	-	-	-	-
<i>Allophyllus</i>	0.2	0.5	-	-	-	-	-	-	-	-	-
<i>Caryota</i>	0.6	0.5	-	-	-	-	-	0.5	0.5	-	-
<i>Scyphiphora hydrophyllacea</i>	0.2	0.5	-	-	-	-	0.1	-	0.5	-	-
Taxon	5.10	5.20	5.49	5.62	6.07	6.20	6.47	6.57	6.69	6.80	
Shrubs/small trees											
<i>Ardisia</i> comp.	-	-	-	-	-	0.5	0.4	0.4	-	-	
Climbers											
<i>Calamus</i> comp. 1	0.2	-	-	-	-	-	-	-	-	-	
Shrubs											
<i>Scyphiphora hydrophyllacea</i>	0.2	-	-	-	-	-	-	-	-	-	
Taxon	0.20	0.30	0.40	0.49	0.75	0.79	0.85	0.89	0.95	0.99	1.10
Herbs/shrubs/under-shrubs											
<i>Crotalaria</i> comp.	-	0.4	-	-	-	-	-	-	-	-	-
Labiatae C6	-	-	-	-	-	-	-	-	-	-	0.08
Trailing herbs/climbers/shrubs/under-shrubs											
<i>Desmodium</i>	-	-	-	-	-	-	0.4	-	-	-	-
Herbaceous creepers											
<i>Ipomoea</i> id. <i>aquatica</i> comp.	-	-	0.2	-	-	-	-	-	-	-	-
Herbs											
<i>Arisaema</i> comp.	-	-	-	0.5	-	-	-	-	-	-	-
Compositae:											
Tubuliflorae undiff.	-	-	0.2	0.5	-	-	-	-	-	0.4	-
Compositae:											
Herbs											
<i>Crinum</i>	-	-	-	-	0.5	-	-	-	-	-	-
<i>Eleocharis</i>	0.6	-	-	-	-	0.3	0.4	-	-	-	-
<i>Fimbristylis</i> comp.	-	0.4	0.2	-	-	-	-	0.4	-	-	0.04
<i>Houttuynia</i> comp.	-	0.4	0.2	-	-	-	-	-	-	-	-
Various											
<i>Ficus</i> small	-	0.3	0.2	-	-	-	-	-	-	-	-
Urticaceae/Moraceae scabrate	-	-	0.4	-	-	-	-	-	-	-	0.04
Aquatic herbs											
<i>Ludwigia</i>	-	0.4	0.2	0.5	-	-	-	-	-	-	-
<i>Nymphoides</i>	0.6	-	-	0.5	-	-	-	-	-	-	-

Taxa with less than 1% representation from core BMR 2 (cont.)

Taxon	1.20	1.30	1.49	1.57	1.63	1.69	1.75	1.81	1.87	1.93	1.99
Herbaceous creepers											
<i>Flagellaria</i>	-	0.2	-	-	-	-	-	-	-	-	-
Herbs											
<i>Carex</i> comp.	-	-	-	0.7	-	-	-	-	-	-	-
Compositae:											
Tubuliflorae undiff.	-	-	-	-	-	-	-	-	-	-	-
<i>Hedyotis</i> 1	-	-	-	-	-	-	-	-	-	0.4	-
<i>Iris</i> sim.	0.1	0.05	-	0.3	-	-	-	-	-	-	-
<i>Xyris</i>	-	-	-	0.3	-	-	-	-	-	-	-
Various											
<i>Ficus</i> small	-	0.05	0.2	0.3	-	-	-	-	-	-	-
<i>Ficus</i> large	-	-	-	-	0.5	-	-	-	-	-	-
Urticaceae/Moraceae scabrate	-	0.05	-	-	-	-	-	-	-	-	-
Aquatic herbs											
<i>Nymphoides</i>	-	-	-	-	-	-	-	-	0.5	-	-
Taxon	2.10	2.21	2.49	2.60	2.70	2.80	2.90	2.99	3.10	3.20	3.49
Shrubs/under-shrubs											
<i>Desmodium</i>	-	-	-	-	-	-	-	-	-	-	0.4
Herbs/under-shrubs											
<i>Donax</i> comp.	-	-	-	0.3	-	-	-	-	-	-	-
Parasitic herbs											
<i>Pedicularis</i> sim.	-	-	-	-	-	-	-	0.5	-	-	-
Herbs											
<i>Carex</i> comp.	-	-	-	-	-	-	-	-	-	-	0.4
<i>Fimbristylis</i> comp.	-	0.4	-	-	-	-	-	-	-	-	-
<i>Hedyotis</i> 1	0.4	-	-	-	-	-	-	-	-	-	-
<i>Hedyotis</i> 2	-	0.4	-	-	-	-	-	-	-	-	-
<i>Tacca</i>	-	-	-	-	0.5	-	-	-	-	-	-
Various											
<i>Ficus</i> small	0.4	-	-	-	-	-	-	-	0.5	0.5	-
<i>Ficus</i> large	-	-	-	-	-	-	-	-	0.5	-	-
Urticaceae/Moraceae scabrate	-	-	-	-	-	-	-	-	-	-	0.4
Taxon	3.61	3.71	3.99	4.10	4.20	4.49	4.60	4.70	4.80	4.90	4.99
Herbs/shrubs/under-shrubs											
<i>Crotalaria</i> comp.	-	-	-	-	0.2	0.4	-	-	-	-	-
Herbaceous creepers											
<i>Flagellaria</i>	0.2	-	-	0.5	-	-	-	-	-	-	-
Climbers/herbaceous creepers											
Convolvulaceae	-	-	-	0.5	-	-	-	-	-	-	-
Herbs											
<i>Begonia</i>	0.2	-	-	-	-	-	-	-	-	-	-
<i>Fimbristylis</i> comp.	-	-	-	-	0.4	-	-	-	-	-	-

Taxa with less than 1% representation from core BMR 2 (cont.)

Taxon	3.61	3.71	3.99	4.10	4.20	4.49	4.60	4.70	4.80	4.90	4.99
Herbs											
<i>Hedyotis</i> 2	-	-	-	-	-	-	-	-	-	-	0.5
<i>Xyris</i>	-	-	-	-	-	-	0.1	-	-	-	-
Various											
<i>Croton</i> comp.	-	0.2	-	-	-	-	-	-	-	-	-
<i>Ficus</i> small	0.2	0.5	-	-	-	0.4	0.1	-	-	-	0.7
Urticaceae/Moraceae scabrate	-	0.5	-	-	-	-	-	-	-	-	-
Taxon	5.10	5.20	5.49	5.62	6.07	6.20	6.47	6.57	6.69	6.80	
<i>Tarenna</i> sim.	-	-	-	-	-	0.5	-	-	-	-	
Herbs/small trees											
<i>Euphorbia</i>	-	-	-	-	-	-	-	-	-	-	0.3
Herbs											
<i>Begonia</i>	-	-	0.5	-	-	-	-	-	-	-	-
<i>Hedyotis</i> 1	-	-	-	-	-	0.4	-	-	-	-	-
<i>Sonerila</i> comp.	-	-	-	-	-	-	-	-	0.6	-	-
Various											
<i>Croton</i> comp.	-	0.4	-	-	-	-	-	-	-	-	-
<i>Ficus</i> small	-	-	-	-	-	-	-	-	-	-	0.6
<i>Ficus</i> large	-	-	-	-	-	-	-	-	-	-	0.3
Taxon	0.20	0.30	0.40	0.49	0.75	0.79	0.85	0.89	0.95	0.99	1.10
<i>Potamogeton</i> comp.	0.3	-	-	0.5	-	-	-	-	-	-	-
<i>Utricularia</i> id. <i>vulgaris</i> comp.	-	-	-	0.5	-	-	-	-	-	-	-
Ferns											
<i>Taenitis</i> sim.	-	-	-	-	-	-	-	-	-	-	0.04
Epiphytic ferns											
<i>Polypodium</i> areolate	-	-	-	-	-	-	-	-	-	-	0.08
Various											
Filices monolete reticulate large	-	-	-	-	-	-	-	-	-	-	0.04
Taxon	1.20	1.30	1.49	1.57	1.63	1.69	1.75	1.81	1.87	1.93	1.99
Ferns											
<i>Adiantum</i>	-	0.05	-	-	-	-	-	-	-	-	-
<i>Selaginella</i> id. 2	-	-	-	-	-	-	-	0.5	-	-	-
Epiphytic ferns											
<i>Polypodium</i> blocky	-	-	-	-	-	-	-	-	-	-	0.5
<i>Polypodium</i> verrucate	-	-	-	0.3	-	-	-	-	-	-	-
Various											
Filices monolete scabrate large	-	-	-	-	-	-	0.4	-	-	-	-

Taxa with less than 1% representation from core BMR 2 (cont.)

[illegible]

TABLE 9: *Taxa with less than 1% representation from core FP 3*

Taxon	0.90	1.10	1.30	1.50	1.70	2.00	2.20	2.40	2.60	2.80
Trees										
<i>Artocarpus</i> comp.	-	0.5	-	-	-	-	-	-	-	-
<i>Betula alnoides</i>	-	0.5	-	-	-	-	-	-	-	-
<i>Cocos nucifera</i>	-	0.5	-	-	-	-	-	-	-	-
<i>Dacrycarpus imbricatus</i>	0.4	-	-	-	-	-	-	-	-	-
Shrubs/trees										
<i>Eugenia</i> comp. small	-	-	-	-	-	-	-	-	0.3	-
<i>Eugenia</i> comp. large	0.5	-	-	-	-	-	-	-	-	-
Shrubs/small trees										
<i>Acacia farnesiana</i>	-	0.9	-	-	-	-	-	-	-	-
<i>Ricinus</i> comp.	-	-	-	-	-	-	0.2	-	-	-
Small trees										
Rutaceae	0.4	0.9	-	-	-	-	-	-	-	-
Shrubs										
<i>Scyphiphora hydrophyllacea</i>	-	-	0.4	-	-	-	-	-	-	-
Climbers										
<i>Pothos</i> comp.	0.4	0.5	-	-	-	-	-	-	-	-
Taxon	3.00	3.20	3.40	3.60	3.80	4.00	4.20	4.40	4.60	
Trees										
<i>Celtis</i> comp.	-	-	-	-	-	0.2	-	-	-	-
<i>Pinus merkusii</i>	0.3	-	-	-	-	-	-	-	0.3	-
<i>Podocarpus</i> id. <i>wallichianus</i> comp.	0.5	-	-	-	-	-	-	-	-	-
<i>Shorea</i> comp.	-	-	-	-	-	0.2	-	-	-	-
Shrubs/trees										
<i>Eugenia</i> comp. small	-	-	-	0.1	-	-	-	-	-	-
Shrubs/small trees										
<i>Cycas</i>	-	-	-	0.1	0.3	-	-	-	-	-
Climbers/trees										
Palmae psilate	-	-	-	0.1	-	-	-	-	-	-
Climbers/shrubs/										
Small trees										
<i>Capparis</i> comp.	-	-	-	-	-	0.2	-	-	-	-
Shrubs										
<i>Aegiceras corniculatum</i>	-	-	-	0.1	-	-	-	-	-	-
<i>Scyphiphora hydrophyllacea</i>	-	-	-	0.1	-	-	-	-	-	-
Taxon	4.80	5.00	5.20	5.40	5.60	5.80	6.00	6.20	6.40	
Trees										
<i>Brownlowia</i> comp.	-	-	-	-	-	-	-	-	0.4	-
<i>Castanopsis</i> comp.	-	-	-	-	-	0.2	-	-	-	-
<i>Pinus merkusii</i>	-	0.4	-	-	-	-	-	-	-	-
<i>Pinus</i> 1	-	-	-	-	-	-	0.2	-	-	-

Taxa with less than 1% representation from core FP 3 (cont.)

Taxon	4.80	5.00	5.20	5.40	5.60	5.80	6.00	6.20	6.40	
Shrubs/trees										
<i>Eugenia</i> comp. small	-	-	-	-	0.4	-	-	-	-	
<i>Eugenia</i> comp. large	-	0.4	-	-	-	-	-	-	-	
<i>Excoecaria</i>	-	-	-	-	-	-	-	-	-	
Shrubs							0.2	-	-	
<i>Scyphiphora hydrophyllacea</i>	-	0.4	-	-	-	-	-	-	-	
Taxon	0.90	1.10	1.30	1.50	1.70	2.00	2.20	2.40	2.60	2.80
Herbs/shrubs/										
Malvaceae	-	-	-	-	-	0.4	-	-	-	-
Herbaceous creepers										
<i>Melothria</i> comp.	-	0.5	-	-	-	-	-	-	-	-
<i>Momordica</i> comp.	0.4	-	-	-	-	-	-	-	-	-
Herbs										
<i>Fimbristylis</i> comp.	-	0.9	-	-	-	-	-	-	-	-
Various										
<i>Ficus</i> small	-	-	-	-	-	-	-	0.4	-	-
Aquatic herbs										
<i>Monochoria</i> comp.	0.7	-	-	-	-	-	-	-	-	-
<i>Nymphoides</i>	0.4	0.5	-	-	-	-	-	-	-	-
Ferns										
<i>Lindsaea orbiculata</i> comp.	-	-	-	-	-	-	0.2	-	-	-
Climbers										
<i>Stenochlaena palustris</i>	0.5	-	-	-	-	-	-	-	-	-
Various										
Filices monolete psilate small	-	0.5	-	-	-	-	-	-	-	-
Filices monolete scabrate small	-	-	-	-	-	0.4	-	-	-	-
Taxon	3.00	3.20	3.40	3.60	3.80	4.00	4.20	4.40	4.60	
Herbs										
<i>Eleocharis</i>	-	-	-	0.1	-	-	-	-	-	-
Various										
<i>Ficus</i> small	-	-	-	0.1	-	-	0.2	-	-	-
Herbs/aquatic herbs										
<i>Ludwigia</i>	-	0.2	-	-	-	-	-	-	-	-
Climbers/epiphytes										
<i>Nephrolepis</i>	0.3	-	-	-	-	-	-	-	-	-
Climbers										
<i>Stenochlaena palustris</i>	-	-	-	0.3	-	-	-	-	-	-
Aquatic ferns										
<i>Acrostichum</i>	-	-	-	-	-	0.2	-	-	-	-
Various										
Filices monolete psilate small	-	0.2	-	0.3	0.3	-	-	-	-	-
Filices monolete scabrate small	-	-	-	0.1	-	-	-	-	-	-

EXCAVATION OF KHOK PHANOM DI

Taxa with less than 1% representation from core FP 3 (cont.)

Taxon	4.80	5.00	5.20	5.40	5.60	5.80	6.00	6.20	6.40
Herbs									
<i>Rhynchospora</i> sim.	-	-	-	-	-	-	0.2	-	-
Various									
<i>Ficus</i> large	0.2	-	-	-	-	-	-	-	-
<i>Ficus</i> small	0.4	0.4	-	-	-	0.2	-	-	-
Ferns									
<i>Pteris</i> id. <i>venusta</i> comp.	-	0.4	-	-	-	-	-	-	-
Climbers									
<i>Stenochlaena palustris</i>	-	0.4	-	-	-	-	-	-	-
Aquatic ferns									
<i>Acrostichum</i>	-	-	-	-	-	0.2	-	0.2	-

IX. NOTES ON POLLEN AND PTERIDOPHYTE SPORE TYPES

By B. K. Maloney

THE terms introduced by Benninghoff and Kapp (1962) have been used in modified form to emphasize the degree of accuracy with which the palynomorphs have been determined. Where no suffix follows the name of the taxon, this indicates that the identification is regarded as certain. Where the certainty of identification needs to be stressed 'id.' (*idem*: identical to) is employed but where there is some doubt 'comp.' (*comparatus*: comparable to) is used. The least positive determinations are followed by 'sim.' (*similis*: similar to). Undiff. is an abbreviation of undifferentiated. The terminology used to describe pollen and spore structure and patterning is as outlined in Faegri and Iversen (1975) and the botanical taxonomy follows the floristic list given in Smitinand (1980).

Accurate determination of pollen and fern spores is dependent upon examination of a good modern comparative reference collection. Most of the taxa named here have been identified using my own reference collection or knowledge of the Department of Geography, University of Hull, collection which I used as a graduate student. However, some identifications are based on published literature and the available publications have been used in conjunction with the listing by Smitinand (1980) and *Flora of Thailand* to refine determinations as far as possible, e.g. that of *Podocarpus id. wallichianus comp.* Unfortunately not all taxa present in Thailand have been described in terms of pollen or spore morphology, but a large number have, in a wide scatter of publications. In the absence of microphotographs, attention is drawn to illustrations of the taxa in the literature, with particular reference to Huang (1972, 1981). In the absence of other sources, occasional reference has been made to microphotographs presented in my unpublished doctoral thesis (Maloney 1979). It should be noted that the inexperienced analyst would be well advised to use Huang's texts as a proxy means of Thai pollen and spore identification with the utmost caution, as inaccurate determinations can easily result from the lack of knowledge of a good, large modern reference collection and of the local flora.

1. Taxon: *Acacia farnesiana*. Life form: shrub/small tree. This pollen type is a polyad of 16 verrucate grains. The species is exotic to Thailand and the pollen only occurs in surface samples. It is illustrated in Huang (1972, Pl. 84: 6-10) and Lieux (1982, Pl. LXXX1:1-6).
2. Taxon: *Acacia comp.* Life form: climber/tree. This pollen type is a polyad of 16 psilate grains. Five species of *Acacia* have central Thai names (Smitinand 1980). A similar pollen type occurs in *Albizia* and 6 species of that genus have central/south-eastern names. *Acacia* and *Albizia* pollen grains are depicted in Huang (1972, Pls. 84-5).
3. Taxon: *Acalypha*. Life form: herb/shrub. This pollen type is triporate and psilate. Three *Acalypha* species have central Thai names and the pollen is illustrated in Huang (1972, Pl. 64).

4. Taxon: *Acer*. Life form: tree. This pollen type is tricolporate, c. $19 \times 14 \mu\text{m}$ in size (equatorial view), tectate, with an inner reticulate layer. *A. oblongum* has a Nakhon Ratchasima name but Smitinand (1980) only reported a north-eastern name for *A. calcaratum*. *A. serrulatum* pollen shown in Huang (1972, Pl. 9:1–10) is rather similar to the subfossil taxon.
5. Taxon: *Adina* comp. Life form: tree. *Haldina* (*Adina*) *cordifolia* is widely distributed in Thailand and *Metadenia trichotoma* (*Adina parvula*) has a Nakhon Ratchasima name. *Nauclea* or *Neonauclea* are other possible sources of this small, spherical tricolporate, psilate-reticulate pollen type, which has small circular pores, but only *Nauclea orientalis* is widespread. Pollen of the above genera is illustrated in Maloney (1979).
6. Taxon: *Aegiceras corniculatum*. Life form: shrub. This pollen type is tricolporate, spheroidal and has small pores. *A. corniculatum* is a mangrove species with central, peninsular and south-eastern (Trat) names. The pollen is described in more detail by Dunbar and Erdtman (1969) but no light microscopy microphotographs have been presented.
7. Taxon: *Aerva*. Life form: climber. The subfossil pollen is polyhedral in shape with circular pores forming depressions within the scabrate polygonal blocks. *A. sanguinolenta* has a central Thai name. *A. javanica* has similar pollen grains (Riollet and Bonnefille 1976, Pl. III:1–7).
8. Taxon: *Albizia procera* comp. Life form: tree. This pollen type has 5–7 pores with granulate margins and a roughly rectangular shape. Similar pollen occurs in *Inga* (Erdtman 1966), not reported from Thailand, and *Albizia procera* (Huang, 1972, Pl. 85:10–13) and probably represents disintegration from polyads.
9. Taxon: *Allophyllus*. Life form: shrub. This pollen type is triporate and reticulate comparing well with that of *A. timorensis* (Huang 1972, Pl. 138:12–19). Four species occur in Thailand, 3 in the central/south-eastern area.
10. Taxon: *Altingia*. Life form: tree. This pollen is polyporate, spherical, reticulate, with a granulate edge to the pores. *A. siamensis* has been reported from Nakhon Ratchasima, *A. excelsa* has northern and eastern names and *A. selangorica* peninsular names. *A. excelsa* pollen is shown on Pl. 1:7 of van Zeist *et al.* (1979).
11. Taxon: *Alyxia* comp. Life form: climber. This pollen is diporate, the pores large, and psilate. Four species of *Alyxia* occur in Thailand but only *A. reinwardtii* has central and south-eastern names. *A. insularis* pollen is illustrated in Huang (1972, Pl. 12:20–2).
12. Taxon: *Amorphophallus* comp. Life form: herb. This pollen type is inaperturate, striate, prolate in equatorial view and spherical in polar aspect. Thirteen species of *Amorphophallus* occur in Thailand, 6 in the likely Khok Phanom Di pollen catchment area. *Pseudodracontium* and *Spathiphyllum* have a similar pollen morphology. Both species of *Spathiphyllum* present in Thailand are exotics (Smitinand 1980) but 2 of the 3 *Pseudodracontium* species occur in the pollen catchment area. Pollen grains of all 3 genera are described and well illustrated in Thanikaimoni (1969).
13. Taxon: Annonaceae. Life form: various. This pollen type is a monad, c. $95 \times 47 \mu\text{m}$ in size and coarsely reticulate in patterning. Apart from *Annona* (all species are exotic) and *Polyalthia*, 30 genera of Annonaceae occur in Thailand (Smitinand 1980). Walker (1971) considered the pollen of all except *Ellipeiopsis*, *Meiogyne*, *Melodorum*, *Muansum* and *Pyramidanthe* and this pollen type could be from either one of these genera or *Alphonsea*, *Cyathocalyx*, *Fissistigma*, *Miliusa*, *Orophea* or *Rauwenhoffia* (which have been described and illustrated). Only *Melodorum* of the first group of taxa has central/south-eastern names but only *Fissistigma* of the latter group lacks such names.

14. Taxon: *Antidesma*. Life form: shrub/small tree/tree. This pollen type is tricolporate, prolate and indistinctly reticulate. Four of the 13 Thai species have central/south-eastern/Saraburi names. *Antidesma* pollen has been described in Punt (1962:22) and illustrated on Pl. II:2 of the same publication.
15. Taxon: *Apodytes* comp. Life form: small tree. This small, triporate, straight-sided, reticulate pollen grain resembles *Apodytes* (Lobreau-Callen 1973, Pl. X:1-3) but could be from another genus in Icacinaceae, e.g. *Gonocaryum*. Smitinand (1980) reported one species of *Apodytes* (*A. dimidiata*), with northern and north-eastern names from Thailand.
16. Taxon: Araceae. Life form: herbaceous creeper. This pollen type is inaperturate, scabrate, c. 11.5 μ m in size, and $\pm$ spherical. *Anodendron* (Thanikaimoni 1969, Pl. I: 17-22) pollen is similar but the possibility that the subfossil pollen is from another genus in Araceae cannot be excluded. Two species of *Anodendron*, both with south-eastern names, occur in Thailand.
17. Taxon: *Ardisia* comp. Life form: shrub/small tree. This pollen is small, tricolporate, psilate-reticulate, with straight colpi sloping angularly to the poles. Twenty-eight species of *Ardisia* occur in Thailand, 11 in the pollen catchment area. *Ardisia* pollen is illustrated in Huang (1972, Pl. 109). The subfossil type is similar in size to that of *A. japonica* (Pl. 109:20-4).
18. Taxon: *Areca*. Life form: tree. This pollen is monolete and reticulate. Three species of *Areca* occur in Thailand: the cultivar *A. catechu*, *A. laosensis* (with a Trat name) and *A. triandra* (Chanthaburi, Trat and northern names). *A. catechu* pollen is shown on Pl. 176:3-6 of Huang (1972).
19. Taxon: *Arisaema* comp. Life form: herb. This pollen type is spherical, c. 14 μ m in diameter, and bacculate in patterning. Three species of *Arisaema* occur in Thailand and *A. siamensis* is widespread. The pollen of 3 *Arisaema* species is illustrated in Huang (1972, Pl. 168) and the subfossil pollen most resembles that of *A. grapsospadix* but could be from another genus in Araceae, e.g. *Gonathanthus* (cf. Thanikaimoni 1969).
20. Taxon: *Artocarpus* comp. Life form: tree. This pollen type is small and triporate. Nine indigenous species (mainly with peninsular names) and 3 exotics (all cultivars) occur in Thailand. *A. lanceolata* pollen is shown in Huang (1972, Pl. 108:3-4). The possibility that the pollen belongs to some other genus in Moraceae cannot be excluded.
21. Taxon: Asclepiadaceae. Life form: climber/creeper. This pollen type is a large distinctive polyad. Nineteen indigenous genera in Asclepiadaceae have been reported from the pollen catchment area and pollen of various genera is illustrated in Huang (1972, Pl. 17-20).
22. Taxon: *Avicennia*. Life form: mangrove tree. This pollen type is tricolporate, verrucate and differs slightly from that of *A. marina* shown in Huang (1972, Pl. 161:1-4). Two species of *Avicennia* (*A. alba* and *A. marina*) have central Thai names but *A. officinalis* only has peninsular names (Smitinand 1980).
23. Taxon: *Azima sarmentosa*. Life form: climber. This type is small, tricolporate and reticulate. Only one species occurs in Thailand and the plant was present at Khok Phanom Di. The pollen of *A. sarmentosa* does not appear to have been described or illustrated in the literature and that of *A. tetracantha* at 21.5 $\times$ 17 μ m (Erdtman 1966:392) is rather larger.
24. Taxon: *Baeckia*. Life form: shrub/small tree. This pollen type is syncolpate, scabrate and rather larger than most *Eugenia* comp. pollen found. *B. frutescens* has Chanthaburi names and pollen of *B. camphorata* is shown in Pike (1956, Fig. 79).

25. Taxon: *Begonia*. Life form: herb. This pollen type is tricolporate, c. $16.5 \times 11.5 \mu\text{m}$ in size (equatorial view), psilate and with longitudinal pores. Eight indigenous species of *Begonia* occur in Thailand, four in the pollen catchment zone. Pollen of 2 *Begonia* species is illustrated in Huang (1972, Pl. 22:1-9).
26. Taxon: *Betula alnoides*. Life form: tree. This pollen type is triporate, with the pores protrusive, and psilate. Smitinand (1980) reported a northern name only, but the taxon occurs in the Khao Yai National Park (Smitinand 1968).
27. Taxon: *Blumea* comp. Life form: herb. This pollen type is tricolporate and echinate, resembling *B. balsamifera* pollen as depicted in Huang (1972, Pl. 43:21-2) but possibly from another Thai genus in Compositae: Tubuliflorae (see notes under Compositae: Tubuliflorae 1).
28. Taxon: *Bombax*. Life form: tree. The distinctive triporate, reticulate pollen type has a rounded triangular polar view. All 3 Thai species of *Bombax* (*B. anceps*, *B. ceiba* (Kapok) and *B. valetonii*) occur in the pollen catchment area. The pollen of *B. malabaricum* DC (= *B. ceiba* L.) is shown on Pl. 26:1-14 in Huang (1972).
29. Taxon: *Borassodendron* comp. Life form: tree. This large monoporate, bacculate-verrucate pollen type is illustrated in Caratini and Tissot (1985, Pl. IV:10-11). *B. machadonis*, with peninsular names, is the only Thai species.
30. Taxon: *Brownlowia* comp. Life form: tree. This pollen type has a typical tilioid appearance and could derive from either *Brownlowia* or *Pentace*. *B. helferiana* with peninsular, northern and north-eastern names is the only Thai species of *Brownlowia*. Three species of *Pentace* occur and *P. burmanica* has a central Thai name (Smitinand 1980). The subfossil pollen resembles the *Brownlowia argentata* type of Caratini and Tissot (1985, Pl. I:8-9) better than that of *B. havillandii*.
31. Taxon: *Bruguiera* comp. 1 and 2. Life form: small tree/tree. These pollen types are small, tricolporate and psilate but differ markedly from each other in shape ($\pm$ spheroidal versus $\pm$ prolate) and colpus structure. The pollen of *Ceriops tagal* (Huang 1972, Pl. 126:35-7) is near to that labelled *Bruguiera* comp. 1 and that of *B. gymnorrhiza* (Pl. 126:32-4) to *Bruguiera* comp. 2. Detailed pollen morphological studies of these genera may prove rewarding. Four species of *Bruguiera* occur in Thailand, 3 with central or south-eastern names (*B. cylindrica*, *B. gymnorrhiza* and *B. sexangula*). *B. parviflora* only has peninsular names. Two species of *Ceriops* (*C. decandra* and *C. tagal*) have central/south-eastern names.
32. Taxon: *Calamus* comp. 1. Life form: climber. This pollen type is monoletate, $28 \times 30.5 \mu\text{m}$ in size, and coarsely reticulate. If not from *Calamus*, it is probably from *Daemonorops*. Thirty-one species of *Calamus* occur in Thailand, 6 in the pollen catchment area: *C. cambojensis*, *C. gracilis*, *C. latifolius*, *C. tenuis*, *C. tigrinus* and *C. viminalis*. One species is widespread (*C. rudentum*) but most of the others are peninsular in distribution. Ten species of *Daemonorops* occur but only one, *D. schmidtii* (Trat) has a south-eastern name. *C. andamanicus* (Thanikaimoni 1971, Pl. XVIII:354-7) is somewhat similar but *C. gracilis* (Pl. XVIII:358-61) is very different.
33. Taxon: *Calamus* comp. 2. This pollen type is monoletate, $35 \times 23 \mu\text{m}$, clavate-verrucate. It matches *C. gracilis* as illustrated in Thanikaimoni (1971) well.
34. Taxon: *Calamus* comp. 3. This type is monoletate, $35 \times 72 \mu\text{m}$ and densely bacculate. It is intermediate in pollen morphology between *C. andamanicus* and *C. gracilis*.
35. Taxon: *Calophyllum*. Life form: tree. Fifteen species occur in Thailand, 6 in the pollen catchment area. This tricolporate, scabrate pollen type is shown on Pl. II (4) of Caratini and Tissot (1985).

36. Taxon: *Canthium*. Life form: shrub/tree. Two of the 10 Thai species, *C. berberidifolium*, a shrub, and *C. brunnescens*, a tree, occur in Nakhon Ratchasima. This triporate, reticulate pollen type is depicted on Pl. II (6) in Caratini and Tissot (1985).
37. Taxon: *Capparis* comp. Life form: climber/shrub/small tree. Eighteen species of *Capparis* occur in Thailand, ten in the pollen catchment area. Two other genera in Capparidaceae are present: *Maerua* and *Stixis*. *M. siamensis* and *S. obtusifolia* occur in central Thailand. The tricolporate *Capparis* pollen type is illustrated in Maloney (1979).
38. Taxon: *Carex* comp. Life form: herb. This pollen type is monoporate, with a psilate-scabrate exine. Huang (1972, Pl. 169:12) has only presented a microphotograph of the four-aperturate *C. chrysolepis* but (p. 251) reports single apertured pollen from several species including *C. baccans*. He also found monoporate pollen in *Bulbostylis* and *Cyperus*, which have similar surface patterning, and in other taxa which do not. This determination must be regarded as tentative. Seven species of *Carex* occur in Thailand, 3 (*C. baccans*, *C. indica* (Trat) and *C. thailandica* in the pollen catchment area).
39. Taxon: *Caryota*. Life form: shrubby palm. This pollen type is small, monolete and reticulate. Three species are present in Thailand. *C. urens*, the only one with a central Thai name, grew at Khok Phanom Di. Pollen of *C. mitis* is shown on Sowunmi (1972, Pl. VIII:4) and Thanikaimoni (1971, Pl. XI:208-9) and *C. urens* in Thanikaimoni (1971, Pl. XI:215-7).
40. Taxon: *Cassia* id. *siamea* comp. Life form: tree. Eleven indigenous species (under shrubs or trees) occur in Thailand and 11 exotics. Eight species are present in the catchment area but the taxon closely resembles the tricolporate, scabrate-rugulate pollen from modern reference material of *C. siamea*, which was growing at the south side of Khok Phanom Di. Some other *Cassia* species cannot be excluded as likely sources however. Huang (1972, Pl. 97:12-13) shows *C. siamea*.
41. Taxon: *Castanopsis* comp. Life form: tree. This pollen taxon includes *Castanopsis* (24 species in Thailand) and *Lithocarpus* (34 species in Thailand). Three species of *Castanopsis* have been reported from the pollen catchment area (*C. costata*, *C. pierrei* (Trat) and *C. piriformis*) and 5 species of *Lithocarpus* (*L. annamensis* and *L. truncatus* from Nakhon Ratchasima, *L. hermandii* (Chonburi), *L. thomsonii* (Prachinburi) and *L. wallichianus* (Trat). Huang (1972, Pl. 70) presents microphotographs of *Castanopsis* and *Lithocarpus* pollen.
42. Taxon: *Casuarina*. Life form: tree. Three species occur in Thailand (*C. equisetifolia* with a central and peninsular distribution) and 2 exotics. *C. equisetifolia* (Phengklai, 1981) is an evergreen tree of sandy beaches. Huang (1972, Pl. 37:1-8) shows pollen of *C. huegeliana*.
43. Taxon: *Celtis*. Life form: tree. This pollen type is 3-4 porate and resembles modern reference pollen of *C. wightii* but not *C. tetrandra*. Three taxa occur in Thailand: *C. philippensis* (northeastern), *C. tetrandra*, quite widespread, and *C. timorensis*, widespread. The pollen may be from *C. timorensis*. Pollen of *C. wightii* is illustrated in Maloney (1979). *Aphananthe aspera* (Huang 1972, Pl. 154:11-15) has a similar pollen. Smitinand (1980) only reported northern names for the one Thai species (*A. cuspidata*).
44. Taxon: *Celosia* comp. Life form: herb. *C. argentea* has central and northern names. The polyporate pollen of *C. argentea* is illustrated in Huang (1972, Pl. 10:29). It differs from *Altingia* in having no small baculae around the pore rims.
45. Taxon: *Cerbera*. Life form: small tree/tree. Two species occur in Thailand, both in the pollen catchment area (*C. manghas* and *C. odollum*). This distinctive triporate pollen type with its wrinkled exine is depicted on Pl. 12:1-2 of Huang (1972).

46. Taxon: Chenopodiaceae/Amaranthaceae. Life form: herb. The subfossil pollen type is pantoporate, reticulate, spherical and ranges between c. 12 and 20 μm in diameter. Seven indigenous genera of Chenopodiaceae and Amaranthaceae additional to *Aerva* and *Celosia* occur in Thailand. Vishnu-Mittre (1963:97) placed *Aerva* in an *Amaranthus* type in which he also included *Achyranthes*. He also recognized a *Celosia* type (*Celosia* and *Allmania*, the latter not reported from Thailand) and a *Cyathula* type (*Cyathula* and *Deeringia*) using surface patterning as the basis of division. The subfossil type spans all these types as defined by Vishnu-Mittre, but *Gomphrena* (2 species in Thailand), fossil type spans all these types as defined by Vishnu-Mittre, but *Gomphrena* (2 species in Thailand), panporate with pores in luminoid depressions, can be separated as can the rather similar *Alternanthera* (3 indigenous species in Thailand). The *Amaranthus* type covers the characteristics of *Suaeda maritima* (cf. Huang 1972, Pl. 38:17-24), a saltmarsh indicator, and the one taxon which it is really desirable, because of this, to separate out.
47. Taxon: *Citrus* comp. Life form: small tree. Four indigenous species and 11 exotics occur in Thailand. Of the indigenous species only *C. latipes* has a central Thai distribution. The pollen is small (19 $\times$ 14 μm), reticulate, and CP4. It is most likely to be from a wild species. Huang (1972, Pl. 130:32-9) shows a somewhat similar four-colporate, reticulate, pollen grain from a wild species (*C. tachibana*).
48. Taxon: *Claoxylon* sim. Life form: shrub/small tree. This taxon is CP5, spherical (19 μm in diameter) and rugulate. Two species are present in Thailand, one (*C. indicum*) reported from Chanthaburi. The pollen resembles *C. brachyandrum* illustrated in Huang (1972, Pl. 65:20-31) claimed by Smitinand (1980) to be an exotic.
49. Taxon: *Cocos nucifera*. Life form: tree. The pollen grains are monolet, of medium size and the colpus has wavy margins. *C. nucifera* pollen is shown in Sowunmi (1972, Pl. VI:5).
50. Taxon: Combretaceae/Melastomataceae. Life form: climber/shrub/small tree. This psilate, $\pm$ prolate pollen type with six colpi, three having pores, is likely to be from *Combretum* /*Terminalia* or *Melastoma*. Fifteen species of *Combretum* occur in Thailand (7 in the pollen catchment area), 13 species of *Terminalia* (10 in the catchment area) and 7 of *Melastoma* (4 in the catchment area). *Terminalia* pollen is illustrated in Huang (1972, Pl. 48:11-15) and similar *Melastoma* pollen in Maloney (1979).
51. Taxon: Commeliniaceae. Life form: herb. This pollen taxon is an aggregate of types differing in surface patterning and size. All are monolet and range from scabrate to rugulate. Eight indigenous genera of Commeliniaceae occur in Thailand and the following have a distribution in the pollen catchment area: *Aneilema* (one species), *Commelina* (3), *Cyanotis* (1), *Floscopa* (1) and *Murdannia* (3). Pollen of all genera, except *Murdannia*, is depicted in Huang (1972, Pl. 168).
52. Taxon: Compositae:Tubuliflorae undiff. Life form: herb. These small tricolporate undifferentiated echinate pollen grains are definitely from Tubuliflorae but are too damaged for closer determination.
53. Taxon: Compositae:Tubuliflorae 1. Life form: herb. This pollen type is tricolporate with baculae. It is not from *Centipeda*, *Ageratum*, *Eclipta*, *Emilia*, *Gynura*, *Spilanthes* or *Tridax* (cf. Huang 1972). This leaves *Erydra*, *Grangea*, *Inula*, *Sphaeranthus* and *Synedrella* as possibilities, judging by Smitinand (1980). *Grangea* is echinate, like the taxa listed above (Stix 1960:73, Chaubal and Deodikar 1965:57), as is *Sphaeranthus* and *Synedrella* (Chaubal and Deodikar 1965:57).
54. Taxon: Convolvulaceae. This pollen type is pantoporate, bacculate, spherical and c. 35 μm in diameter, small for Convolvulaceae. It matches the smaller *Ipomoea insignis* type described on p. 190 of

- Sengupta (1972) and illustrated on Pl. X:7-8. This species is not reported from Thailand in Smitinand (1980) and perhaps some *Ipomoea* species in addition to *I. insignis* are characterized by the possession of larger and smaller groups of pollen grains.
55. Taxon: *Crinum*. Life form: herb. Six indigenous, and one exotic, species are present in Thailand. Three occur in central Thailand: *C. amoenum*, *C. asiaticum* and *C. latifolium*. *C. asiaticum* has been illustrated in Huang (1972, Pl. 167:6-7) and this monolete, reticulate pollen type with large irregularly shaped lumina very much resembles the sub-fossil taxon.
 56. Taxon: *Crotalaria* comp. Life form: herb/under-shrub/shrub. Eighteen indigenous (and 3 exotic) species occur in Thailand, 8 in the pollen catchment area. This pollen taxon somewhat resembles the tricolporate, reticulate pollen grains of *C. verrucosa* depicted in Huang (1972, Pl. 88: 11-14).
 57. Taxon: *Croton* comp. Life form: various. Eleven indigenous and one exotic species of *Croton* occur in Thailand but the bacculate or echinate *Croton* type patterning occurs in other genera (e.g. *Actephila*, *Blachia*, *Elateriospermum*) present in Thailand. Three of the *Croton* species have been reported from the pollen catchment area (*C. tigillum* is shown in Huang 1972, Pl. 66:1-4). The only other taxon with a *Croton* pattern and a central or south-eastern name is *Baliospermum montanum*, a shrub.
 58. Taxon: *Cycas*. Life form: shrub/small tree. Five indigenous and one exotic species are present in Thailand, 2 (*C. circinalis* and *C. siamensis*) in the pollen catchment area. Smitinand (1972) reported *C. rumphii* from the south-east. This is a species of sandy seashores and beach forests. The pollen is monolete, psilate, sub-spheroidal, similar to *C. taiwaniana* (Huang 1972, Pl. 1:20-2).
 59. Taxon: Cyperaceae undiff. Life form: herb. Seven genera other than those represented in the modern pollen reference collection occur in Thailand and four are found in the pollen catchment area: *Fuirena* (*ciliaris*), *Hypolytrum* (*nemorum*), *Juncellus* (*inundatus*) and *Lepironia* (*articulata*). This pollen type is probably from one or more of these genera, possibly not *Hypolytrum* judging by the microphotographs of *H. latifolium* in Huang (1972, Pl. 170:2-3).
 60. Taxon: *Cyperus* comp. Life form: herb. Twenty-eight indigenous (and 2 exotics) occur in Thailand, 17 recorded from the pollen catchment area. *Lipocarpa* has a similar pollen type but only one species (*L. argentea*, north-eastern) has been reported. Several *Cyperus* species are illustrated in Huang (1972, Pl. 169) and *L. senegalensis* on Pl. 170:6.
 61. Taxon: *Dacrycarpus imbricatus*. Life form: tree. Reported from Trat, Chanthaburi and Nakhon Ratchasima. Three-bladdered pollen grains also occur in *Podocarpus*. This pollen taxon is depicted in Maloney (1979).
 62. Taxon: *Dacrydium elatum*. Life form: tree. The only Thai species. Reported from Bangkok and Trat. This pollen taxon is illustrated in Sivak (1975, Pl. XII:16-18, Pl. XVII: 4-6).
 63. Taxon: *Decaspermum*. Life form: shrub/small tree. Two species occur, *D. cambodianum* in central Thailand and *D. fruticosum* with a southern and northern distribution. *D. gracilentum* pollen is depicted in Huang (1972, Pl. 110:1-4). The pollen of the sub-fossil taxon is larger than *Eugenia* comp., granulate, but syncolpate.
 64. Taxon: *Derris*. Life form: climber/tree. Five of the 12 Thai species occur in the pollen catchment area. *Derris* can occur as a climber in mangrove forest. The large-pored, tricolporate reticulate pollen grains of 2 species (*D. laxiflora* and *D. trifoliata*) are illustrated in Huang (1972, Pl. 88:15-19).

65. Taxon: *Desmodium*. Life form: trailing herb/climber/under-shrub/shrub. Thirteen indigenous (and one exotic) species occur in Thailand, 6 in the pollen catchment area. The large-pored tricolporate, reticulate pollen of several *Desmodium* species is illustrated in Huang (1972, Pl. 88:20–8; Pl. 97:14–23 and Pl. 143:17–21).
66. Taxon: *Diospyros*. Life form: small tree/tree. Fifty-five indigenous and 2 exotic species are present in Thailand, 30 in the pollen catchment area (Smitinand 1980). Phengklai (1981) recorded 60 species, mostly trees of lowland forest, however. This tricolporate pollen type most resembles *D. eriantha* as depicted in Huang (1972, Pl. 60:6–8).
67. Taxon: *Dipterocarpus*. Life form: tree. Sixteen species occur in Thailand, 10 in the pollen catchment area. The pollen somewhat resembles the *D. confertus* type of Caratini and Tissot (1985, Pl. II:13).
68. Taxon: *Donax*. Life form: under-shrub/herb. *D. grandis* occurs at Trat and in central Thailand. *Schumannianthus* may have a similar pollen type (*S. dichotomus* occurs in central Thailand). The monolet, granulate pollen of *D. cannaeformis* is shown on Pl. 173:18–21 in Huang (1972).
69. Taxon: *Elaeocarpus*. Life form: tree. This tricolporate, psilate pollen taxon is an aggregate of 2–3 types varying principally in pollen grain size. Identification to species/species groups may be possible with a complete modern pollen reference collection. Fourteen species occur in Thailand, 6 in the pollen catchment area. Several species of *Elaeocarpus* are illustrated in Huang (1972, Pl. 62:1–15).
70. Taxon: *Eleocharis*. Life form: herb. Coarsely scabrate pollen grains with indistinct pores. Five indigenous (and one exotic) species occur in Thailand: *E. acutangula* and *E. fistulosa* have been reported from Trat and *E. dulcis* from central Thailand. A microphotograph of *E. congesta* is present in Huang (1972, Pl. 169:18).
71. Taxon: *Eriobotrya*. Life form: tree. *E. bengalensis* has been reported from Chanthaburi. This pollen type has been identified using Huang (1972). It is tricolporate, prolate, psilate similar to *E. deflexa* (Huang 1972, Pl. 127:9–10) but could be from another genus in Rosaceae.
72. Taxon: *Eriocaulon*. Life form: herb. A distinctive syncolpate, spherical pollen grain. Eight species of *Eriocaulon* occur in central Thailand, 5 in the pollen catchment region. Microphotographs of 2 species are shown on Pl. 171:4–7 of Huang (1972).
73. Taxon: *Eugenia* comp. Life form: shrub/tree. An aggregate of larger (above 12 μ m) and smaller syncolpate psilate pollen grains. Forty-four indigenous species of *Eugenia* (and 3 exotics) are present in Thailand, 12 in the pollen catchment area. *Acmena*, one species in Thailand (*A. polyantha*), with a central, Trat, peninsular distribution has a similar pollen type as may *Cleistocalyx* (*C. operculatus*: peninsular distribution). *Eugenia* (*Syzygium*) pollen is shown in Huang (1972, Pl. 110:21–8).
74. Taxon: *Euodia* comp. Life form: small tree. Five species are present in Thailand, only one in the pollen catchment region: *E. roxburghiana*. The pollen is tricolporate and finely reticulate. *Euodia* pollen, illustrated in Huang (1972, Pl. 136) as *Evodia*, is more coarsely reticulate and that shown in Maloney (1979) is closer to the sub-fossil type.
75. Taxon: *Euphorbia*. Life form: herb/small tree. Eleven indigenous and 11 exotic species are reported in Smitinand (1980). The pollen type resembles *E. hirta* (collected on Khok Phanom Di) and illustrated by Huang (1972, Pl. 66:13–16). Four other species occur in the pollen catchment area: *E. antiquorum*, *E. hypericifolia*, *E. lacei* and *E. thymifolia*. *E. thymifolia* pollen (Huang 1972, Pl. 67:15–20) is slightly different from that of *E. hirta*.

76. Taxon: *Excoecaria*. Life form: shrub/tree. Three indigenous and one exotic species occur in Thailand, 2 in the pollen catchment area: *E. agallocha* (a shrub/small tree of mangrove) and *E. bantamensis* (a tree). The sub-fossil pollen is tricolporate, reticulate. Pollen grains of *E. bicolor* and *E. philippinensis* are described in Punt (1962:97, 99).
77. Taxon: *Ficus* small. Life form: various. Sixty-one native and 4 exotics are present in Thailand, 31 in the pollen catchment area. The pollen is diporate, ellipsoid in shape and psilate. The exine is very thin. *F. natalensis* is illustrated in Hamilton (1976, Pl. 2:12).
78. Taxon: *Ficus* large. Life form: various. This pollen type is rather larger than the usual *Ficus* and it is possible that it might be from some other genus, e.g. *Antiaris* or *Laportea*, with diporate pollen grains.
79. Taxon: *Fimbristylis* comp. Life form: herb. Nineteen species occur in Thailand, 7 in the pollen catchment area. The pollen is one aperturate, subspheroidal, scabrate and much smaller than the *Scirpus* and *Rhynchospora* types. Pollen of several species is described in Huang (1972:257–8) and that of *F. miliacea* and *F. squarrosa* is illustrated on Pl. 169:19–20.
80. Taxon: Flacourtiaceae. Life form: shrub/tree. This small tricolporate, psilate-reticulate pollen taxon resembles *Flacourtia* (2 indigenous and one exotic species, all in the pollen catchment area, in Thailand) but it could be from another genus in Flacourtiaceae, e.g. *Casearia*, *Garuga*, *Homalium* or *Protium* (cf. Keating 1973). *Flacourtia* grows on Khok Phanom Di.
81. Taxon: *Flagellaria*. Life form: herbaceous creeper. There is a single species with a southern distribution in Thailand. This taxon is monoporate, spheroidal and finely reticulate. It is illustrated in Huang (1972, Pl. 171:8–9).
82. Taxon: *Garcinia* 1. Life form: small tree/tree. Tricolporate, psilate $14 \times 11.5 \mu\text{m}$, with protruding pores. Twenty indigenous species, and 1 exotic (*G. mangostana*), occur in Thailand, 8 in the pollen catchment area. This pollen type resembles that of *G. merguensis* (which has Trat and Chanthaburi names) but is smaller. The other 5 species are *G. hanburyi*, *G. nigrolineata* (Trat only), *G. rostrata*, *G. schomburgkiana*, *G. speciosa* and *G. vilersiana*.
83. Taxon: *Garcinia* 2. Life form: small tree/tree. This pollen type is small four-colporate with elm-like reticulations. It could be from one of the above species. *Garcinia parviflora* (Maloney 1987) certainly has such a patterning, but is usually tricolporate.
84. Taxon: *Garcinia* 3. Life form: small tree/shrub. CP5, psilate $18.5 \times 23.7 \mu\text{m}$. This could be from one of the species listed above. Indeed the tricolporate and 5 colporate pollens could be from the same species.
85. Taxon: *Glochidion*. Life form: shrub/tree. This pollen type is small CP4, reticulate; 16 species occur in Thailand, 7 in the pollen catchment area. The pollen of several species is shown in Huang (1972, Pl. 68:1–15).
86. Taxon: Gramineae. Life form: herb. Very many genera occur. A few two-pored pollen grains were present but this feature is not restricted to one grass species. *Paspalum* is more coarsely scabrate than most pollen grains found. Data on pollen grain size allow better sample to sample correlation and have already been used.
87. Taxon: *Grewia* comp. Life form: shrub/tree. This pollen type is medium-sized, tricolporate, prolate, reticulate. Sixteen species occur in Thailand, 7 in the pollen catchment area. *Grewia* pollen is depicted in Huang (1972, Pl. 153:19–23). *Triumfetta* has a very similar pollen type.

88. Taxon: *Hedyotis* 1. Life form: herb. Twenty-three species are present in Thailand, 7 in the pollen catchment area. This pollen type is tricolporate, prolate, reticulate. Tricolporate pollen of *H. paniculata* and *H. uncinella* is shown on Pl. 132:23–6 of Huang (1972).
89. Taxon: *Hedyotis* 2. Life form: herb. This pollen type is CP4, prolate, reticulate, and is comparable to modern reference material of *Hedyotis capitellata* (southern, northern distribution). However, Huang (1972, Pl. 132:19–20) indicates that *H. corymbosa* is CP4 and *H. diffusa*, both present in Thailand, is CP5 and the descriptions (p. 204) indicate that both can be tricolporate. So both *Hedyotis* 1 and 2 may have been produced by the same species.
90. Taxon: *Houttuynia* comp. Life form: herb. *H. cordata* (central, northern) is the only Thai species. The sub-fossil pollen is small, monocolpate, and has a granulate surface patterning. *H. cordata* pollen is illustrated in Huang (1972, Pl. 140:16–17).
91. Taxon: *Hyptis* comp. Life form: shrub. Two species (*H. brevipes* and *H. suaveolens*), both with a southern distribution, occur in Thailand but this hexacolporate pollen type resembling *Hyptis* as illustrated by Huang (1972, Pl. 79:15–20) might be from another genus in Labiatae.
92. Taxon: *Ilex* small. Life form: shrub/small tree. Three species of *Ilex* occur in Thailand: *I. cymosa*, *I. triflora* and *I. umbellulata*. *I. cymosa* and *I. triflora* certainly have small bacculate-clavate tricolporate pollen grains but *I. umbellulata* (reported from Chanthaburi) is absent from the modern pollen reference collection. Pollen of several *Ilex* species is shown in Huang (1972, Pl. 14).
93. Taxon: *Ipomoea* id. *aquatica*. Life form: creeping herb. This pollen grain has short spines, is 72 μ m in diameter and polyporate. It has been determined using Sengupta (1972). *I. aquatica* comp. grows near Khok Phanom Di today.
94. Taxon: *Ipomoea* id. *asarifolia*. Life form: herb. This pollen type is 66 μ m in diameter, with curved 6.5 μ m spines, and is polyporate. It has also been determined using Sengupta (1972) and the species occurs in the Khok Phanom Di area today.
95. Taxon: *Iris* sim. Life form: herb. *I. collettii* (northern) has been reported from Thailand. This large, monolete, reticulate pollen type may well be from Liliaceae rather than Iridaceae but the patterning is clearer than in Liliaceae and the pollen of *I. formosana* (Huang 1972, Pl. 171:23–4) is not too dissimilar.
96. Taxon: *Itea*. Life form: shrub. This pollen type is diporate and psilate resembling *I. virginica* (Lieux 1982 Pl. LXXVIV:8–13) but possibly from a genus in Apocynaceae, e.g. *Anodendron* (Huang 1972, Pl. 12:20–2). One species of *Itea* (northern and north-eastern names) occurs in Thailand.
97. Taxon: Labiatae CP3. Life form: herb/shrub/under-shrub. The pollen is tricolpate, c. 11.5 $\times$ 14 μ m in equatorial view and scabrate-rugulate. Nineteen indigenous genera apart from *Hyptis* and *Scutellaria* occur in Thailand; representatives in the pollen catchment area: *Anisochilus*, *Epimeredi*, *Leonotis*, *Leucas*, *Ocimum*, *Orthosiphon* and *Pogostemon*. *Ocimum* is hexacolpate and supra-reticulate (Huang 1972, Pl. 80:9–11). *Anisochilus* is hexacolpate, prolate and reticulate (Vasanthy 1976, Pl. XXII:384–7). *Orthosiphon* is hexacolpate (El-Gazzar and Watson 1968) and *Pogostemon* is tricolpate but supra-reticulate (Vasanthy 1976, Pl. XXIV:414–8), so the pollen is not from these genera.
98. Taxon: Labiatae C6. Life form: herb/shrub/under-shrub. This pollen type is similar to *Hyptis* but prolate. It was found in the same sample as *Hyptis* comp. and could be a variant. Similar pollen occurs in *Elsholtzia* (Nair 1965), one species in Thailand, possibly *Orthosiphon* (El-Gazzar and Watson 1968), 3 species in Thailand, 2 with central names and *Anisochilus* (Vasanthy 1976, Pl. XXII:384–7) which has 2 Thai species, one (*A. harmandii*) with Trat, Chonburi names.

99. Taxon: *Lasianthus*. Life form: shrub. A large (58 μ m) triporate scabrate pollen grain with a thick exine. Twelve species of *Lasianthus* occur in Thailand, 6 in the pollen catchment area. *Lasianthus* pollen illustrated in Huang (1972, Pl. 133) is reticulate but modern reference material shows that it can be degraded to a scabrate patterning.
100. Taxon: Lauraceae. Life form: tree. This pollen grain is inaperturate, spherical, c. 30 μ m in size, and microechinate. Lauraceae pollen does not usually preserve and is not readily determined below the family level. Fourteen genera occur in Thailand and the following have representatives in the pollen catchment area: *Actinodaphne* (2 species), *Beilschmiedia* (1 species), *Cinnamomum* (7 species), *Dehaasia* (1 species), *Litsea* (5 species), *Neolitsea* (2 species), *Persea* (1 species), *Phoebe* (2 species) and *Temmodaphne* (1 species). Pollen of most of the above genera is illustrated in Huang (1972:81–2).
101. Taxon: *Licuala* comp. Life form: shrub/small tree. This pollen grain is monolete and finely scabrate. *Licuala*, as illustrated by Caratini and Tissot (1985, Pl. IV: 8), is the closest match but other genera cannot be ruled out. Six indigenous and one exotic species of *Licuala* occur in Thailand, 3 in the pollen catchment area. *Licuala* sp. was growing in a garden on the south side of Khok Phanom Di.
102. Taxon: Liliaceae. Life form: climber/herb. This pollen type is large, monolete and psilate to faintly reticulate in patterning. Eleven indigenous genera occur in Thailand and the following species are likely to be present in the pollen catchment area: *Asparagus racemosus*, *Chlorophytum orchidiastrum*, *Dianella ensifolia*, *Diosporum calcaratum*, *Gloriosa superba* and *Ophiopogon intermedius*. *Dianella* has trilete pollen and can readily be eliminated while *Gloriosa superba* (Nair and Sharma 1964) is monolete but with a foveolate exine. *Asparagus*, *Chlorophytum* and *Diosporum* all have pollen grains similar to the sub-fossil taxon (cf. Nair and Sharma 1964) as Huang (1972, Pl. 173:10) has *Ophiopogon*.
103. Taxon: *Ludwigia*. Life form: herb/aquatic herb. This is an aggregate of triporate monad and tetrad pollen grains. The monads and tetrads may originate from differing species. The taxonomy of *Ludwigia* is somewhat confused. Smitinand (1980) reported only one species in the genus, *L. parviflora*, with peninsular names, from Thailand but 2 of *Jussiaea* (*J. repens* and *J. suffruticosa*) together with *Fissendocarpa linifolia*, all of which Raven (1977) placed in *Ludwigia*. *J. repens*, an aquatic herb, and *F. linifolia*, a herb, both have central Thai names. Raven's taxonomy is as follows: *L. parviflora* = *L. perennis* L., *J. repens* = *L. adscendens* (L.) Hara, *J. suffruticosa* = *L. octovalis* (Jacq) Raven, and *F. linifolia* = *L. hyssopifolia* (G. Don) Exell.
104. Taxon: *Lumnitzera*. Life form: small tree. This pollen type is most distinctive: C6P3, prolate, and reticulate. Two species, both present in the pollen catchment area (*L. littorea* and *L. racemosa*), occur in Thailand and *L. racemosa* pollen is illustrated in Huang (1972, Pl. 48:1–5).
105. Taxon: *Macaranga* comp. Life form: small tree/tree. This pollen type is small, tricolporate, $\pm$ spherical, and has thick colpi. Sixteen species occur in Thailand, 8 in the pollen catchment area. *M. tanarius* pollen is depicted on Pl. 68:28–31 of Huang (1972).
106. Taxon: Magnoliaceae. Life form: shrub/tree. This pollen type is large, monolete and rugulate. Seven genera in Magnoliaceae are present in Thailand but only 3 have central/south-eastern names: *Talauma* (*T. hodgsonii*, *T. siamensis*), *Kmeria* (*K. duperreana*) and *Paramichelia* (*P. baillonii*). Pollen of *Talauma* (Fig 7:h-n, Fig. 8:a-g), including *T. hodgsonii*, and *Paramichelia baillonii* (Fig. 11:g-l) is shown in Praglowski (1974). The sub-fossil type could be from either of these genera, or others in Magnoliaceae, e.g. *Magnolia* or *Michelia* (cf. Agababian 1972, Praglowski 1974).

107. Taxon: *Mallotus* comp. Life form: shrub/tree. This pollen type is comparable to *Macaranga* but is larger. It is not impossible for it to be from a *Macaranga* species. Thirteen species of *Mallotus* have been reported from Thailand, 8 of them from the pollen catchment area. The pollen of 3 species is illustrated in Huang (1972, Pl. 68:28–34; Pl. 69:1–3) and *Macaranga* and *Mallotus* have been dealt with in detail in Punt (1962).
108. Taxon: Malvaceae. Life form: herb/small tree. This pollen type is pantoporate, spherical, 72 μ m in diameter, and has spines c. 8 μ m long. Ten indigenous genera of Malvaceae occur in Thailand, 6 in the pollen catchment area: *Abelmoschus* (one indigenous and 2 exotic species), *Abutilon* (3 species), *Decaschista* (2 species), *Hibiscus* (6 species), *Pavonia* (1 species), *Sida* (4 species), *Thespesia* (2 species) and *Urena* (1 species). *Abelmoschus*, *Abutilon*, *Hibiscus* and *Sida* were present on or near Khok Phanom Di. Pollen grains of all these genera have been described, and those of some illustrated, in Christensen (1986), and *Sida* appears to be the closest match to the sub-fossil type, although other genera cannot definitely be excluded.
109. Taxon: *Mastixia* comp. Life form: tree. This is a large tricolporate scabrate grain, 54 μ m in breadth in polar view. One species, with a northern distribution (*M. euonymoides*), has been reported from Thailand. *Mastixia* pollen is illustrated in Ferguson (1977: Fig. 9).
110. Taxon: *Melothria* comp. Life form: herbaceous creeper. Named using Huang (1972, Pl. 57:1–6). This pollen type is triporate (pores annulate), 40 $\times$ 36 μ m in polar view and finely reticulate and resembles *M. maderaspatana* well. Five species occur in Thailand, 3 in the pollen catchment area: *Melothria* (*Mukia*) *maderaspatana*, *M. (Solena) heterophylla* and *M. perpusilla* (*Zehneria maysorensis*). *M. heterophylla* pollen is tricolporate (Huang 1972, Pl. 56: 11–16) but *M. perpusilla* has not been described or illustrated.
111. Taxon: *Milletia* sim. Life form: climber/shrub/tree. This pollen type is tricolporate, with large pores, $\pm$ spherical and reticulate, rather resembling *M. reticulata* (Huang 1972, Pl. 92:11–16). Seventeen species are present in Thailand, 3 in the pollen catchment area (*M. leucantha* and *M. pendula*, both trees, and *M. racemosa*, a climber). However, this pollen could be from another legume genus.
112. Taxon: *Mimosa pudica*. Life form: under-shrub. This taxon has a very distinctive small, tetrahedral tetrad pollen type (Vishnu-Mittre and Sharma 1962, Pl. 1:2; Rao and Ong 1972: Fig. 13). It is indigenous to Thailand and the exotic *M. pigra* has a rather different polyad pollen type.
113. Taxon: *Momordica* comp. Life form: herbaceous creeper. This pollen type is tricolporate with thick costae colpi, a microreticulate patterning, $\pm$ spherical, and c. 30 μ m in size. Three species occur in Thailand, 2 (*M. charantia* and *M. cochinchinensis*) in the pollen catchment area. *M. charantia* pollen is illustrated in Huang (1972, Pl. 57:11–20).
114. Taxon: *Monochoria* comp. Life form: aquatic herb. This monocolpate, reticulate pollen type is indistinguishable from that of the introduced *Eichhornia crassipes*. Two species of *Monochoria* occur in Thailand, both in the pollen catchment area: *M. hastata* and *M. vaginalis*. *E. crassipes* and *M. vaginalis* pollen is shown on Pl. 177 of Huang (1972).
115. Taxon: *Moringa*. Life form: small tree. This tricolporate pollen type is quite similar to that of *Calophyllum*, but is psilate. *M. oleifera*, planted north of Khok Phanom Di, is the only Thai species. *M. oleifera* pollen is illustrated in Huang (1972, Pl. 108:25–8).
116. Taxon: *Mussaenda* sim. Life form: climber shrub. This pollen type is four-porate and scabrate. It is either from a genus in Rubiaceae, of which *Mussaenda* is most likely, or an aberrant pollen grain of *Celtis tetrandra*. Nine indigenous species of *Mussaenda* (together with 2 exotics) occur in

- Thailand, 5 in the pollen catchment area. The greatest similarity is with the *Mussaenda* illustrated in Maloney (1979). That shown in Huang (1972) differs greatly.
117. Taxon: *Nymphaea* comp. Life form: aquatic herb. This pollen type is syncolpate, spheroidal and has gemmate processes. It resembles *N. tetragona* as shown in Huang (1972, Pl. 107:33). Two native species occur in Thailand: *N. cyanea*, a herb of northern distribution, and *N. nouchali*, which is present in the pollen catchment area. There are 3 exotic species.
 118. Taxon: *Nymphoides*. Life form: aquatic herb. This taxon has a distinctive tricolpate (syncolpate) coarsely granulate pollen type (C4 pollen grains occur occasionally). Five species are present in Thailand, 3 in the pollen catchment area. *N. indicum* was found in association with *Neptunia oleracea*, *Ceratopteris thalictroides*, and other ricefield weeds north of Khok Phanom Di. *N. coreana* and *N. cristatum* pollen grains are depicted in Huang (1972, Pl. 73:8-13).
 119. Taxon: *Oncosperma*. Life form: palm tree. Pollen of this taxon has been illustrated by Caratini and Tissot (1985, Pl. I: 6). Its patterning resembles *Ilex* (clavate), but it is monocolpate. Two species, of southern distribution, occur in Thailand: *O. horrida* and *O. tigillaria*.
 120. Taxon: *Ottelia* sim. Life form: aquatic herb. This 23 μ m in diameter, inaperturate, warty pollen type has been named using Huang (1972:13-14). *O. alismoides*, the only Thai species, occurs in the pollen catchment area but there is a slight possibility that this pollen may be from *Blyxa* (also aquatic herbs). The pollen shown in Huang is certainly much larger in size.
 121. Taxon: Palmae psilate. Life form: climber/tree. Twenty-three indigenous palm genera, apart from those already mentioned, are present in Thailand. Not all are represented in the modern pollen reference collection but this 35 $\times$ 19 μ m, monolete, psilate pollen type resembles that of *Livistona* (6 species in Thailand, 3 indigenous and 3 exotic, but none reported from the study area), although other genera cannot be excluded. *Livistona* pollen is described in Thanikaimoni (1970) and illustrated in Maloney (1979).
 122. Taxon: Palmae scabrate. Life form: ? climber. This pollen is monolete, scabrate, c. 35 $\times$ 18.5 μ m and may derive from *Daemonorops* (10 species in Thailand, all of peninsular distribution, except *D. schmidtii*, reported from Trat).
 123. Taxon: Palmae reticulate. Life form: ? tree. This pollen type is monolete, reticulate, c. 23 $\times$ 16.5 μ m in size and may be from *Nenga* (one species, *N. pumila*, of southern distribution, in Thailand), which is illustrated in Caratini and Tissot (1985, Pl. IV:2).
 124. Taxon: Palmae bacculate - rugulate. Life form: climber/tree. This pollen type is monolete, rugulate c. 40 $\times$ 21 μ m in size, and bacculate to rugulate in surface patterning. It could be from *Cyrtostachys lakka* which has Bangkok and peninsular names. Pollen of *Cyrtostachys* is illustrated in Thanikaimoni (1970, Pl. XVI:304-5).
 125. Taxon: Palmae rugulate. Life form: climber/tree. This monolete pollen grain is c. 59 $\times$ 35 μ m in size and tectate. It may be degraded. It is not possible to assign it to a genus even tentatively.
 126. Taxon: *Pandanus*. This pollen grain is very small (c. 10 μ m in diameter), monoporate or occasionally monolete, and scabrate. *Pandanus* pollen is illustrated in Huang (1972, Pl. 176:19). Fifteen indigenous species occur in Thailand, 6 in the pollen catchment area.
 127. Taxon: *Passiflora* id. Life form: herbaceous creeper. Four species (3 exotic) occur in Thailand. This large, CP6, reticulate pollen grain matches reference pollen of *P. foetidum*, thought to be indigenous. The other genus in *Adenia* (4 species in Thailand, 2 in the pollen catchment area: *A. pierrei* and *A.*

- viridiflora*), a genus of climbers, has very different, small, CP3-4, reticulate pollen (Spirlet 1965, Pl. 1:1-25). *P. foetidum* pollen is described in Presting (1965).
128. Taxon: *Pedicularis* sim. Life form: parasitic herb. This pollen grain is small, *c.* 14μ , scabrate and dicolpate, with a thick exine. It may be an aberrant tricolpate pollen grain but, if not, is probably from *Pedicularis*. Two species, with a central Thai distribution, *P. rhynchodonta* and *P. siamensis*, occur. The pollen resembles that of *P. siphonantha* (Nair 1965, Pl. XI:145) quite closely.
 129. Taxon: *Phoenix*. Life form: tree. Four indigenous and 2 exotic species occur in Thailand but only *P. paludosa*, the mangrove date palm, occurs in the pollen catchment area. *Phoenix* pollen is best illustrated in Kedves (1980, Pl. XI:3-14). It is small, monolete, tectate and scabrate-reticulate.
 130. Taxon: *Phyllanthus*. Life form: herb/small tree. This pollen grain is hexacolpate, reticulate, and $21 \times 14\mu$ in size. Huang (1972:113) has described rather similar pollen from *P. emblica*. Twenty-five species of *Phyllanthus* occur in Thailand, 15 in the pollen catchment region.
 131. Taxon: *Pinus merkusii*. Life form: tree. This pollen type has two large, reticulate air bladders. The species has been reported from central Thailand (Smitinand 1980) but is common in dry deciduous dipterocarp and lower montane forests at 600-1300m altitude (Phengklai 1972).
 132. Taxon: *Pinus* 1. Life form: tree. This pollen type has two smaller, reticulate air bladders and may be from *P. kesiya*, the only other Thai species, a common tree of lower montane forest in northern and north-eastern Thailand (Phengklai 1972).
 133. Taxon: *Piper*. Life form: climber/shrub. This pollen type is very small, *c.* 5μ in diameter, monoporate or monocolpate and scabrate. Thirteen indigenous and 1 exotic species are present in Thailand, with 6 reported from the pollen catchment area. Pollen of *Piper* spp. is shown in Huang (1972, Pl. 115:5-10).
 134. Taxon: *Pistia* sim. Life form: aquatic herb. *P. stratiotes*, with central and northern names, is the only Thai species. This pollen grain is small, monolete, psilate (cf. Huang 1972, Pl. 168:14) but other taxa in Araceae probably have similar pollen.
 135. Taxon: *Podocarpus* id. *neriifolius* comp. Life form: tree. The pollen of this species is illustrated in Maloney (1979). It has two air bladders and the body of the grain is spherical in shape. *P. neriifolius* has been reported from central Thailand, Nakhon Ratchasima, the north and north-east. It is not impossible that this pollen type is from a species in *Podocarpus* other than *P. neriifolius*.
 136. Taxon: *Podocarpus* id. *wallichianus* sim. Life form: tree. This pollen type, which has two air bladders, resembles that of *P. amarus*, illustrated in Maloney (1979) and differs from *P. neriifolius* in that the body of the pollen grain (between the two air bladders) is rhomboid. Four species of *Podocarpus*, apart from *Dacrycarpus* (*Podocarpus*) *imbricatus* and *P. neriifolius* are present in Thailand but only *P. pilgeri* and *P. polystachyus* occur in the pollen catchment area. *P. motleyi* has southern names and *P. wallichianus* southern and northern names. The sub-fossil pollen resembles Fig. 61 A (p. 38) of *P. wallichianus* in Erdtman (1957) but this identification must remain tentative.
 137. Taxon: *Polyalthia* comp. Life form: shrub/tree. This pollen grain is a large scabrate-rugulate tetrad most resembling modern reference material of *Polyalthia*. Fifteen *Polyalthia* species occur in Thailand, 5 in the pollen catchment area. Somewhat similar pollen is present in *Mitrephora* (cf. Walker 1971, Pl.13:6) but this has a reticulate exine (8 species occur in Thailand, 3 with Chanthaburi names) and *Pseudovaria* (Pl. 15:3-6). The *P. philippensis* pollen grains illustrated are verrucate, however. Three species occur in Thailand, none with central or south-eastern names.

138. Taxon: *Polyosma* comp. Life form: shrub/tree. This pollen grain is large, tricolporate, the pores being aspidote, the colpi short, and psilate. The taxon is illustrated in Maloney (1979). One species, *P. arguta*, occurs in Thailand (Trat). *P. cambodiana* pollen is described in Erdtman (1966:401).
139. Taxon: *Potamogeton* comp. Life form: aquatic herb. Monolete, sub-spheroidal reticulate pollen grains with thin exines. The two Thai species have northern names only but probably have a more widespread distribution. *Potamogeton* spp. are shown on Pl. 177:5–8 in Huang (1972).
140. Taxon: *Pothos* comp. Life form: climber. This inaperturate, spherical, finely scabrate type, c. $11.5\mu\text{m}$ in diameter, resembles *Pothos* as illustrated in Huang (1972, 168:15) but could be from another genus in Araceae. Five species of *Pothos* occur in Thailand, 2 in the pollen catchment area.
141. Taxon: *Prunus* sim. Life form: tree. This pollen type resembles *Pygeum* (= *Prunus*, Smitinand 1980) illustrated in Huang (1972 Pl. 13–15) but could be from another genus in Rosaceae. Four indigenous species, and one exotic, are present in Thailand, but only *P. ceylanica* (Trat) occurs in the south-east.
142. Taxon: *Quercus*. Life form: tree. This tricolpate, scabrate, pollen type resembles Sumatran *Quercus* (Maloney 1979) and differs in surface patterning from that of British species, so it is not a contaminant. Nineteen species occur in Thailand but only two have been reported from the south-east (*Q. dussaudii* and *Q. semiserrata* (Trat)).
143. Taxon: *Randia* comp. Life form: climber/shrub/tree. This $18.5\mu\text{m}$ pollen type is triporate and scabrate-rugulate. Pollen of *Randia* species is illustrated in Huang (1972, Pl. 134:22–9). Nineteen species are present in Thailand, 10 in the pollen catchment region. Reference pollen of *Celtis tetrandra* is rather similar, however.
144. Taxon: *Rauvolfia* comp. Life form: shrub/small tree. This pollen type with its four prominent colpi and circular pores resembles *Rauvolfia* as depicted in Huang (1972; Pl. 13:11–19) but could be from another genus in Apocynaceae. Four species of *Rauvolfia* occur in Thailand, 3 in the pollen catchment zone.
145. Taxon: *Rhizophora*. Life form: tree. Two species of *Rhizophora* occur in Thailand (*R. apiculata* and *R. mucronata*). These differ very slightly in pollen type viewed under high power light microscopy via an oil immersion objective (Muller and Caratini 1977) but the pollen is so abundant in the sediments from near Khok Phanom Di to render species identification unachievable.
146. Taxon: *Rhus* sim. Life form: small tree. This small (c. $18.5 \times 11.5\mu\text{m}$) tricolporate, striate pollen type is definitely from Anacardiaceae. It resembles that of *Rhus* (Selling 1947, Pl. 27:395–7) but is rather close to *Camptosperma* (Caratini and Tissot 1985, Pl. II: 7) as it has longitudinal pores. *R. chinensis*, with a northern name, is the only Thai species of *Rhus* and *C. auriculata* (southern) of *Camptosperma*. *Lannea* (*L. coromandelica* occurs at Trat) is another possibility.
147. Taxon: *Rhynchospora* sim. Life form: herb. This single-apertured, medium-sized scabrate pollen type could be from *Rhynchospora* or *Scleria*. Pollen grains of both genera have been illustrated in Huang (1972, Pl. 170). Two species of *Rhynchospora* are present in Thailand, both in the pollen catchment area, and 13 of *Scleria* with 6 in the pollen catchment area.
148. Taxon: *Ricinus* comp. Life form: shrub/small tree. *Ricinus* and *Homonoia* have a similar tricolporate, psilate, pollen type (Punt 1962:86). One species of *Ricinus* grows in Thailand (*R. communis*, cultivated at Khok Phanom Di) and one of *Homonoia* (*H. riparia*).
149. Taxon: Rutaceae. Life form: climber/shrub/small tree. This pollen type is tricolporate, reticulate, c. $19 \times 14\mu\text{m}$ in equatorial view and definitely from Rutaceae. It is not from *Acronychia*, *Aegle*, *Atalanta*, *Clausena*, *Feronia*, *Euodia*, *Glycosmis*, *Luvunga*, *Toddalia* or *Zanthoxylum*. The other genera

with taxa reported from the pollen catchment area are: *Feroniella*, *Hesperethusa*, *Micromelium* and *Paramignya*. As *Paramignya*, a climber, occurs in mangrove, it is a likely source. Unfortunately this taxon is not represented in the pollen reference collection, nor does it appear to be described in the literature. It is not mentioned in Thanikaimoni (1980).

150. Taxon: *Salix* comp. Life form: tree. This tricolporate, reticulate pollen type resembles that of *Salix warburgii* illustrated in Huang (1972, 138:1-4). Two species occur in Thailand: *S. babylonica*, an exotic, and *S. tetrasperma*, reported from the pollen catchment region. *S. tetrasperma* is described in Nair (1965:40) and *S. babylonica* is illustrated in Lieux and Godfrey (1982, Pl. LXIV:8-14).
151. Taxon: *Santiria* sim. Life form: tree. This tricolporate, psilate, pollen type resembles *Santiria* as depicted in Maloney (1979), but could be from a species of *Canarium*. One species of *Santiria* (*S. conferta*, with a southern name) occurs in Thailand and 5 of *Canarium* (2 reported from the pollen catchment area). *S. lavigata* pollen is described in Rao and Lee (1970:260).
152. Taxon: *Saurauia*. Life form: shrub/small tree. Most species of *Saurauia* have a small tricolporate, psilate, pollen grain differing from that of *Elaeocarpus* in polar area index and by having straight thick colpi curving late towards the pole. Four species occur in Thailand (Keng 1972), but only *S. tristyla* and *S. roxburghii* have been reported from the pollen catchment area and the pollen of the former is atypical of the genus. *S. roxburghii* is found along streams in or at the edge of evergreen forest from 100 to 1700m.
153. Taxon: *Schima wallichii*. Life form: tree. This tricolporate, reticulate, pollen type has been illustrated in Van Zeist *et al.* (1979, Pl. 1:2-3). The tree has a Nakhon Ratchasima and Trat name, and occurs in scrub, savanna and bamboo forest (Keng 1972).
154. Taxon: *Scirpus* comp. Life form: herb. Four species of *Scirpus* occur in Thailand, 3 in the pollen catchment area. *S. juncoides* and *S. mucronatus* are ricefield weeds near Khok Phanom Di. This large one-aperturate scabrate pollen type resembles reference material of *S. mucronatus* but could overlap the *Rhynchospora* type at the smaller end of the size range.
155. Taxon: *Scutellaria* sim. Life form: herb. This tricolporate, reticulate, c. $18.5 \times 14 \mu\text{m}$, pollen type resembles *Scutellaria* as illustrated in Huang (1972, Pl. 81:5-10) but could be from another genus in Labiatae. One *Scutellaria* species (*S. incurva*), with Prachinburi and northern names, has been reported from Thailand.
156. Taxon: *Scyphiphora hydrophyllacea*. Life form: shrub. A small, $\pm$ spherical, tricolporate, reticulate pollen grain with slightly protruding longitudinal pores depicted in Darwin (1979, Fig. 1:G). A mangrove species with Bangkok and peninsular Thai names which, because of its pollination mechanism, is unlikely to shed much pollen into the atmosphere.
157. Taxon: *Shorea* comp. Life form: tree. This pollen type is tricolpate and spherical in equatorial view. The surface patterning is reticulate. Twenty-one indigenous (together with one exotic) species occur in Thailand, 8 in the pollen catchment region. Pollen of *Shorea* and other genera within Dipterocarpaceae is illustrated in Maury *et al.* (1975).
158. Taxon: *Smilax* comp. Life form: climber. This pollen type is small, inaperturate and microechinate resembling *Smilax* as shown in Selling (1947, Pl. 56:920-1). Eleven species of *Smilax* and one of *Heterosmilax* are present in Thailand. *Heterosmilax* has a northern name only but 3 species of *Smilax* occur in the pollen catchment area.
159. Taxon: *Smithia*. Life form: herb. Pollen of this tricolpate, prolate, reticulate type is shown in Huang (1972; Pl. 96:18-20). Two species occur in Thailand: *S. sensitiva* (illustrated by Huang), collected a few kilometres east of Khok Phanom Di, and *S. ciliata*, which has a northern distribution.

160. Taxon: *Solanum*. Life form: climber/shrub. This pollen type is not always readily separable from the very variable *Rhizophora*. It is tricolporate, rugulate-reticulate and has been separated on the basis that the ora are connected as a belt across the centre whereas they are not in *Rhizophora*. Fourteen native and 2 exotic species have been reported from Thailand, 12 from the pollen catchment area. The pollen of several species of *Solanum* is shown in Huang (1972, Pl. 145–6).
161. Taxon: *Sonerila* comp. Life form: herb. This pollen taxon is tricolporate, c. $14 \times 11.5 \mu\text{m}$, and resembles *Sonerila* as depicted in Vasanthy (1976, Pl. XXVI:457–60) but could be from another genus in Melastomataceae or, possibly, Combretaceae. Two species of *Sonerila* occur in Thailand, (*S. deflexa* (Nakhon Ratchasima) and *S. quadrangularis* (Chanthaburi)).
162. Taxon: *Sonneratia alba*. Life form: tree. Mangrove trees with central and southern names. The pollen has been described and profusely illustrated by Muller (1969, 1978). It is triporate, verrucate and lacks meridional ridges.
163. Taxon: *Sonneratia caseolaris*. Life form: tree. Mangrove trees with a central Thai name. The pollen is readily separable from that of *S. alba* (cf. Muller 1969, 1978). The tectum is psilate in polar view and it has irregularly rugulate or grooved meridional ridges.
164. Taxon: *Sonneratia* id. *ovata* comp. Life form: tree. Mangrove trees with a Chanthaburi name. The pollen is rather similar to that of *S. alba* (Muller, 1969 Pl. XI:5–9, Pl. XII:1–10) but the tectum is irregularly rugulate-verrucate in polar view.
165. Taxon *Stephania*. Life form: climber. This triporate, reticulate, spherical pollen type has been illustrated in Huang (1972, Pl. 107:24–30). Seven species (one a shrub) occur in Thailand but only one in the pollen catchment area: *S. pierrei*.
166. Taxon: *Styrax* sim. Life form: shrub/tree. This pollen type is tricolporate, psilate, $18.5 \times 14 \mu\text{m}$, and of rhomboid shape. It resembles reference pollen of *Styrax paralleloneurus*. Seven species of *Styrax* occur in Thailand, none with a central or south-eastern name. *Styrax* pollen resembling the sub-fossil taxon is illustrated in Lieux (1982, Pl. LXXVI:1–11).
167. Taxon: *Symplocos* id. *pendula* comp. Life form: shrub/tree. This triporate pollen taxon resembles the *S. pendula* type of van der Meijden (1970, Pl. 1:1–5). Smitinand (1980) recorded nine species of *Symplocos* from Thailand, 4 in the pollen catchment area: *S. caudata*, *S. impressa*, *S. laurina* and *S. racemosa*, but Nooteboom (1981) described 18 species.
168. Taxon: *Tacca*. Life form: herb. This monolete, reticulate pollen type matches *Tacca* as depicted in Selling (1947, Pl. 56:922–3). Five species are present in Thailand, 4 in the pollen catchment area.
169. Taxon: *Tarenna* sim. Life form: shrub. A tricolporate, reticulate pollen type with protruding pores somewhat resembling *Tarenna* (cf. Huang 1972, Pl. 135:9–12). Eight species of *Tarenna* occur in Thailand, 6 in the pollen catchment area. It is possible that other genera in Rubiaceae may have a similar pollen type.
170. Taxon: *Trema*. Life form: small tree. Small diporate, scabrate to rugulate pollen grains. *Trema* is often a regrowth tree. Two species are present in Thailand but only *T. orientalis* has a central Thai name. Pollen of this species is shown in Huang (1972, Pl. 154:20–4).
171. Taxon: *Tribulus* comp. Life form: herb. This pollen type is many-pored, spherical, reticulate and resembles both *T. cistoides* (Selling 1947, Pl. 25:356–7) and *T. terrestris* (Huang 1972, Pl. 165:15–20) but is much smaller in size. Two species occur in Thailand, both with central and northern distributions: *T. cistoides* and *T. terrestris*.

172. Taxon: *Tristania* comp. Life form: shrub/small tree. This taxon is very small, psilate and syncolpate, resembling *T. nerifolius* (Pike 1956: Fig. 53). Three species are present in Thailand, but not in the pollen catchment area.
173. Taxon: *Typha angustifolia*. Life form: herb. A monoporate, reticulate, roughly spherical pollen grain. *T. angustifolia* (with central and northern Thai names) is the only Thai species. *Sparganium*, which has a similar pollen type, has not been reported from Thailand. *T. angustifolia* is depicted on Pl. 177:10–12 in Huang (1972).
174. Taxon: Urticaceae/Moraceae psilate. Life form: various. This pollen type is small (psilate 10 μ m in diameter), psilate, and has 2–4 pores. It could be from one of several genera especially in Urticaceae (cf. Hamilton 1976).
175. Taxon: Urticaceae/Moraceae scabrate. Life form: various. Similar to the above pollen taxon but distinctly scabrate. It could be from one of several genera in Urticaceae or Moraceae.
176. Taxon: *Utricularia* id. *bifida* comp. Life form: aquatic herb. This pollen type is CP4, psilate, and could be from one of the following species listed by Smitinand (1980): *U. bifida*, *U. caerulea*, *U. delphinioides* or *U. minutissima* (cf. Huynh 1968).
177. Taxon: *Utricularia* id. *stellaris* comp. Life form: aquatic herb. This pollen type is CP 14–16, psilate and is probably from *U. stellaris* but could be from *U. aurea* (cf. Huynh 1968). The other species reported in Smitinand (1980), *U. punctata*, is CP 24–8 and occurs as tetrads (Thanikaimoni 1966: 270–1).
178. Taxon: *Vaccinium*. Life form: shrub/small tree. This scabrate-rugulate tetrad pollen type has been depicted in Huang (1972, Pl. 157:55–7; Pl. 158:1–12). Two species occur in Thailand, both in the pollen catchment area. *V. bracteatum*, (Huang 1972, Pl. 157:55–7), a shrub, occurs on ricefield bunds east of Khok Phanom Di.
179. Taxon: *Vernonia*. Life form: climber/herb/shrub. This tricolporate, echinate, pollen type is definitely from *Vernonia*, but not from the tree *V. arborea*. Twelve other species occur in Thailand. Those reported from the pollen catchment area are climbers, shrubs and herbs: *V. cinerea* (which grows on Khok Phanom Di), *V. elliptica* and *V. juncea*. The pollen is not from *V. cinerea* (cf. Jones 1970: Figs. 2–4).
180. Taxon: Violaceae comp. Life form: shrub. This pollen type is tricolpate, prolate 19 $\times$ 14 μ m in size, reticulate, and somewhat resembles modern reference pollen of *Rinorea* (8 species in Thailand, 2 in the pollen catchment area: *R. anguifera* and *R. virgata*) but could be from another genus in another family. *R. astrolatas* pollen seems to differ somewhat, see the description in Erdtman (1966:450).
181. Taxon: *Vitex* comp. Life form: shrub/tree. This pollen type is tricolpate, prolate, reticulate and resembles *V. negundo* illustrated in Huang (1972, Pl. 163:12–14). Thirteen indigenous species of *Vitex* occur in Thailand, and one exotic in the pollen catchment area.
182. Taxon: *Xylocarpus*. Life form: tree. A four colporate, scabrate-rugulate pollen type (cf. Pl. III (8) in Caratini and Tissot 1985). Three species occur in Thailand, all in the pollen catchment area. A mangrove taxon.
183. Taxon: *Xyris*. Life form: herb. This pollen type, illustrated in Maloney (1979) is large, monocolpate, tectate, reticulate. Five species of *Xyris* have been reported from Thailand, two from the pollen catchment area.

184. Taxon: *Zizyphus* comp. Life form: climber/small tree. This oblate, psilate tricolporate pollen taxon is illustrated in Huang (1972, Pl. 126:28–9). A somewhat similar pollen type occurs in certain genera of Sapindaceae but not those reported from Thailand. Six species of *Zizyphus* occur in Thailand, 3, including *Z. oenoplia*, which grows on Khok Phanom Di, from the pollen catchment area. Other genera in Rhamnaceae with central/south-eastern representatives (*Colubrina*, *Gouania* and *Ventilago*) could have species similar in pollen morphology.
185. Taxon: *Acrostichum*. Life form: aquatic fern. This trilete scabrate spore type is illustrated in Tardieu-Blot (1963, Pl. VIII:1–8). Two species, both occurring in mangrove and indistinguishable morphologically, are present in Thailand: *A. aureum*, with central and peninsular names, and *A. speciosum* (Trat).
186. Taxon: *Adiantum*. Life form: fern. This trilete, verrucate, medium-sized spore has straight laesurae extending to the poles and resembles *A. caudatum* (Huang 1981, Pl. 72:2–3). Four indigenous (and four exotic) species occur in Thailand, 3 in the pollen catchment area.
187. Taxon: *Asplenium* id. *tenerum* comp. Life form: epiphytic fern. *A. tenerum* (Nayar and Devi 1964a:233) has a lightly folded sparsely spinulose perine, a description matching the sub-fossil type extremely well. Four species of *Asplenium* occur in Thailand, all in the pollen catchment area. This monolet spore is not from *A. nidus* or *A. squamulatum* but could be from *A. confusum* or *A. tenerum*. *A. confusum* spores have not been described in the literature nor are they in the modern reference collection.
188. Taxon: *Asplenium* id. undiff. Life form: epiphytic fern. The perine is incomplete, so this spore could be from any of the taxa listed above.
189. Taxon: *Ceratopteris thalictroides*. Life form: aquatic fern. This trilete spore is very large with a distinctive convolute striate perine (cf. Huang 1981, Pl. 31:1–2). The genus is monotypic and the fern was found growing immediately north of Khok Phanom Di.
190. Taxon: *Ceratopteris* psil. Life form: aquatic fern. Very large trilete spore with the perine only partly present or absent, almost certainly from *Ceratopteris*, although some could be from *Lygodium*.
191. Taxon: *Crypsinus* comp. Life form: epiphytic fern. These large monolet spores have a distinct margo to the laesura and a patterning of few spines. Two species of *Crypsinus* occur in Thailand, with northern and southern names, but the spores could be from *Drynaria* (3 species in Thailand, 2 reported from the pollen catchment area) or *Leptochilus* (two species present, one with a central name). Several *Crypsinus* spores with rather more spines are illustrated in Huang (1981, Pl. 40:5–11; Pl. 41:1–8 and Pl. 42:1–5). *Drynaria fortunei* (Pl. 53:5–6) is not spiny but several *Drynaria* species shown in Nayar and Devi (1964b) are more so than the sub-fossil type. Neither Thai species of *Leptochilus* is illustrated in Huang (1981) but *L. decurrens* (Pl. 47:1–2) is more profusely echinate than the sub-fossil type.
192. Taxon: *Diplazium*. Life form: fern. This monolet spore type with a sparsely-folded perine is illustrated in Huang (1981, Pl. 105:1–8; Pl. 106:1–11; Pl. 108:3–6). Three species are present in Thailand, two in the pollen catchment area.
193. Taxon: *Dicranopteris*. Life form: climbing fern. This trilete, psilate-scabrate spore has distinctive distal folds between the rays of the laesura (cf. Bolchovitina 1967). Additional illustrations of *D. linearis* are present in Huang (1981, Pl. 25:1–13). One species, with southern and northern names, *D. linearis*, occurs in Thailand. The sub-fossil spores resemble those of *D. linearis* var *linearis*.

194. Taxon: *Lindsaea orbiculata* comp. Life form: fern. This trilete verrucate spore type resembles *L. orbiculata* (Huang 1981, Pl. 61: 8–9). However, Smitinand (1980) reported only one species, *L. tenera*, with a north-eastern name from Thailand. This is neither described nor illustrated by Huang and *Adiantum* has similar spores but with larger verrucae.
195. Taxon: *Lindsaea* psil. Life form: fern. This spore type is structurally similar to the above but lacks a perine. It could be from other taxa with medium-sized trilete spores.
196. Taxon: *Lycopodium cernuum*. Life form: fern. The distinctive trilete, rugulate spores of this widespread taxon are depicted in Wilce (1972, Figs. 7–8).
197. Taxon: *Lycopodium clavatum*. Life form: fern. Stained marker *L. clavatum* spores were added to each sample but one sample contained a few which were unstained and showed no signs of a second acetylation. *L. clavatum* has northern and peninsular Thai names. The trilete rugulo-reticulate spores of *L. clavatum* are illustrated in Huang (1981, Pl. 2:1–3).
198. Taxon: *Lycopodium foveolate*. Life form: epiphytic fern. This trilete spore type could derive from one of 5 taxa reported from Thailand: *L. carinatum* (Huang 1981, Pl. 1:7–8), *L. hamiltonii* (Huang 1981, Pl. 3:1–3), *L. nummularifolium* (Knox 1950, Fig. 41), *L. phlegmaria* (Huang 1981, Pl. 6:7–9, or *L. squarrosum* (Huang 1981, Pl. 3:7–9. Of these only *L. nummularifolium* has not been reported from the pollen catchment area.
199. Taxon: *Lygodium* id. *microphyllum* comp. Life form: climbing fern. The spore of this taxon is illustrated in Caratini and Tissot (1985, Pl. V:6). Two other taxa of *Lygodium* (*L. flexuosum* and *L. salicifolium*) occur in the pollen catchment area. *L. salicifolium* is said to have quite smooth spores (Holtum 1959), while Erdtman and Sorsa (1971) note warty spores. *L. flexuosum* has finely verrucose spores (Holtum 1959).
200. Taxon: *Lygodium* psil. Life form: climbing fern. These trilete spores resemble *L. microphyllum* in morphology but may be from another taxon.
201. Taxon: *Microlepia*. Life form: fern. These small frequently triquetrate trilete spores are either psilate or scabrate. The laesura has a margo. Two species occur in Thailand both with central Thai names. Spores of several *Microlepia* species are shown in Huang (1981, Pl. 59–60).
202. Taxon: *Nephrolepis*. Life form: climbing/epiphytic fern. *Nephrolepis auriculata* spores are depicted in Huang (1981, Pl. 73:11–13). These are small, monoletate and verrucate, closely resembling the sub-fossil type. Three indigenous species are present in Thailand, none reported from the pollen catchment area. Some small monoletate spores lacking a perine could be from this source.
203. Taxon: *Ophioglossum*. Life form: epiphytic fern. This spore is trilete with short laesurae not extending to the poles. The surface patterning is scabrate. One species, *O. pendulum*, with a peninsular distribution, occurs in Thailand. *O. petiolatum* (Huang 1981, Pl. 21:1–3) resembles the sub-fossil type.
204. Taxon: *Polypodium areolate*. Life form: epiphytic fern. This monoletate spore could derive from the following Thai genera: *Araiostegia* (2 species with northern names), *Microsorium* (3 species, 1 with a Chonburi name), *Pleopeltis* (1 species, northern) or *Polypodium* (1 species, northern).
205. Taxon: *Polypodium blocky*. Life form: epiphytic fern. This taxon has angular areolae and is probably also from the above genera.
206. Taxon: *Polypodium scabrate-verrucate*. Life form: epiphytic fern. This taxon is probably from the above genera.

207. Taxon: *Polypodium verrucate*. Life form: epiphytic fern. This taxon is probably from the above genera.
208. Taxon: *Pteris vittata*. Life form: fern. This taxon has a very distinctive spore type with a complex surface patterning of tuberculae along the laesural margins in proximal view and a reticulate distal face. It is well illustrated in Huang (1981, Pl. 71:4-7) and cannot be mistaken for any other *Pteris* species except *P. longifolia*, a likely synonym. *P. longifolia* spores are described and illustrated in Joshi (1966). Smitinand (1980) gave northern names only for *P. vittata*.
209. Taxon: *Pteris* id. Life form: fern. Fern spores with the distinctive equatorial collar but otherwise lacking a perine and which cannot therefore be determined more closely.
210. Taxon: *Pteris* id. *venusta* comp. Life form: fern. This spore type resembles *P. venusta* as depicted in Huang (1981, Pl. 71:1-3). Eight species of *Pteris*, apart from *P. vittata*, occur in Thailand, 3 in the pollen catchment area: *P. blumeana*, *P. ensiformis* (Huang 1981, Pl. 68:8-11) and *P. wallichiana* (Huang 1981, Pl. 71:8-10).
211. Taxon: *Pteris* id. *semipinnata* comp. Life form: fern. The spores of this taxon resemble those of *P. semipinnata* as illustrated in Huang (1981, Pl. 69:11-12) in surface patterning but could be within the range of variation of the *P. venusta* type.
212. Taxon: *Pteris* undiff. Life form: fern. Damaged spores of *Pteris* sometimes with only part of the perine present.
213. Taxon: *Selaginella* id. 1. Life form: fern. This trilete microspore is c. $11.5 \times 7 \mu\text{m}$ in size and sparsely bacculate on the proximal face. Five species of *Selaginella* have been reported from Thailand but only one (*S. pubescens*) from the pollen catchment area. It does not resemble any taxon illustrated in Huang (1981) but is somewhat similar to those in the *S. biformis* group of Knox (1950, Pl. XIV: 151-7).
214. Taxon: *Selaginella* id. 2. Life form: fern. A macrospore present in only one sample.
215. Taxon: *Stenochlaena palustris*. Life form: climbing fern. This monolet bacculate-clavate spore is depicted in Caratini and Tissot (1985, Pl. V:2). *Stenochlaena* is common in mangrove. *S. palustris* is the only Thai species and has central, Chonburi and Nakhon Ratchasima names.
216. Taxon: *Taenitis* sim. Life form: fern. This trilete spore resembles that of *T. blechnoides* (Erdtman 1957, Fig. 184), the only Thai species, and which has Chanthaburi and peninsular names.
217. Taxon: *Thelypteris* sim. Life form: fern. A large monolet fern spore with a profusely folded perine. This could derive from a *Thelypteris* species (8 in Thailand, mainly with northern names, but 2 from the pollen catchment area: *T. interrupta* and *T. multilineata*). Other possibilities are *Cyclopeltis* (one species, *C. semicordata*, with a Bangkok name in Thailand), *Dryopteris* (4 species present, none with central or south-eastern names), *Pleocnemia* (*P. winitii*, central and northern names, is the only species), *Pteridrys* (*P. syrmatica*, distribution as *Pleocnemia winitii*, is the only species) or *Tectaria* (5 species: *T. rockii* has a Trat name).
218. Taxon: Filices monolet psilate small. Life form: fern. Spores of this form genus could be from several taxa, e.g. *Asplenium*, *Stenochlaena*, etc.
219. Taxon: Filices monolet scabrate small. Life form: fern. Spores of this form genus could be less degraded forms of the psilate type.

220. Taxon: Filices monolete rugulate small. Life form: fern. Spores of this type may also be less degraded forms of the small psilate form genus.
221. Taxon: Filices monolete psilate large. Life form: fern. These spores are unlikely to be from the same taxa as the psilate small type. They lack a margo to the laesura and could represent degraded Polypodiaceae spores other than those of *Crypsinus* comp.
222. Taxon: Filices monolete scabrate large. Life form: fern. Possibly from similar sources to the large psilate spores.
223. Taxon: Filices monolete rugulate large. Life form: fern. These could derive from some genera in Polypodiaceae, the perine probably being degraded.
224. Taxon: Filices monolete reticulate large. Life form: fern. Large fern spores of uncertain origin.
225. Taxon: Filices trilete psilate large. Life form: fern. Large spores (c. $70\mu\text{m}$) convexly rounded in proximal view with the laesura extending to the poles. Of uncertain origin.
226. Taxon: Filices trilete psilate medium. Life form: fern. This spore type occurred only once. The spore was c. $47\mu\text{m}$ in size, psilate, the exine was scalloped and the laesure did not reach the poles.

X. THE PHYTOLITHS

By B.K. Maloney and I. Rovner

INTRODUCTION

PHYTOLITHS are microscopic opaline silica bodies which develop within the cells of numerous monocotyledonous and dicotyledonous plant families. Well-developed phytoliths adopt the morphology of the cells occupied, but intermediate forms abound. They have been used in environmental archaeology because they survive where pollen is destroyed by the drying out of sediments or by microbial activities. Like pollen, they are degraded or destroyed where sediment is highly calcareous, but pollen and phytoliths can be found together, and may provide complementary information, in acidic wet-land sediments.

Phytolith taphonomy has been little studied but most workers assume that phytoliths are deposited *in situ* and that they are not washed down through the soil. It is unlikely that this is totally correct although it may be true in most instances. Baker (1959a, 1959b), for instance, has recorded them from Australian dusts and they may be taken up by animals through eating plants and be deposited in their faeces.

Comparatively little research has been carried out on South-East Asian phytoliths although some data are available (Pearsall 1986) for the Philippines, and it is necessary to construct a comparative reference collection from correctly identified plant specimens to establish which actually accumulate silica and which morphological types each species or group of species has. As far as Khok Phanom Di is concerned, information contained in Piperno (1985) with reference to low-land Panama is of most value. She found that phytoliths distinctive at the family level occurred in Gramineae, Palmae, Maranthaceae, Cyperaceae, Commeliniaceae and Orchidaceae, that phytoliths were rare or absent in Amaranthaceae, Chenopodiaceae, Convolvulaceae, Labiatae, Lauraceae, Malvaceae, Melastomataceae, Myrtaceae, Rhizophoraceae, Rubiaceae and Solanaceae, and that phytoliths were present but not often distinctive at the family level in Bignoniaceae, Combretaceae, Euphorbiaceae, Leguminosae, Sterculiaceae and Verbenaceae. Araceae, Amaryllidaceae, Liliaceae and Xyridaceae were reported as not producing phytoliths and they were also absent from *Carica papaya* (Caricaceae), *Dioscorea* spp. (Dioscoreaceae) and *Ipomoea batatas* (Convolvulaceae).

The following cultigens did contain silicified cells: *Manihot esculenta* (manioc), which had stellate hair cells (also present in Euphorbiaceae, however), *Cucurbita pepo*, *Lagenaria siceraria* (confirmed by Wilson 1985), *Ananas comosus*, *Annona muricata*, *Psidium guajava* and *Canna edulis*. As taxonomy is often not significant in Verbenaceae, it may not be possible to distinguish *Avicennia*, and as phytoliths are rare or absent in Rhizophoraceae, phytoliths probably cannot be used to separate *Rhizophora* from *Bruguiera* and *Ceriops*. Indeed Amos (1952) stated that silica had not been observed in four specimens of *Avicennia* which had been studied or in nine of

Bruguiera, five of *Carallia*, two of *Ceriops* and six of *Rhizophora*. Taxa of back mangrove, e.g. *Excoecaria* (Euphorbiaceae) and *Lumnitzera* (Combretaceae) may not be distinguishable.

The possibility of identification of Palmae phytoliths to the family level is no improvement over pollen analysis which enables generic and sometimes species recognition. However, as Gramineae, Maranthaceae, Cyperaceae and Commeliniaceae phytoliths are distinctive, there is scope for distinguishing herbaceous swamp and confirmation, if not elaboration, of the pollen record. Clearly, cultivation of many root crops cannot be established using phytoliths as Araceae (the family includes taro, *Colocasia esculenta*), Dioscorea (yams) and *Ipomoea batatas* (sweet potato, a recent introduction to Thailand) do not produce phytoliths. Those which do (*Manihot esculenta*, *Cucurbita pepo* and *Lagenaria siceraria*) may all be introductions, although there is debate about *Lagenaria*. The fact that *Annona muricata* and *Psidium guajava* (not according to Amos 1952) both produce phytoliths offers hope that indigenous fruit trees (likely to be wild) in Annonaceae and Myrtaceae (*Eugenia jambos* is a cultivar) can be separated by using the evidence of phytoliths. A separation of Amaranthaceae from Chenopodiaceae phytoliths would provide useful ecological information as the only indigenous taxon in Chenopodiaceae is *Suaeda maritima*, a likely salt-marsh indicator, while most of the Amaranthaceae are agricultural weeds. Sub-division of Convolvulaceae might be of value: while *Ipomoea pes-caprae* pollen (Sengupta 1972) can be isolated from the rest, it is large and unlikely to be dispersed far and yet is a potentially important indicator of sandy-coast vegetation. Solanaceae include some cultivars, e.g. *Solanum melongena* (egg plant), which cannot be distinguished from other taxa in the genus using pollen, while Labiatae includes plants used in ceremonial, e.g. *Ocimum sanctum*. Other cultivars occur in the Leguminosae, so it is unfortunate that the taxonomy is often not significant. The two cultivars in Malvaceae present in Thailand, *Abelmoschus* and *Gossypium*, are probably recently introduced exotics.

Several cultivars which occur in Thailand are not mentioned in Piperno (1985): the grasses rice, sugar cane and bamboo, various fruit trees, e.g. *Mangifera indica* (Anacardiaceae), *Garcinia mangostana* (Guttiferae) and bananas (*Musa* spp.). Amos (1952) reported that silica was absent from *Mangifera* and *Garcinia mangostana* although some species in *Garcinia* do accumulate silica. Detailed research on the banana suggests that recognition of cultivars using phytoliths is an almost impossible task (Wilson 1985), while Pearsall (1986) discovered that rice did produce one distinctive phytolith type but she failed to find this preserved in archaeological sediments from the Philippines or in ricefield soils. Watanabe (1968) stated that for rice, long cells with unicellular hairs are diagnostic, while Fujiwara (1976) claimed that the silica bodies of the motor cell of rice could be distinguished clearly from that of other plants. He was further cited (Rovner 1984:3) as stating that he has identified not only rice phytoliths from Japanese archaeological contexts, but also the type of agriculture practised by using the associated weed phytoliths. As the findings do not appear to have been published, they cannot be subjected to critical review. It should be pointed out, however, that Pearsall (1986) found some grass species with both Chloridoid and Panicoid type phytoliths. Wilson (1985) reported vaguely that phytoliths of *Saccharum robustum* and *S. spontaneum* were similar to those of other grasses, while Gillespie *et al.* (1985) claimed that *Saccharum* could be distinguished to the genus.

Amos (1952) has published much information of use in assessing phytoliths as a means of tracing the presence of cultivated trees. Certain species in Urticaceae have silica deposited within the cell wall of the stinging hair, but phytoliths have not been reported from teak (*Tectona grandis*),

Girardinia, *Bombax*, *Durio*, *Aleurites*, *Flacourtia*, *Cinnamomum*, *Leucaena*, *Mucuna*, *Sesbania*, *Tamarindus*, *Ficus*, *Morus*, *Decaspermum*, and *Eugenia* or *Prunus*.

It seems to have been presumed that the cells of a silica-accumulating species become increasingly rich in silica with age. If this is so, herbs should have their maximum silica content at the end of the growing season, and indeed Mehra and Sharma (1965) have stated that phytoliths were commoner in the older parts, the parts which mature first, of the Indian sedges which they studied. Shrubs and trees present a rather different problem: no study appears to have been made of when the maximum content is achieved. Indeed such a study would be impossibly difficult with long-lived trees. If the temperate-area oaks used for dendrochronological purposes accumulate silica it might be possible to assess this (gymnosperms do not accumulate much silica (Amos 1952:10) and the Fagaceae which he studied were found to be silica free) but even then it must not be assumed that species which cannot be monitored in this way will behave in a similar manner. This complication was noted early on in studies of plant silica by Amos (1952:7).

Amos stated that the form of silica present in timbers had been reported by different investigators as inclusions, concretions, corpuscles, deposits and echinulate bodies, but he separated out two types which he labelled 'silica inclusions' and 'vitreous silica'. The term 'silica inclusions' was employed where the phytoliths did not completely fill the cell and vitreous silica where it was deposited on cell walls or completely filled the lumen of the containing cell. The presence of silica inclusions was found to be characteristic of the genus in some instances but not in others. Vitreous silica, unfortunately, did not occur so commonly but it was reported from the following genera which occur in Thailand: *Dillenia*, *Michelia*, *Manglietia*, *Talauma*, *Artocarpus*, *Gynotroches* (Rhizophoraceae), *Stereospermum*, *Protium*, *Hydnocarpus*, *Cocos nucifera*, *Livistona*, *Calamus latifolius*, and bamboo (*Dendrocalamus strictus* has phytoliths which are wedge-shaped in longitudinal section and bottle-shaped in transverse section). Crystals of calcium oxalate, which may also be regarded as phytoliths, were found to be present in some timbers, including members of the Elaeocarpaceae, some of which also have siliceous but not vitreous silica. Mehra and Sharma (1965) reported calcium oxalate crystals in *Scirpus squarrosus* and *Scleria tesellata* (Cyperaceae).

Clearly, there are conflicts between the conclusions of Piperno and Amos. These can be explained by the low number of species studied per family and the fact that trees of the same species may accumulate silica differently at different locations. It does seem at this stage, however, that phytolith analysis only offers the possibility of improved identification in relation to the grasses.

PREPARATION METHODS, RESULTS AND DISCUSSION

Maloney examined twenty-four samples from cores KL 2, BMR 2 and the archaeological site itself (Maloney 1986) while Rovner studied six samples from core KL 2. With the exception of hydrofluoric acid, pollen analysis preparation methods were used by Maloney while Rovner initially deflocculated the samples with Calgon, then oxidized the organic matter using 30 per cent H_2O_2 and finally destroyed carbonates with 10 per cent HCl. Additional heavy liquid separation with a zinc bromide solution calibrated to a 2.3 specific gravity would have normally been used but unfortunately the samples supplied by B.K.M. were too small to attempt this without risk of loss. Maloney examined sub-samples mounted in silicone fluid (AK 2000) but Rovner used distilled water as the mounting/dispersal fluid for his quick scan assessment.

Three of the four samples from the excavation which were examined were poor in phytoliths and the main type present, elongated rods, probably derives from herbs. In contrast, the sample from burial 149 contained an estimated 231,000 phytoliths/cm³, a figure which compares well with those from some of the KL 2 samples. About 25 per cent of these were definitely from grasses, almost all (bulliform) in the Festucoid category of Piperno (1985). Two saddle-shaped Chloridoid phytoliths were present and one of Panicoid type. In all, fourteen morphological groups capable of subdivision were recognized. Some types may derive from herbs such as Compositae, Cyperaceae and Commelinaceae but none from palms was present. The burial was associated with material which may be bark cloth: strands of white, fibrous plant matter with some entangled elongated rod-shaped phytoliths.

Several phytolith types present in the burial 149 sample and those from the grasses occurred in some samples from KL 2. The 5.5–6.0m section of core BMR 2 contained few phytoliths, not surprisingly given the dominance of Rhizophoraceae in the pollen record. Only one of the grass phytoliths was determinable to sub-family, and that was Chloridoid. Phytoliths were also scarce in the 1.5–2.0m section of the core but Chloridoid and Panicoid grass types occurred in small numbers in some samples, adding support to the bulliform type dominating the grass component and small numbers of Chloridoid and Panicoid types present. The KL 2 samples examined by Rovner were those labelled m 8, m 12, m 16, m 20, m 24 and m 27 and were from the following depths: 0.63, 1.94, 2.78, 3.74, 4.84 and 6.04m. The four lower samples contained relatively high frequencies of diatoms and sponge spicules but few phytoliths. Those which were present included robust silicified mesophyll cell types and a few plain elongate rods, possibly from grasses. Only one grass short cell phytolith, a dumb-bell form, was noted in each of the 2.78 and 3.74m samples.

Sponge spicules and diatoms were also quite common in the upper samples and the phytolith frequency was enormous. Types present included a full range of epidermal short cells and elongate long cells, trichomes, silicified hair cells and silicified bulliform cells. Chloridoid short cells (saddles) and Panicoid cross bodies, bilobates and variant bilobates (trilobates, lobed-shank dumb-bells, etc.) were common and plain and ornamented elongates (denticulate, sinuous-shaped rods) derived from grasses were very common. Robust phytoliths and possible dicotyledon hair cell bases, troughed cells, and antler-like elongates were also present. The conclusion that the samples represent warm, marshy grassland or cultivated ricefields is in accord with the pollen analytical data. Quick scanning suggested that Panicoid phytoliths dominated substantially but that Chloridoid grasses might comprise the natural flora; so depth distribution ratios could provide information on the history and usage of grasses. Clearly this conclusion depends upon the assumption that Panicoid type phytoliths are actually from Panicoidae and Chloridoid from Chloridoidae.

XI. THE OSTRACODES AND FORAMS

By K.G. McKenzie

INTRODUCTION

ONE hundred and twenty samples, from the KL 2 pollen core and the eastern section in the excavations, were prepared for coarse-fraction analysis. Of these, all the KL 2 core samples and 56 of the east section samples were examined in detail with particular attention to their ostracode and foraminiferan microfaunas. Environmental interpretation of the site based on these parameters indicates that the uplands provenance was probably granitic and that, at the commencement of human occupation, Khok Phanom Di was near the sea. Later, as the sea level fell, the regional environment became brackish and polyhaline, as indicated by the ostracode *Cyprideis* and the forams *Haplophragmoides* and *Trochammina*. The rare occurrence of freshwater ostracodes with affinities to modern ricefield taxa suggests that the occupants may have farmed rice nearby. Brick-red samples with associated blebs of fused flux confirm the presence of a local pottery industry.

MATERIALS AND METHODS

The samples come from two quite distinct sources. The KL 2 core was taken from 150m north of the site and covers the period between *c.* 6000 BC to the recent past. In this sample, only the fractions finer than 125 μ m (sieve mesh diameter) were available for analysis. They were examined without further preparation under a binocular microscope.

The samples from the east section were selected when the excavations were complete. At that juncture, each section was drawn, and a sample of every visible context was removed, its Munsell colour recorded, and bagged for any laboratory study which might be found of value. Each sample submitted was first weighed, then wet-sieved on a 63 μ m (mesh aperture) sieve to remove silt and clay, dried and weighed again. This gave the percentage of silt + clay in each sample.

The remnant fractions were submitted to binocular microscope examination. In all, identifiable coarse fraction components from twenty KL 2 core samples and fifty-six of the 107 east section samples were determined. Their variety was considerable. Mineralogical constituents included quartz and mica grains, carbonate detritus and blebs of a glaze-like substance. The microfauna was more diverse, consisting of fish bones, juvenile gastropods and pelecypod spats, bryozoan fragments, sponge spicules, echinoid spines and, possibly, holothurian anchors as well as crustacean limbs and the ostracode valves and foraminiferan tests of particular interest to this report.

Coarse fraction analysis is a well established procedure for describing sediment samples but one that is relatively little used nowadays. Normally, the method requires sieving of the samples under investigation into at least 6 size fractions (2mm, 1mm, 500 μ m, 250 μ m, 125 μ m and 60 μ m), the silt and clay being discarded. Thus, it is a useful supplementary technique to pollen-spore

analysis, in which such coarser grades are removed and only the fine ones analysed. And it also supplements analyses based on macro-remains, since these are usually confined to material coarser than 2mm.

Because all the Khok Phanom Di sample splits were very small – weights ranged from 0.2 to 45.4gm – it was not feasible to sieve each fraction smaller than $63\mu\text{m}$ into the subsets indicated above; instead, each was examined as a single unit. This cut down the analysis time considerably. For the same reason (small sample size), it seemed inappropriate to make detailed counts of the very great variety of components that were encountered in the binocular examination of samples, especially as the target microfauna (ostracodes and foraminiferans) were generally rare. Hence, these results are qualitative.

Nevertheless, it will become apparent that coarse fraction analysis with determinations of ostracoda and foraminifera is not only convenient technically in archaeological excavations but also useful in establishing salient features of the general palaeoenvironment.

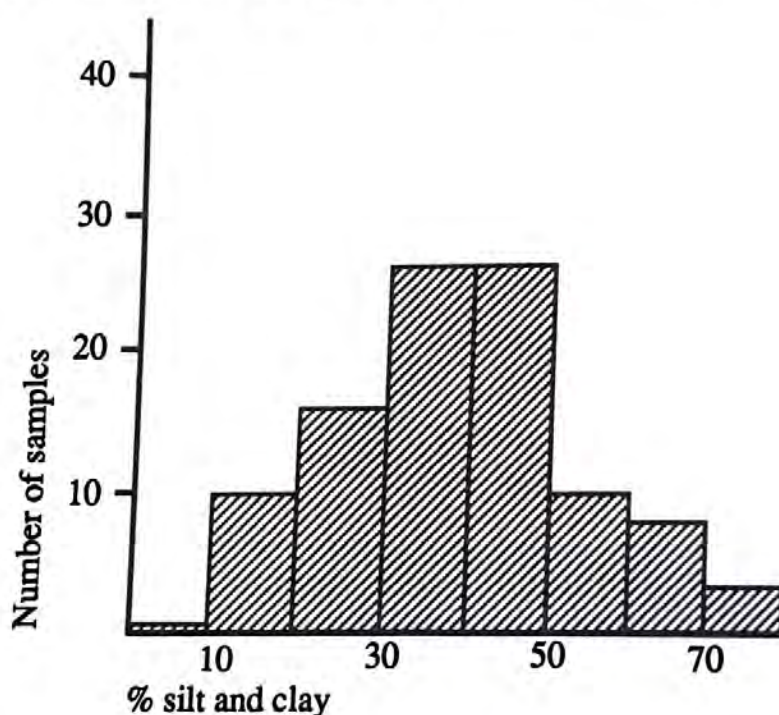


FIG. 37. The percentage frequency of clay and silt in cultural soil samples from the eastern section

RESULTS

Silt + clay. Fig. 37 is a histogram of the amount of silt + clay in 100 east section splits. Clearly, over half have 30–50 per cent silt + clay; just over a quarter contain less than 30 per cent silt + clay (actually 6.3–29.9 per cent); and only about one-fifth of the samples have more than 50 per cent silt + clay (actually 50.6–79.5 per cent). Thus, most of these samples are fine – or very fine-grained sands – rather than silty-clayey.

Mineralogical constituents. Quartz grains were the commonest mineral, but they were abundant only in samples E-14, E-50, E-95 and E-139 of the 56 east section splits examined in detail. In the other 52 of these samples, quartz grains were usually rare (37 samples), but sometimes frequent-common. Mostly, the grains were subangular to subrounded in shape, with frosted or semi-polished surface textures; but in a few samples (E-12, E-50, E-54), rounded and polished grains were noted.

Mica grains were uncommon in the east section samples, but observed commonly in the KL 2 core series of samples. Usually, the mica was muscovite. In addition fibres probably derived from the bark-cloth shrouds used in the mortuary ritual were present in sample E-122.

Plant detritus. Although an analysis of plant materials was not the purpose of this study, it is noted that practically every sample examined in detail (the entire KL 2 core and 53 of the 56 east section samples) contained some plant detritus. The most common plant debris was carbonized strap-like pieces probably representing either grasses or marine/estuarine phanerogams.

Faecal pellets. Similarly, faecal pellets were found in practically all the samples, including 52 of the 56 east section samples which were examined in detail. They provide secure evidence of the richness of small invertebrate life around and near Khok Phanom Di.

Molluscs, bryozoans, echinoderms, sponges and crustaceans. Most of the sample splits contained evidence of the presence in the vicinity of the site of populations of molluscs, bryozoans, echinoderms and sponges. The mollusc remains were usually fragments of gastropods and occasional entire juvenile gastropods or else rare pelecypod spats. Two types of bryozoan remains occurred – fragments of mat-like schizoporellan colonies and pieces of stick-like dendritic colonies. The echinoderm remains included pieces of echinoid tests, echinoid spines and holothurian anchors. Sponges were represented by monaxonid and tetraxonid spicules. Rarely, samples carried abundant crustacean remains. This was the case, for example, in E-28.

Fish bones and other phosphatic remains. The only indication of vertebrate remains in the sample splits were phosphatic debris, including small pieces of bone, which are assumed to be parts of fish. Such fragments occur in almost all the samples. They are particularly prominent in E-9, E-21 and E-76.

Carbonate debris and flux blebs in reddish soils. Carbonate detritus occurred virtually throughout the KL 2 core and was also determined in many of the east section samples. Sometimes, such debris predominated in the fractions coarser than 500 μ m (samples E-17, E-24, E-28 and E-36). Some of the splits are brick-red in colour (sample E-6), suggesting a fire in their immediate vicinity. This conclusion is reinforced by the co-occurrence of globular blebs of fused flux, indicative of an associated pottery industry at Khok Phanom Di.

Ostracoda and foraminifera. The original objective of this study was the determination of any associated ostracodes and foraminiferans in the sample splits, followed by environmental interpretations based on these assemblages. At first glance, and under ordinary magnifications, the samples appeared barren; but using a research-quality Zeiss binocular microscope at higher magnification (60x) and with stronger illumination led to success.

Although always rare, the ostracodes and forams in the samples examined in detail proved surprisingly diverse, comprising around 10 species of Ostracoda and 20-25 species of Foraminifera. All the specimens were small, and all the ostracode species occurred only as juvenile stages. Nevertheless, several determinations to species were possible. Table 10 gives the results.

TABLE 10: *Ostracoda and Foraminifera determined from Khok Phanom Di sample splits (KL 2 core and east section)*

Ostracoda	Sample
<i>Cytherelloidea</i> sp.	M-14, M-21, M-24
? <i>Stenocypris</i> sp.	E-67
? <i>Cypridopsis</i> sp.	E-67
<i>Microcytherura</i> sp.	E-80
<i>Jankeicythere</i> cf. <i>koenigswaldi</i> (Keij, 1954)	M-25
<i>Cyprideis</i> sp.	M-26; E-24, E-36, E-54, E-74
<i>Hemicytheridea</i> cf. <i>cancellata</i> (Brady, 1868)	M-21, M-25
<i>Hemicytherura</i> sp.	E-116
<i>Neocytheretta</i> sp.	M-17, M-26
<i>Tandonella</i> sp.	M-21, M-24, M-25, M-26
indet. trachyleberidid juv.	M-24, M-26
Foraminifera	
<i>Trochammina</i> sp.	E-21, E-22, E-42, E-47, E-68, E-122, E-124, E-131
<i>Haplophragmoides</i> sp.	E-9, E-12, E-14, E-15, E-21, E-26, E-34, E-67, E-80, E-86, E-116, E-122, E-124, E-126, E-131
<i>Miliammina</i> sp.	E-12, E-131
indet. Textulariina (2 spp.)	E-17, E-68, E-88, E-116
<i>Quinqueloculina tropicalis</i> Cushman, 1926	M-23, M-24, M-26; E-80, E-116
<i>Quinqueloculina</i> sp.	E-116
<i>Triloculina</i> sp.	E-80
<i>Miliolinella labiosa</i> (D'Orbigny, 1839)	E-116
<i>Brizalina spathulata</i> (Williamson, 1858)	M-13, M-24, M-26
<i>Ammonia beccarii</i> Brunnich, 1772	M-15, M-20, M-21, M-22, M-24, M-25, M-26; E-80
<i>Discorbis</i> sp.	E-80, E-116
<i>Cibicides</i> sp.	E-116
<i>Anomalina</i> sp.	E-116
<i>Eponides</i> sp.	E-116
<i>Rosalina</i> sp.	E-80
<i>Elphidium depressulum</i> (Cushman, 1933)	M-21, M-25; E-80, E-116
<i>Nonionella</i> sp.	M-25, M-26; E-80
<i>Cribrononion simplex</i> Cushman, 1933	M-24
indet. Rotaliina spp.	M-14, M-15, M-16, M-18, M-19, M-20, M-22, M-23
<i>Globigerina</i> sp.	E-116
<i>Oolina</i> sp.	E-80

ENVIRONMENTAL ANALYSIS

The KL 2 core (M-samples). In this core, samples are barren of useful microfauna until sample M-13, except for a few monaxonid spicules in M-11 and some insect remains in M-12. From M-13 to M-27, however, both ostracodes and foraminifera appear regularly, although they are always few in number per sample (the depth below datum for these samples in core KL 2 is set out in Table 11). The indications are for marginal marine environments throughout this lower part of the core. Of

TABLE 11: *The depth below ricefield datum (in metres) of the samples taken from core KL 2. (For the sedimentological section from this core, see Fig. 21)*

Sample	M-8	M-9	M-10	M-11	M-12	M-13	M-14	M-15	M-16	M-17
Metres	0.76	1.10	1.30	1.74	1.94	2.24	2.60	2.74	2.78	3.10

Sample	M-18	M-19	M-20	M-21	M-22	M-23	M-24	M-25	M-26	M-27
Metres	3.30	3.60	3.74	4.10	4.34	4.64	4.84	5.10	5.84	6.04

the taxa determined (Table 10), the ostracode *Cyprideis* sp. and the foram *Ammonia beccarii* are euryhaline indices. The other species are associated usually with nearshore marine environments, but have affinities also for such environments as deltas and protected embayments. Clearly, the coring site was near the sea, at the seawards end of a deltaic floodplain or estuary.

East section (E-samples, Fig. 38). This is the eastern section of the excavated area. Table 10 shows that the Ostracoda are quite different from those identified in the KL 2 core samples and a similar conclusion is warranted for the Foraminifera. Overall, a less marine and more brackish regime is indicated than for the lower part of core KL 2.

Three of the Ostracoda found in this section have considerable value as ecological indices. As noted already regarding core KL 2, the genus *Cyprideis* is a good euryhaline index. However, under conditions of much reduced salinities – about oligohaline – *Cyprideis* develops a series of carapace nodes the pattern of which may be species-specific, although that does not concern us here. The node sites can be recognized even in later (A-1, A-2) juvenile stages. These stages were identified in east section specimens, and were observed to be completely free of any nodes or indications of nodes. Thus, it is unlikely that the general palaeoenvironment was oligohaline or fresher.

Nevertheless, an important result of this investigation was the discovery of two fragments of freshwater ostracodes in sample E-67. Although fragmentary, I believe the taxa are possibly *Stenocypris* and *Cypridopsis*. Both these genera are commonly encountered in South-East Asian continental aquatic environments, including ricefields. While there are no data on the Ostracoda of Thai ricefields, Victor and Fernando (1980) have reported all the ricefield species known elsewhere in South-East Asia. Their list cites six species of *Stenocypris* and a species of the closely related genus *Chrissia* as occurring in regional ricefields. They also cite two species of *Cypridopsis*. Since freshwater Ostracoda genera are rather distinctive, it is unlikely that my determinations are grossly inaccurate. Indeed, it is held highly likely that there were ricefields in the vicinity of the site.

The remaining Ostracoda, from E-80 and E-116, are the genera *Microcytherura* and *Hemicytherura*. Of the two, the latter indicates nearshore marginal marine conditions but the former, while typically collected nearshore, is also associated with protected bay, lagoonal and estuarine situations.

The ecologically-sensitive Foraminifera at Khok Phanom Di include the genera *Trochammina*, *Haplophragmoides*, *Miliammina*, *Ammonia*, *Elphidium* and *Globigerina*. Table 10 shows that E-80 and E-116 are the most diverse samples; their species make-up suggests nearshore marine conditions and sandy-silty substrates (miliolid and rotaliid genera). The foram *Globigerina* is a planktonic marine taxon which implies that E-116 at least was deposited at a time when the coastline and an open ocean were not far away.

The textulariine foram genera (*Trochammina*, *Miliammina*, *Haplophragmoides*), on the other hand, are well known as brackish-water indices. The first and latter of these are the most common forams of the east section samples, with *Haplophragmoides* more euryhaline-indicative than *Trochammina*. The several specimens of *Haplophragmoides* in samples E-80 and E-116 were found attached to sediment particles whereas the other forams in these samples were fresh-looking. Probably, these specimens of *Haplophragmoides* represent an earlier (more estuarine) substrate which has been recycled. Either the specimens were washed downstream near the collection site and buried there, or they represent an earlier estuarine sedimentation phase near the collection locality itself which has been reworked.

CONCLUSIONS

Two important points need to be emphasized before coming to summary conclusions on the environmental indications from coarse fraction analysis at the Khok Phanom Di site. Firstly, all the microfauna comprises small and very small elements which range in size from less than 2mm to 63 μ m. This factor, combined with their uniform rarity in virtually all samples, suggests strongly that the site was never inundated. If this happened, one could expect the occurrence in the archaeological sections of thin levels rich in marine or estuarine microfauna and macrofauna. If such material exists, it was not provided to me. Thus, the microfauna, not only tiny but light, arrived at the site indirectly, either blown in by the wind from an exposed shore or carried in by chance with other materials brought to the site.

The other important preliminary point regards the physical geographic setting. Khok Phanom Di lies very near the boundary between green marine clays (the natural datum) and brackish-water soils. Further, the site is close to a tributary that leads into the Bang Pakong River. When the site was occupied, the Holocene, sea level fluctuated between 3.5–4m and 6–8m higher than the present sea level, and the estuary on or near which the site was located could have been the ancestral Bang Pakong River itself, with access to a mangal flora (see Maloney, chapter VI). Apart from the uppermost occupation level, which postdates a decline in the local sea level, the site was occupied between c. 2000 and 1500 BC.

Bearing these points in mind, the coarse fractional analyses results indicate that the KL 2 boring location was near a marine habitat with the open sea not far away (evidence of *Globigerina*, diverse rotaliids, trachyleberids, *Neocytheretta*). The archaeological site, however, was located near an estuary with a low-lying, marshy hinterland. As the sea level fell, the local aquatic envi-

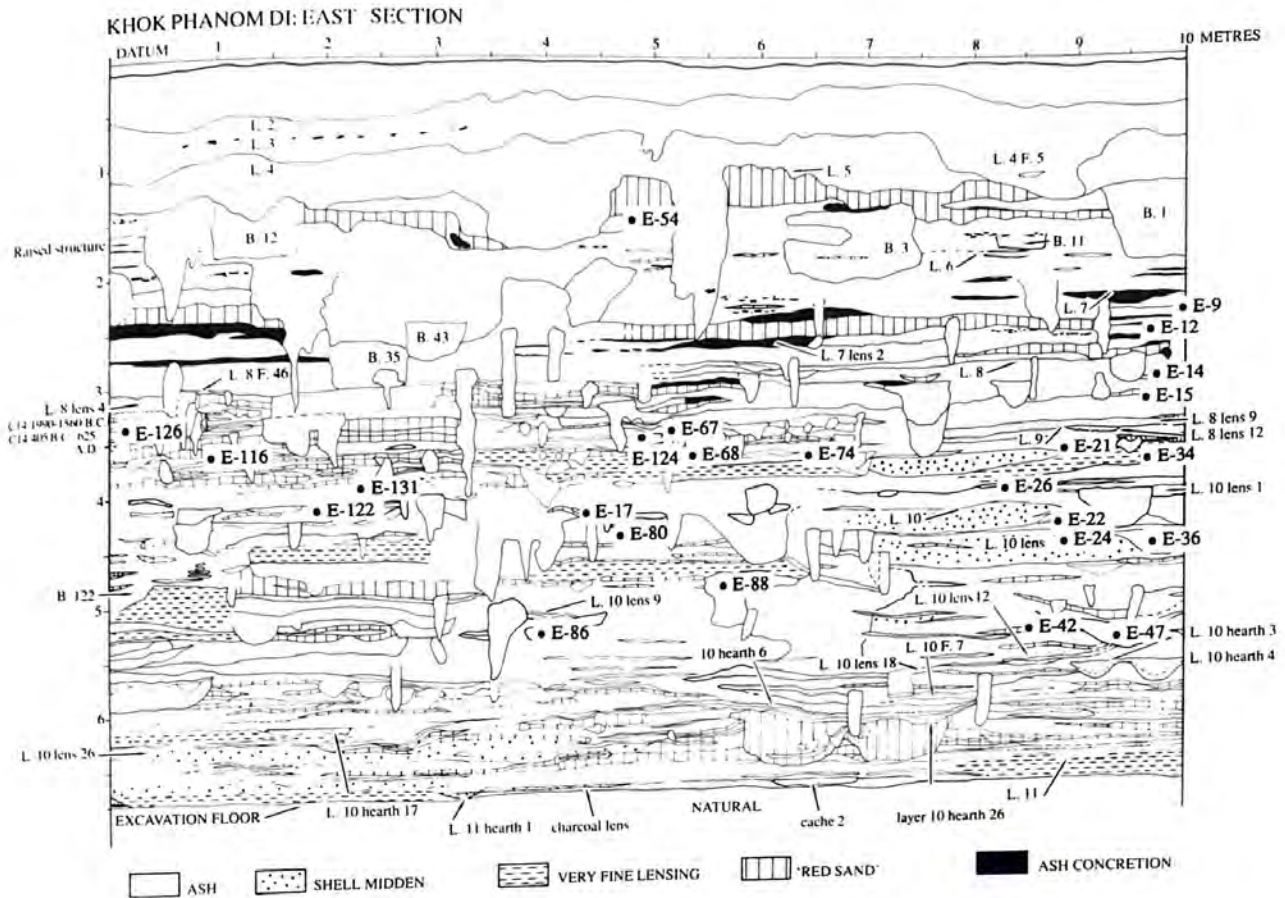


FIG. 38. The eastern section of Khok Phanom Di, showing the location of the samples

ronment became brackish and there was some recycling of upstream or local estuarine sediments (occurrence of *Haplophragmoides* with attached substrate) indicating an active, rather than sluggish, estuary nearby. The common occurrence of such taxa as *Cyprideis* and *Ammonia* indicate that tidal and seasonal factors favoured polyhaline species, i.e. there were, probably, diurnal and seasonal variations in salinity. The generally high percentage of silt and clay in most sample splits indicates a relatively mature fluvial system. The fluvial current was strong enough to wash most mica particles out to sea. The remnant quartz grains, which are mostly subangular to subrounded and have frosted to semi-polished surface textures, indicate that their provenance was not too distant, and was probably granitic. It was sufficiently distant, however, for removal of virtually all the provenance feldspars by geochemical breakdown well upstream of Khok Phanom Di.

The occurrence of freshwater ostracodes – taxa not tolerant of brackish salinities – in E-67 strongly suggests access to local ponds. The ubiquitous presence of rice in the cultural contexts, as well as probable rice-harvesting knives reinforces the likelihood that such freshwater ponds

were either near or were themselves the source of rice. Finally, the presence of brick-red soils and associated small blebs of fused flux confirms a local pottery-making industry.

WORKPOINTS

These preliminary conclusions can be considerably embellished and made more detailed following a sampling programme which takes into account the desirability of further coarse fraction analysis. As noted, this type of analysis (including microfaunal studies) fits neatly into the hiatus between macrofaunal analysis and palynology. Hopefully, this promising line of enquiry will be pursued further.

The physical setting of Khok Phanom Di is quite different from that of coastal New South Wales, Australia (Albani 1978; Yassini and Jones 1987; Bentley 1988; Yassini and Wright 1988). Nevertheless, just as studies of New South Wales coastal Foraminifera and Ostracoda have proved very helpful in environmental interpretation of the New South Wales Quaternary (McKenzie and Pickett 1984), a research programme based on the determination of the modern Gulf of Siam marine, estuarine and hinterland freshwater Ostracoda and Foraminifera would lead to more detailed insights into the development of the environment in the Bang Pakong Valley during the Quaternary. Such an approach was followed recently and fruitfully in the interpretation of the very important hominid site at Sangiran, central Java (McKenzie and Sudijono 1981).

XII. THE LARGE MAMMALIAN FAUNA

By Alan Grant and C.F.W. Higham

INTRODUCTION

THIS study seeks to investigate several archaeological questions relating to the faunal assemblage from Khok Phanom Di. The first goal is the identification and quantification of the larger mammalian taxa represented in the fossil record, and to consider any temporal changes in their relative abundance. Secondly, upon construction of a species list, an evaluation of the likely palaeoenvironment in the vicinity of the mound during the period of deposition is sought, using relevant ecological information on the taxa identified. A third goal is to establish whether there is evidence for the possible domestication of any of the mammalian taxa (notably canids, suids, and bovids). Finally, upon consideration of the stratigraphic depth of the excavation, evidence for a coastal-estuarine orientation from the earliest cultural layers, known sea level changes in prehistory, and the present location of the site, 22km from the coast, a measurement of the relative status of mammalian fauna compared with marine resources is determined.

THE DATA: MATERIAL AND METHODS

This part of the faunal analysis is concerned with the large mammalian fauna in occupation layers. Initially the mammalian component of the faunal remains was extracted from the marine remains (turtle, crab, fish) from bags direct from the excavation square and fine screening (noting that this faunal analysis is concerned only with the large mammalian remains from occupation layers). After this preliminary sorting, the bone fragments were cleaned (where possible) and set out according to their provenance. The mammalian material was then classified into taxa. Reference was made to the University of Otago Archaeology Laboratory comparative collection for identification. All anatomically identifiable bone fragments were assigned to family, genus and, where possible, species. In the case of inter-specific size overlap, measurement of skeletal parts aided in taxonomic identification. Because of the particular diagnostic difficulties in speciating fragmentary vertebrae, ribs and some cranial and diaphysial fragments, these bones do not figure prominently in the analyses. Each taxon was individually analysed. Analysis of bone fracture patterns and bone treatment (as by Kijngam 1979) was not performed. However, obvious surface features like cut marks and charring were noted, as was the general state of preservation of the bone. The skeletal parts were measured using dial-calipers, and followed the standards defined by von den Driesch (1976).

As a measure of relative taxonomic abundance, the number of individual animals per taxon in each (excavated) layer and context was calculated, based upon limb-bone characteristics (size and the state of epiphyseal fusion) and tooth wear and eruption. Effort was made to match bone pairs during the quantification procedure. The spit values were pooled to form level, and subsequently,

zonal estimates. The number of identified specimens per taxon (NISP) was also calculated for each stratum.

The following larger mammalian taxa were identified from the excavation: pig, large and small deer, water buffalo and cattle, canids and non-human primates. The sections following will discuss the results of the faunal analysis. Each taxon will be individually treated. A general ecological background is presented, and problems of identification discussed. Where possible, the status of the taxon from other prehistoric sites in South-East Asia is included. Unfortunately there are few published reports of faunal analyses from this region. Most of the reference material derives from the faunal reports from Ban Chiang, Ban Na Di and Non Nok Tha (Kijngam 1979; Ban Na Di, Kijngam 1984a; Non Nok Tha, Higham 1975b). These are all prehistoric sites on the Khorat plateau of North-East Thailand, and span General Periods A–C (c. 3000–1 BC; Bayard 1984). The occupants of all three sites practised a broad spectrum subsistence system of hunting, fishing and collecting, as well as raising domestic dog, cattle and pig, and cultivating rice. Results and conclusions are presented, and reference is made to accompanying tables recording the incidence of bones and the dimensions of measurable limb bones and dentition.

WATER BUFFALO (*BUBALUS BUBALIS*) AND CATTLE (BOVIDAE)

Bubalus bubalis Linnaeus, 1758

Indigenous to South-East Asia, the wild water buffalo (*Bubalus bubalis*) in Thailand is now confined to refuges in Uthai Thani province. The preferred habitat of wild water buffalo is open forests or elephant-grass jungles near swamps where it can graze and have ready access to water (Lekagul and McNeely 1977:702). The low-lying swampy grasslands and high water table regime of the river floodplains would have provided favourable conditions for water buffalo in prehistory.

Domestic water buffalo play an important role in the wet-rice cultivation system of South-East Asia, and a major question to be asked of bovid remains from archaeological sites in this region concerns the timing and the process of domestication. Kijngam (1979:32–3; 1984:359) has concluded that the water buffalo remains from Ban Chiang (except for two bones from probably wild forms), and from Ban Na Di correspond in size to modern Thai domestic stock. Water buffalo remains were only common at Ban Na Di from layers 6–5 (c. 400 BC) and at Ban Chiang during the Middle Period. Water buffalo remains are rare in the north-east Thai sites of Non Nok Tha (Higham 1975a:39–43), Ban Tong, and absent at Ban Phak Top (*op. cit.*).

Bovidae

Three species of cattle are indigenous to South-East Asia: *Bos javanicus* D'Alton, 1823 (banteng), *Bos gaurus* Smith, 1827 (gaur), and *Bos sauveli* Urbain, 1937 (kouprey) (Lekagul and McNeely 1977:703–15). Cattle inhabit a more varied range of habitats than water buffalo, grazing on grasses of open plains as well as browsing in woodlands and forests. The banteng is better adapted to the open plains than the gaur, while kouprey are reported to inhabit low rolling hills where both plains and a variety of forest types exist. Historically, kouprey were known only in restricted areas of northern Cambodia and southern Vietnam (Lekagul and McNeely 1977:712).

Although Kijngam (1979:8-33) has been able to distinguish between water buffalo and cattle on the basis of morphological differences for several bones, he found that there was a problem in distinguishing between the different species of *Bos* and between the wild and domestic forms. The difficulty inherent in the archaeological identification of *Bos* sp. is compounded by the lack of comparative material for these species. Therefore, we will follow Kijngam's classification and describe all three as 'Bovidae'. It should be noted here that the category 'Bovidae' in this study may include specimens which are likely to be water buffalo, but which do not exhibit specifically identifiable morphological differences.

The analysis of the bovid remains from Non Nok Tha, Ban Chiang and Ban Na Di reveals that the majority of the cattle bones are small, with similar dimensions to modern Thai domesticates. The larger, more robust specimens identified are considered to come from hunted wild cattle. Remains of these domesticates are present from the initial occupation of these sites, and at Non Nok Tha and Ban Na Di the limb bones of these bovids were often interred with the dead (Higham 1975b:141-2; Kijngam 1979:29-30; Kijngam 1984a:353-8).

Remains of bovid and water buffalo are uncommon. Both are absent from zone A, rare in zone B and are most abundant in zone C (Table 12).

TABLE 12: *The number of individuals of Bubalus bubalis and Bovidae sp. by zone*

Zone	<i>Bubalus</i>	Bovidae
A	-	-
B	2	3
C	8	10
Individuals	10	13

The measurements of bones identified as *Bubalus bubalis* were compared with archaeological and modern samples, and it is concluded that they derive from large, and very probably wild, water buffalo. Certainly all the phalanges identified come from water buffalo, and are larger than presumed domestic specimens from both Ban Na Di and Ban Chiang.

The dentition and state of epiphyseal fusion of the limb bones reveal that most of the bovids and water buffalo were at least sub-adult at death. The proximal ends of the first phalanges and femur of the European ox fuse at 18-24 and 42 months, while the distal ends of the radius and metapodials fuse at 42-48 and 24-30 months respectively (Cornwall 1974:229). There are no complete adult mandibles or crania in the assemblage so *Bubalus* cannot be distinguished from Bovidae. As can be seen from Table 13, there are very few deciduous teeth. Most of the permanent teeth are in primary and secondary wear. The incisors from layer 2:1 are very heavily worn and come from an old animal. Molars from layer 2:1 are in secondary eruption and derive from the one animal, which would, if domestic, have an estimated age of 16-17 months (see Kijngam 1979:220 for the estimated age of domestic Bovidae from dentition development).

TABLE 13: *The incidence of bones from Bubalus bubalis and Bovidae*

[illegible]

TABLE 14: *The measurements of bones from Bubalus bubalis and Bovidae. *: paired teeth, **: epiphysis unfused, +: measurement from an epiphysis*

Species	Bone	Layer	GL	PW	WPAS	DW	MW	Comment	
<i>B. bubalis</i>	Metacarpal	3:3	-	-	-	+	-	DE **	
	Unciform	2:1	-	-	-	-	-	charred	
	Scaphoid	2:1	-	-	-	-	39.6	-	
	Fore phalanx	2:1	-	-	-	+	-	DE fused	
		3:3	85.0	46.0	41.5	41.3	-	-	
	Fore phalanx 2	2:1	-	+	-	-	-	PE fused	
		2:3	-	+	-	-	-	PE fused	
		3:3	59.7	41.8	41.3	35.5	-	-	
		3:4	70.2	48.1	44.6	36.5	-	-	
		3:4	-	+	-	-	-	PE **	
	Metatarsal	4:3	-	+	-	-	-	-	
		9:1	-	-	-	+	-	DE **	
	Rear phalanx 1	2:1	-	-	-	37.2	-	-	
		5:3	83.0	43.5	37.9	37.9	-	-	
	Rear phalanx 2	2:1	-	-	-	34.1	-	-	
		3:3	(62.0)	39.5	38.5	32.4	-	-	
	Phalanx 3	4:5	-	31.5	-	-	-	-	
		2:1	-	+	-	-	-	PE **	
Bovidae	Bone	Layer	GW	a/pL	PW	DC	DW	Comment	
	Radius	2:1	-	-	+	-	-	PE **	
		7:4	-	-	-	-	75.0	DE **	
	Femur	3:1	-	-	+	-	-	PE **	
		3:3	-	-	+	-	-	PE **	
		3:3	-	-	+	-	-	PE **	
		4:2	-	-	-	(52.0)	-	-	
	Cuboid nav.	2:1	57.5	51.0	-	-	-	-	
Bovidae	Maxillary teeth	Layer	LPM ²	LPM ³	LPM ⁴	LM ¹	LM ²	LM ³	Wear
		2:1	16.6	-	-	-	-	-	2°
		2:1	dec.	-	-	-	-	-	3°
		2:1*	-	-	-	(21.4)	-	-	early
		2:1*	-	-	-	+	-	-	early
		2:1	-	-	-	-	f	-	2°
		2:2	16.5	-	-	-	-	-	1°
		3:1*	-	-	(16.7)	-	-	-	early
		3:1*	-	(16.9)	-	-	-	-	early

The measurements of bones from Bubalus bubalis and Bovidae (cont.)

Bovidae Maxillary teeth	Layer	LPM ²	LPM ³	LPM ⁴	LM ¹	LM ²	LM ³	Wear
3:2*	-	-	-	-	-	-	+	1°
3:2*	-	-	-	-	-	f	-	1°
7:6	-	-	ue	-	-	-	-	-
9:6	-	-	-	-	-	-	33.4	1°

Bovidae Mandibular teeth	Layer	I ₁	I ₂	LPM ₂	LPM ₃	LPM ₄	LM ₁	LM ₂	LM ₃	Wear
2:1*	-	-	-	-	-	-	-	(23.9)e	-	unworn
2:1*	-	-	-	-	-	-	-	f	-	unworn
2:1	-	-	-	-	-	-	-	-	f	2°
2:1	-	-	-	(22.1)	-	-	-	-	-	2°
2:1*	+	-	-	-	-	-	-	-	-	3°
2:1*	-	+	-	-	-	-	-	-	-	3°
2:1	-	-	f	-	-	-	-	-	-	2°
2:2	-	+	-	-	-	-	-	-	-	1°
2:2	-	-	-	-	f	-	-	-	-	2°
2:2	-	-	-	f	-	-	-	-	-	unworn
2:2	-	-	-	-	-	-	(24.1)	-	-	1°

CANIDAE

The canid remains from Khok Phanom Di could have conceivably derived from either the indigenous canids of South-East Asia, the Asian jackal (*Canis aureus* Linnaeus, 1758), and the wild dog (*Cuon alpinus* (Pallas, 1811)), or the domestic dog (*Canis familiaris*). The nearest wild wolf (*Canis lupus*) populations are in India or China. Morphological study and multivariate analysis of crania and mandibles of domestic dog, wild jackal, cuon, wolf, and the canid bones from Ban Chiang and related north-east Thai sites by Higham *et al.* (1980) revealed that the Ban Chiang canids were domestic and descended ultimately from the wolf, which, as noted, is not indigenous to South-East Asia. Kijngam (1984a:354-6) has identified the canids from Ban Na Di to be domestic.

Canid remains from the site are rare with only nine individuals represented, and each individual, except one, was identified from only one bone or tooth. Stratigraphically, the canids are represented in all three zones: two in zone A, two in zone B, and five in zone C. Unfortunately no cranial bone and only two mandibular fragments were recovered from the site. All the tooth measurements taken fall within the size range of the domestic dog from Ban Chiang and Ban Na Di. However, with such a small sample it is impossible to be more precise, and all one can say is that the canids from Khok Phanom Di were possibly derived from domestic dog (none appears to be from the wild dog *Cuon alpinus* because of the presence of two cusps on the heel of the M₁).

At both Ban Chiang and Ban Na Di, dog mandibles were not charred, but the teeth were exposed to heat, possibly, Kijngam suggests, reflecting cooking the mandible with meat attached. Both mandibles from Khok Phanom Di reveal traces of charring, and one canine was also charred. That two permanent but unerupted lower first molars were found would seem to indicate that mandibles were smashed.

TABLE 15: *The measurements of bones and teeth (alveolar) from Canis sp. *: PE unfused*

Bone	Layer	DW	WC ¹	WC ₁	LPM ₄	LM ₁	LPM ₁₋₄	H mand.
Maxilla	3:1	-	ue	-	-	-	-	-
	10:3	-	5.5	-	-	-	-	-
Mandible	2:3	-	-	6.3	-	-	-	-
	3:1	-	-	-	10.7	-	36.0	18.0
	3:2	-	-	-	-	21.1e	-	-
	8:4	-	-	-	-	ue	-	-
	9:6 1.9	-	-	-	-	19.7	-	-
Humerus	10:16	27.9*	-	-	-	-	-	-

If we consider that the Khok Phanom Di canids are domestic, then the age at death calculated on the basis of tooth eruption and wear, and epiphyseal fusion of bones, would produce mortality data as set out in Table 16.

TABLE 16: *The mortuary data from Canis sp.*

Age	Individuals
very young	1
young	3
sub-adult	3
adult	1
old	-
at least sub-adult	1

The most notable feature of this taxon is the paucity of specimens and the relative youthfulness of the population represented. From the limited amount of charring and the virtual absence of post-cranial and fractured bone (assuming that the canids are domestic) it would seem to point to the conclusion that the dogs were not used as a food source or, if so, irregularly. Whereas Kijngam notes that most of the dogs consumed at Ban Chiang and Ban Na Di were of full body size at death, it is apparent that at Khok Phanom Di most were not fully adult at death. It may well be that a proportion of the canid bones represent the jackal (*Canis aureus*). The Asiatic jackal is an omnivorous hunter and scavenger, and is often commensal with man.

TABLE 17: *The incidence of bones from Canis sp. from levels 10, 9, 8, 5, 3 and 2*

Bone	10:16	10:14	10:3 1.2	9:6 1.9	8:4	6:3	3:3	3:2	3:1	2:3
Canine ¹	-	-	1	-	-	-	-	-	1	1
M ₁	-	-	-	-	1	-	-	1	-	-
M ¹	-	-	-	-	-	1	-	-	-	-
M ²	-	-	-	-	-	1	-	-	-	-
Mandible	-	-	-	1	-	-	-	-	1	-
Humerus	1	-	-	-	-	-	-	-	-	-
Ulna	-	1	-	-	-	-	-	-	-	-
Tibia	-	1	-	-	-	-	-	-	-	-
Astragalus	-	-	-	-	-	-	1	-	-	-
Individuals	1	1	1	1	1	1	1	1	2	1

THE LARGE DEER

Eight species of deer are indigenous to Thailand: *Tragulus napu* (Cuvier, 1822) (greater mouse deer), *Tragulus javanicus* (Osbeck, 1765) (lesser mouse deer), *Muntiacus muntjak* (Zimmerman, 1780), *Muntiacus feae* (Thomas and Doria, 1889) (muntjac or barking deer), *Cervus porcinus* Zimmerman, 1780 (pig deer), *Cervus unicolor* Kerr, 1792 (sambar deer), *Cervus schomburgki* (Blyth, 1863) (Schomburgk's deer), and *Cervus eldi* McClelland, 1842 (Eld's deer). In palaeoenvironmental terms it is important that these larger deer are distinguished because each has a preferred habitat. However, specific identification is difficult because of the similarity in shape between the post-cranial bones from each form. Unfortunately, the unavailability of comparative skeletal material from *C. schomburgki*, which is now extinct, and *C. eldi*, which is rare and endangered, means that their identification and differentiation was based upon antler, bone size, dentition and archaeological data from faunal reports (Lekagul and McNeely 1977:699; Kijngam 1979; 1984a).

Cervid remains are common in prehistoric sites in Thailand. At Ban Chiang, deer were consistently present and became more abundant with time, especially after Period 4. Kijngam has concluded that Schomburgk's deer is rare, if present at all, at that site, and that the large cervid bones belong to the sambar deer. The medium-sized deer was identified as *Cervus eldi*. Both species were equally abundant, and most of the Ban Chiang cervid bones were from butchered adults (Kijngam 1979:39-45). A similar species range and temporal change was recorded from Ban Na Di, but with *C. eldi* more common than *C. unicolor* in the earlier layers (Kijngam 1984a:363-6).

The sambar (*C. unicolor*) is the largest deer species. Occurring in a wide range of habitats, it prefers forest and woodland, and likes feeding in areas of secondary growth and open grassland (Lekagul and McNeely 1977:687). *C. schomburgki* is intermediate in size between sambar and Eld's deer. Lekagul and McNeely (*ibid*:695) consider it to be especially adapted to the extensive open marshlands of grasses, canes and shrubs of the Chao Phraya floodplain, where its branched antler system would not restrict its movement as it would in denser forest vegetation.

Historically, Schomburgk's deer was common in the central plains of Thailand. However, hunting and the conversion of their favoured habitat (swamp-grasslands) for wet-rice cultivation saw their numbers rapidly diminish, and the species became extinct some forty years ago. It may be significant that Lekagul and McNeely describe how elevated patches of ground became 'island refuges' to Schomburgk's, Eld's, and pig deer, and to other small mammals during the seasonal flooding of the alluvial plains. It should also be noted that such 'islands' were vulnerable to predation (*ibid*:695).

C. eldi is a medium-sized deer with a complex set of antlers that are flattened and branched. Although now restricted to deciduous forests by predation and habitat destruction, it is suspected that it probably once preferred grazing open swampy terrain, similar to that reported for Schomburgk's deer.

Because of the extent of antler fragmentation, only pedicels and brow tines (cut and shed) could be positively identified. The ring and pedicel circumference of a shed brow tine from layer 3:3, suspected from photographs of being *C. schomburgki* antler, was found to lie at the upper range of measurements for Schomburgk's antler in Lekagul's collection (*ibid*:694). Sambar deer can be identified in zone C by its antler pedicel, as can Eld's deer. Antler fragments were not considered when calculating the number of individual animals. For this study, the number of specimens of antler was recorded and accorded to sambar, although no doubt the sample contains fragmented antler from both Schomburgk's and Eld's deer).

Because there is no published report on bone dimensions from prehistoric *C. schomburgki* and comparative material is lacking, the archaeological identification of this cervid is extremely difficult. As noted above, there is a serial size range for the large deer from Eld's up to sambar, with Schomburgk's as the intermediate species. Although there would have been some size overlap between the sambar and Schomburgk's deer (and to a lesser extent between Schomburgk's and Eld's deer), it was felt that specimens of Schomburgk's deer could be reasonably differentiated from the other cervids. Using the criteria of limb-bone size, epiphyseal fusion and dental dimensions compared with the sub-adult sambar comparative samples, remains designated as Schomburgk's deer were taken to be those that were smaller and more frequently fused than the sambar, and larger than dimensions recorded for Eld's deer. By this method it was hoped that the majority of the specimens that were from Schomburgk's deer could be identified.

Because of the similar habitats of *C. eldi* and *C. schomburgki*, and the fact that the extent of the latter species is not able to be completely defined, it was decided to aggregate these two species into a group which contains all Eld's and most Schomburgk's specimens. The smallest measurements recorded will equate to all of the former, and the larger measurements to most of the latter.

As can be seen from Table 18, each cervid group was evenly exploited throughout the occupation of the site. There were few specimens in zone A, but the relative frequencies of both groups rose markedly during zone B, particularly in the upper levels of this zone, while in zone C they become even more abundant. In this uppermost zone, there was a proportional increase in the abundance of *Cervus unicolor* relative to *Cervus eldi* and *Cervus schomburgki* from their respective frequencies in zone B. Full comment on the relative frequencies between Eld's and Schomburgk's deer is difficult. Both seem to be equally abundant in zones A and C, with Eld's deer more abundant within zone B.

Most of the larger deer were of full body size at death, that is, sub-adult or adult. There were very few young individuals recorded. Analysis of the dentition for both deer groups shows that most of the teeth were permanent, and most were in primary or secondary wear. The majority

TABLE 18: *The number of individual larger cervids per zone*

Zone	<i>C. unicolor</i>	<i>C. schomburgki</i> <i>C. eldi</i>
A	5	7
B	13	20
C	32	35
Individuals	52	60

of deciduous teeth found were dPM⁴, which are the last deciduous premolars to be replaced by permanent teeth. A noticeable feature of the deer remains was the increased quantity of fractured bone indicating butchery in zone C. The metapodials were heavily fractured, and these and other bones of the extremities were well represented. The large limb bones were less common, which probably indicates heavy butchery treatment.

TABLE 19: *The dimensions of limb bones and teeth from the larger cervids. * erupting tooth*

Species	Bone	Layer	LdPM ⁴	LPM ³	LPM ⁴	LM ¹	LM ²	LM ³
<i>C. unicolor</i>	Maxilla	2:1	15.8	-	-	-	-	-
			-	12.0	-	-	-	-
			-	-	11.8	-	-	-
		2:2*	-	-	-	18.4	-	-
			-	13.6	-	-	-	-
			-	13.6	-	-	-	-
		2:3	-	-	12.0	-	-	-
			-	-	-	-	21.2	-
			-	-	-	-	-	21.8
		3:1	18.5	-	-	-	-	-
			-	-	12.3	-	-	-
			-	12.4	-	-	-	-
		3:2	-	-	12.6	-	-	-
			-	-	-	19.6	-	-
			-	-	-	18.5	-	-
		3:3	-	-	-	-	21.2	-
			-	-	13.5	-	-	-
			(16.4)	-	-	-	-	-
		3:4	-	-	-	-	19.5	-
			-	12.8	-	-	-	-
			-	e	e	-	-	-
		3:5	-	-	-	17.2	-	-
			-	-	-	-	20.8	-
			-	13.9	-	-	-	-
		4:1	-	-	-	-	21.2	-
			15.7	-	-	-	-	-
			-	11.5	12.5	-	-	-
		4:2	-	-	-	-	-	21.1
			-	-	-	(17.5)	-	-
			17.3	-	-	-	-	-
		4:3	-	-	-	17.9	-	-
			17.5	-	-	-	-	-
			13.1	-	-	-	-	-
		6:7	-	-	-	17.0	-	-
			15.8	-	-	-	-	-

The dimensions of limb bones and teeth from the larger cervids (cont.)

Species	Bone	Layer	LdPM ⁴	LPM ²	LPM ³	LPM ⁴	LM ¹	LM ²	LM ³
<i>C. eldi or schomburgki</i>									
	Maxilla	2:1	-	-	-	-	-	-	ue
			-	-	-	-	20.0	-	-
			-	-	-	-	18.6	-	-
		2:2	-	-	-	-	-	17.5	-
			-	-	-	-	-	-	(18.4)
		*	-	-	-	-	-	18.3	-
		*	-	-	-	-	-	18.5	-
		2:3	-	-	-	-	-	e	-
		3:1*	-	-	-	-	-	20.0	-
		*	-	-	-	-	-	20.1	-
			-	-	-	-	-	18.5	-
		3:2	(15.3)	-	-	-	-	-	-
		3:3	(15.1)	-	-	-	19.1	17.4	-
			-	-	-	-	-	17.0	-
			-	-	-	-	-	19.4	-
			-	-	-	-	-	-	19.8e
		3:4	-	-	-	-	-	-	20.0e
		4:1	-	-	-	-	-	19.8	-
		4:2	14.6	-	-	-	-	-	-
		5:3	15.5	11.2	-	-	18.6	19.5	-
		6:3	-	-	-	11.4	(18.0)	(19.9)	(21.6)
		7:2 1.2	-	-	-	-	14.6	16.8e	-
		9:6 1.9	(12.8)	-	-	-	(14.1)	(16.5)	-

Species	Bone	Layer	LdPM ₂	LdPM ₄	LPM ₃	LPM ₂₋₄	LM ₁	LM ₂	LM ₃
<i>C. unicolor</i> Mandible									
		2:2	-	-	-	-	20.3	-	-
		3:1*	-	-	-	-	20.6	-	-
		3:1*	-	-	-	-	20.5	-	-
		3:2	13.7	-	-	-	-	-	-
		3:3	-	-	-	-	20.9	-	-
		10:2	-	-	-	13.1	-	-	-

C. eldi or schomburgki

2:1	-	-	-	-	-	-	-	29.7
2:2	-	14.2	-	-	-	-	-	-
2:3	-	-	-	-	-	15.1	-	-
3:1	-	-	-	-	-	-	(20.0)	-
3:3	-	-	-	-	-	-	17.7	-
3:4	-	12.2	-	-	-	-	-	-

The dimensions of limb bones and teeth from the larger cervids (cont.)

Species	Bone	Layer	LdPM ₂	LdPM ₃	LdPM ₄	LPM ₃	LPM ₂₋₄	LM ₁	LM ₂	LM ₃
<i>C. eldi</i> or <i>schomburgki</i>	Mandible	4:1	-	-	-	-	-	15.0	18.8	28.2
		4:1	-	-	-	-	-	15.7	-	-
		5:2	(9.3)	(12.2)	(19.59)	-	(16.5)	-	-	-
		6:5	-	-	-	37.9	-	-	-	-
		7:3	(8.6)	(12.1)	(18.4)	15.7	-	e	-	-

Species	Bone	Layer	GL	DW	GB	DPA	a/pL
<i>C. unicolor</i>	Radius	3:1	-	-	44.6	-	-
	Ulna	4:4	-	-	-	46.8	-
	Scaphoid	3:1	27.6	-	-	-	30.6
	Lunate	5:1	23.9	-	-	-	29.8
	Metacarpal	3:1	-	38.7	-	-	-
		3:1	-	-	38.4	-	-
		3:3	-	41.2	-	-	-
		3:4	-	40.4	-	-	-

Species	Bone	Layer	GL	PW	DW	GB	GLI	GLm	SH	SB	a/pL	
<i>C. unicolor</i>	Pelvis		4:1	-	-	-	-	-	-	28.8	13.9	-
			10:2	-	-	-	-	-	-	23.5	-	-
	Tibia	5:3	-	-	48.0	-	-	-	-	-	-	-
	Lat. mall.	3:2	-	-	-	-	-	-	-	-	23.9	-
	Calcaneum	4:2	118.4	-	-	39.1	-	-	-	-	-	-
	Astragalus	2:3	-	-	35.9	-	53.6	49.5	-	-	-	-
		3:3	-	-	34.0	-	51.4	48.2	-	-	-	-
		3:4	-	-	35.6	-	54.9	50.9	-	-	-	-
		4:2	-	-	36.3	-	55.2	50.8	-	-	-	-
	Cuboid nav.	3:2	-	-	-	-	34.8	-	-	-	42.0	-
		3:5	-	-	-	-	40.6	-	-	-	(34.3)	-
		4:3	-	-	-	-	(43.3)	-	-	-	35.7	-
	E/m Cuneif.	4:1	24.6	-	-	-	-	-	-	-	-	-
	Metatarsal	2:2	-	33.3	-	-	-	-	-	-	-	-

Species	Bone	Layer	GL	PW	WPAS	DW
<i>C. unicolor</i>	Phalanx 1	2:1	-	-	-	21.1
		2:2	62.1	-	-	18.4
		2:2	-	-	-	21.4
		2:3	-	21.5	-	-
		3:2	65.2	20.6	-	20.4
		3:3	-	17.7	-	-
		4:2	65.2	21.0	-	19.3
		4:2	-	-	-	20.4

The dimensions of limb bones and teeth from the larger cervids (cont.). + from an epiphysis

Species	Bone	Layer	GL	PW	WPAS	DW
<i>C. unicolor</i>	Phalanx 1	4:3	59.4	18.8	-	17.8
		4:3	61.3	20.0	-	17.4
		4:3	57.4	19.6	-	19.1
		4:3	62.7	20.8	-	18.7
		6:3	62.4	20.1	-	18.8
		10:14	61.4	18.8	-	17.4
	Phalanx 2	2:2	51.8	20.2	-	18.9
		3:3	50.5	21.5	-	15.1
		3:4	-	-	-	13.3
		4:1	-	19.4	-	-
		4:3	-	-	-	15.6
		6:1	48.9	(18.8)	-	13.8
	Phalanx 3	3:3	-	-	15.4	-
		4:1	-	-	15.3	-

Species	Bone	Layer	GL	PW	DW	GB	GLP	LG	BG	DPA	BPC	a/pL
<i>C. eldi</i> or <i>schomburgki</i>	Scapula	3:1	-	-	-	-	-	37.6	33.2	-	-	-
		4:2	-	-	-	-	-	-	(28.1)	-	-	-
		10:11	-	-	-	-	-	35.7	-	-	-	-
	Radius	2:3	-	45.9	-	-	-	-	-	-	-	-
		4:2	-	48.0	-	-	-	-	-	-	-	-
	Ulna	2:2	-	-	-	-	-	-	-	39.5	-	-
		4:1+	-	-	-	-	-	-	-	-	24.4	-
		5:2+	-	-	-	-	-	-	-	42.4	27.0	-
		10:17	-	-	-	-	-	-	-	36.5	-	-
	Cuneiform	10:19	-	-	-	-	-	-	-	37.7	24.2	-
		3:1	28.5	-	-	-	-	-	-	-	-	20.8
		4:1	30.0	-	-	-	-	-	-	-	-	20.4
	Lunate	3:1	-	-	-	21.8	-	-	-	-	-	27.5
		3:4	-	-	-	19.4	-	-	-	-	-	23.2
	Scaphoid	2:2	(22.6)	-	-	-	-	-	-	-	-	27.9
		2:2	24.4	-	-	-	-	-	-	-	-	28.2
		2:2	(25.4)	-	-	-	-	-	-	-	-	-
		3:1	-	-	-	-	-	-	-	-	-	25.6
	Magnum	3:1	20.7	-	-	-	-	-	-	-	-	-
		2:2	17.3	-	-	-	-	-	-	-	-	20.3
		3:1	(22.9)	-	-	-	-	-	-	-	-	23.0
		3:4	22.9	-	-	-	-	-	-	-	-	25.9
	Unciform	2:2	15.3	-	-	15.0	-	-	-	-	-	19.0

The dimensions of limb bones and teeth from the larger cervids (cont.)

Species	Bone	Layer	GL	PW	DW	GB	GLP	LG	BG	DPA	BPC	a/pL
<i>C. eldi</i> or <i>unicolor</i>	Metacarpal	3:4	-	33.5	-	-	-	-	-	-	-	-
		4:5	-	35.0	-	-	-	-	-	-	-	-
		5:5	-	-	(34.6)	-	-	-	-	-	-	-
		6:3	-	-	(32.6)	-	-	-	-	-	-	-

Species	Bone	Layer	GL	PW	DW	GB	GLI	GLm	a/pL
<i>C. eldi</i> or <i>schomburgki</i>	Patella	3:5 (47.5)	-	-	-	39.9	-	-	-
	Tibia	7:1	-	-	41.2	-	-	-	-
	Lat. mall.	2:2	-	-	-	-	-	-	20.6
		3:1	-	-	-	-	-	-	21.0
	Calcaneum	3:5	90.6	-	-	-	-	-	-
		4:1	108.4	-	-	33.3	-	-	-
		4:1	104.5	-	-	34.4	-	-	-
		4:2	-	-	-	30.7	-	-	-
		5:3	-	-	-	32.2	-	-	-
		10:13	-	-	-	31.6	-	-	-
	Astragalus	2:1	-	-	-	-	50.0	-	-
		2:2	-	-	-	-	-	48.4	-
		2:2	-	-	(23.0)	-	39.6	36.3	-
		2:2	-	-	-	-	-	39.7	-
		2:2	-	-	-	-	-	43.5	-
		3:1	-	-	-	-	-	43.9	-
		3:2	-	-	-	-	-	48.7	-
		3:3	-	-	30.3	-	47.0	45.2	-
		4:1	-	-	32.1	-	-	48.3	-
		4:1	-	-	31.7	-	-	45.3	-
		5:1	-	-	31.9	-	50.4	46.3	-
	Cuboid nav.	2:1	-	-	-	38.9	-	-	32.6
		4:2	-	-	-	38.6	-	-	33.8
		4:2	-	-	-	38.8	-	-	30.7
	Metatarsal	4:1	-	-	34.4	-	-	-	-
		6: 1.1	-	-	35.7	-	-	-	-
		10:15	-	-	34.6	-	-	-	-
	Phalanx 1	2:2	-	17.9	-	-	-	-	-
		2:3	-	-	17.3	-	-	-	-
		3:2	-	-	17.3	-	-	-	-
		3:2	-	-	15.8	-	-	-	-
		3:4	-	15.6	-	-	-	-	-
		4:2	-	-	15.4	-	-	-	-
	Phalanx 2	2:1	-	18.2	-	-	-	-	-

TABLE 20: *The incidence of bones from Cervus unicolor and Cervus eldi or Cervus schomburgki*

[illegible]

The incidence of bones from Cervus unicolor and Cervus eldi or Cervus schomburgki (cont.)

Species	Bone	6:7	6:3	6:1	5:5	5:3	5:2	5:1	4:5	4:4	4:3	4:2
<i>C. unicolor</i>	Phalanx 2	-	-	1	-	-	-	-	-	-	1	2
	Phalanx 3	-	-	-	-	1	-	-	-	-	-	-
	Metapodial	-	-	1	-	-	-	-	-	1	1	2
	Individuals	1	1	1	1	1	1	2	1	1	2	3
Species	Bone	4:1	3:5	3:4	3:3	3:2	3:1	2:3	2:2	2:1		
<i>C. unicolor</i>	Antler	25	1	15	15	23	39	28	10	16		
	Skull	-	-	-	-	3	-	-	-	-		
	dec PM ⁴	1	-	-	-	1	1	1	-	1		
	PM ²	-	-	-	-	-	-	-	-	-		
	PM ³	-	1	3	-	1	1	1	3	2		
	PM ⁴	-	-	1	-	1	1	1	1	2		
	M ¹	1	-	1	1	-	1	-	-	1		
	M ²	-	1	1	-	-	2	-	1	1		
	M ³	2	-	-	-	-	1	-	1	-		
	Incisor ₁	-	-	-	-	-	1	-	-	-		
	M ₁	-	-	-	1	1	1	-	1	-		
	Tooth frag.	-	-	-	1	1	9	5	9	98		
	Maxilla	1	-	-	-	1	1	-	1	-		
	Mandible	-	1	3	-	1	1	-	2	-		
	Scapula	1	-	-	1	-	-	-	-	-		
	Humerus	-	1	-	1	-	1	1	2	1		
	Radius	-	-	1	1	2	1	-	-	-		
	Ulna	1	-	-	-	-	-	-	-	-		
	Carpal	-	-	1	-	-	1	-	-	-		
	Metacarpal	1	-	2	3	-	5	-	2	1		
	Pelvis	6	1	3	1	3	2	-	-	-		
	Tibia	-	-	-	-	-	-	-	-	1		
	Astragalus	-	-	1	1	-	-	2	1	2		
	Calcaneum	1	-	-	1	1	2	2	4	2		
	Cuboid nav.	-	1	-	-	2	-	-	-	4		
	Tarsals	1	-	2	-	1	-	-	-	-		
	Metatarsal	2	1	2	2	2	3	-	4	1		
	Phalanx 1	6	-	1	2	3	3	3	3	3		
	Phalanx 2	1	-	2	3	-	1	-	1	3		
	Phalanx 3	1	-	-	1	-	-	-	-	-		
	Metapodial	2	-	3	2	-	2	-	3	1		
	Individuals	3	1	3	3	3	4	2	3	3		

The incidence of bones from *Cervus unicolor* and *Cervus eldi* or *Cervus schomburgki* (cont.)

Species Bone	11:1	10:19	10:17	10:13	10:11	9:6	1. 9	9:5	8:5	8:2	8:1	7:7
<i>C. eldi</i> or <i>schomburgki</i>												
Antler	-	-	-	-	-	-	-	-	1	-	-	-
Incisor ₁	-	-	-	-	-	-	-	-	-	1	-	-
Maxilla	-	-	-	-	-	1	-	-	-	-	-	-
Scapula	-	-	-	-	1	-	-	1	-	-	-	-
Humerus	-	-	-	-	-	-	-	-	-	-	-	-
Radius	-	-	-	-	-	-	-	-	-	-	-	-
Ulna	-	1	1	-	-	-	-	-	-	-	-	1
Metacarpal	-	-	-	-	-	-	-	-	-	-	-	-
Tibia	1	-	-	-	-	-	-	-	-	-	-	-
Calcaneum	-	-	-	1	-	-	-	-	-	-	-	-
Cuboid nav.	-	-	-	-	-	-	-	-	-	-	1	-
Individuals	1	1	1	1	1	1	1	1	1	1	1	1
Species Bone	7:3	7:1.2	7:1	6:5	6:3	6: 1.1	5:5	5:4	5:3	5:2	5:1	
<i>C. eldi</i> or <i>schomburgki</i>												
dec PM ⁴	-	-	-	-	-	-	-	-	1	-	-	-
Incisor ₂	-	-	1	-	-	-	-	-	-	-	-	-
Maxilla	-	1	-	-	1	-	-	-	1	-	-	-
Mandible	1	-	-	1	-	-	-	-	-	1	-	-
Humerus	-	-	-	-	-	-	-	-	-	-	1	-
Ulna	-	-	-	1	-	-	-	-	1	-	-	-
Carpal	-	-	-	-	-	-	-	-	-	-	-	-
Metacarpal	-	-	-	-	1	1	1	1	-	-	-	-
Tibia	-	-	1	-	-	-	-	-	-	-	-	-
Astragalus	-	-	-	-	-	-	-	-	-	-	1	-
Metatarsal	-	-	-	-	-	1	-	-	-	-	-	-
Individuals	1	1	1	1	1	2	1	1	3	1	1	
Species Bone	4:5	4:3	4:2	4:1	3:5	3:4	3:3	3:2	3:1	2:3	2:2	2:1
<i>C. eldi</i> or <i>schomburgki</i>												
Antler	-	-	-	-	-	1	2	-	1	-	-	2
dec PM ⁴	-	-	1	1	-	-	1	1	-	-	-	-
M ¹	-	-	-	1	-	-	-	-	-	-	-	2
M ²	-	-	-	-	1	1	1	-	2	1	3	1
M ³	-	-	-	2	-	1	-	-	-	-	1	2
Incisor ₁	-	-	1	-	-	1	-	1	1	-	-	-
Incisor ₂	-	-	1	-	-	-	-	1	-	-	-	-
Incisor ₃	-	-	-	-	-	-	-	1	-	-	-	-
PM ₂	-	-	-	-	-	-	-	-	1d	-	-	-
PM ₃	-	-	-	-	1d	-	-	-	-	-	1d	-

The incidence of bones from Cervus unicolor and Cervus eldi or Cervus schomburgki (cont.)

Species Bone	4:5	4:3	4:2	4:1	3:5	3:4	3:3	3:2	3:1	2:3	2:2	2:1
<i>C. eldi or schomburgki</i>												
M ₂	-	-	-	-	1	1	1	-	3	-	-	1
M ₃	-	-	-	-	-	1	1	1	1	-	-	-
Tooth frag.	-	-	-	-	-	2	-	3	5	2	9	7
Maxilla	-	-	-	1	-	-	2	-	1	-	-	-
Mandible	-	-	-	1	1	-	-	-	1	-	-	-
Scapula	-	-	1	-	-	-	-	-	1	-	-	-
Humerus	-	-	2	-	-	-	-	-	1	1	1	1
Radius	-	-	1	-	-	1	-	-	-	1	-	-
Ulna	-	-	-	-	-	1	2	-	-	2	2	-
Carpal	-	-	-	1	-	-	-	1	5	-	5	-
Metacarpal	1	-	-	-	-	2	-	-	-	-	-	-
Pelvis	-	-	-	-	1	-	-	-	1	-	-	-
Femur	-	-	-	-	-	-	-	1	-	-	-	-
Tibia	-	1	1	-	1	1	-	1	1	1	1	1
Patella	-	-	-	-	1	-	-	-	-	-	-	-
Astragalus	-	-	-	1	-	-	2	1	2	1	6	2
Calcaneum	-	-	2	2	1	4	-	-	1	1	1	2
Cuboid nav.	-	-	2	-	-	-	-	-	1	-	-	4
Tarsal	-	-	-	-	-	-	-	-	1	-	1	-
Metatarsal	-	-	1	2	-	-	-	1	2	-	-	1
Phalanx 1	-	-	2	-	-	2	-	2	1	1	1	1
Phalanx 2	-	-	-	-	-	-	-	-	-	-	-	1
Phalanx 3	-	-	1	1	-	-	-	-	-	-	-	-
Metapodial	-	-	1	1	-	1	1	3	3	3	3	1
Individuals	1	1	3	4	2	3	3	2	3	3	5	5

THE SMALL DEER

In his analysis of the cervid remains from Ban Chiang and related sites in North-East Thailand, Kingam (1979) stressed that the similar size of *Muntiacus muntjak* (the muntjac) and *Cervus porcinus* (the pig deer) makes it virtually impossible to distinguish between them unless antler is present. There is no antler from Khok Phanom Di of the size range of these two species, so the distinction between them is not attempted. This is unfortunate since, according to Lekagul and McNeely (1977:677,682), each has its preferred habitat, with the pig deer preferring marshland and the muntjac grassy clearings and forest margins.

Small deer at Khok Phanom Di are very much a characteristic of zone C, that is late in the sequence. All but three of the bones found belong to layers 2-4 (Table 21). Within zone C, there was a preponderance of adult animals, with twelve adult individuals represented and only three sub-adults. No bone was found from a young animal. The two mandibles from layer 6:8 come from an adult pig deer. The dimensions of the bones, which are set out in Table 22, indicate similarity with both modern animals and those found at Ban Chiang and related sites.

TABLE 21: *The incidence of bones from either Muntiacus muntjak or Cervus porcinus*

Bone	9:6	6:8	4.5	4.4	4:3	4.2	4:1	3:5	3:4	3:3	3:2	3:1	2:3	2:2	2:1
Mandible	-	2	1	-	-	-	-	-	-	-	-	-	-	-	1
dec. PM ⁴	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
Incisor	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
PM ²	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
PM ³	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-
PM ₄	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-
M ¹	-	-	-	-	-	-	-	-	-	1	-	2	-	2	-
M ₁	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
M ₂	-	-	-	1	-	1	2	-	-	-	1	1	-	1	-
M ₃	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-
Molar frag.	-	-	-	-	-	-	-	1	-	-	-	-	-	5	-
Scapula	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-
Radius	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Metacarpal	-	-	-	-	-	2	-	-	-	1	1	1	2	1	2
Magnum	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Unciform	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
Lunate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phalanx 1	-	-	-	-	-	1	-	-	-	-	-	3	-	-	-
Phalanx 2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1
Pelvis	-	-	-	-	-	-	1	-	-	-	1	-	-	1	-
Tibia	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Cuboid navicular	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Metatarsal	-	-	-	-	1	-	-	2	-	-	-	1	-	-	-
Astragalus	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-
Individuals	1	1	1	1	1	1	1	1	1	2	2	2	3	3	1

TABLE 22: *The measurements of bones from either Muntiacus muntjak or Cervus porcinus*

Bone	Layer	L	PW	MW	DW	LM ₁	LM ₂	LM ₃	LM ³
Radius	3:2	-	-	-	26.0	-	-	-	-
Metacarpal	3:1	-	20.3	-	-	-	-	-	-
Tibia	3:2	-	37.5	-	-	-	-	-	-
Metatarsal	3:5	-	-	-	23.3	-	-	-	-
Phalanx 1	3:1	32.5	9.8	-	-	-	-	-	-
	3:1	33.5	-	-	-	-	-	-	-
Phalanx 2	2:1	27.0	10.4	-	-	-	-	-	-
	2:1	29.5	11.0	-	-	-	-	-	-
	3:2	26.0	9.0	-	-	-	-	-	-
	3:2	26.0	9.1	-	-	-	-	-	-
Unciform	2:2	-	-	12.0	-	-	-	-	-
	2:2	-	-	12.8	-	-	-	-	-
Magnum	2:2	-	-	10.2	-	-	-	-	-
Astragalus	3:4	30.2	-	18.6	-	-	-	-	-
Mandible	2:1	-	-	-	-	10.0	-	-	-
	2:2	-	-	-	-	9.0	-	-	-
	2:2	-	-	-	-	-	14.0	-	-
	2:3	-	-	-	-	-	-	20.9	-
	2:3	-	-	-	-	-	-	19.3	-
	3:1	-	-	-	-	9.1	-	-	-
	3:2	-	-	-	-	-	-	18.5	-
	3:3	-	-	-	-	9.5	-	-	-
	4:1	-	-	-	-	-	12.0	-	-
	4:3	-	-	-	-	-	12.2	-	-
	6:8	-	-	-	-	10.8	13.2	(21.0)	-
Maxilla	2:2	-	-	-	-	-	-	-	10.5

MACACA SP. AND PRESBYTIS SP.

Two non-human primate genera were identified from the excavation. *Macaca* sp. (macaque) and *Presbytis* sp. (langur or leaf monkey) belong to the superfamily Cercopithecoidea. No gibbon (*Hylobates* sp.) was identified during the analysis of the primate remains.

Published data on primate fauna from archaeological sites in mainland South-East Asia are scarce. No primate remains are recorded from Ban Chiang and related sites in North-East Thailand (Kijngam 1979; 1984a), nor, it seems, at Samrong Sen (Mansuy 1923). As yet, the non-burial faunal spectrum from Ban Kao has not been published, but no primates were recorded in burial contexts there (Hatting 1967). Primate remains have been recovered from Hoabinhian contexts. The rhesus macaque (*Macaca mulatta* (Zimmermann, 1780)) has been identified at Con Moong in North Vietnam (Vu The Long 1977:19-23), and Higham reports gibbon, macaque, langur and slow loris at Spirit Cave and Banyan Valley Cave (Higham 1977). Unfortunately, no reports from sites with a similar coastal orientation as Khok Phanom Di exist.

Lekagul and McNeely (1977:275-304) describe five species of macaque and four species of langur as being indigenous to Thailand. *Macaca mulatta* and *Macaca assamensis* (McClelland, 1839) (Assamese macaque) are described as Indian forms, and *Macaca arctoides* (Geoffroy, 1831) (stump-tail macaque) as an Indochinese form, all of which are essentially upland species. The Malayan forms, *Macaca nemestrina* (Linnaeus, 1766) (pig-tailed macaque) and *Macaca fascicularis* (Raffles, 1821) (crab-eating macaque) are more lowland species, with *M. nemestrina* inhabiting inland evergreen or deciduous forest and *M. fascicularis* favouring but not confined to coastal forests. Langurs have a more specialized diet than macaques, possessing as they do a sacculated stomach capable of digesting large amounts of shoots and leaves. Langurs are larger, more arboreal, live in smaller groups and occupy smaller home ranges than do macaques (Chivers 1980). Macaques are more frugivorous and omnivorous than the leaf and fruit eating langurs, and occupy a wider range of habitats.

Unfortunately, because of limited comparative material, the primates could not be identified to species level. Nevertheless, it is possible to make some predictions based upon known distributions and habitat preferences of the primates in question, on the preliminary palaeoenvironmental information we have about the site, and the faunal material itself. The most likely macaque species represented at Khok Phanom Di (at least in zones A and B when the site was located near a mangrove and estuarine-swampland ecosystem) is *Macaca fascicularis*. This species inhabits a wide range of niches, including primary forest, but it is more commonly found in coastal forests, on off-shore islands and in its 'classic' habitat, mangrove forest, where it feeds upon crabs, crustacea and shellfish in addition to fruit, leaves and insects (Lekagul and McNeely 1977:293). Chivers (1980) and Wheatley (1982) also note its preference for riverine and secondary forest, and it has been known to inhabit disturbed habitats, such as isolated pockets of woodland, and visit agricultural areas. Overall, *Macaca fascicularis* is described as being adapted to edge habitats (*op. cit.*).

Identifying which species of langur is/are represented at the site is more problematical. Phayre's langur (*Presbytis phayrei* Blyth, 1847) can be confidently eliminated because it is restricted to upland forests. Both the banded langur (*Presbytis melalophos* (Raffles, 1821)) and the dusky langur (*Presbytis obscura* (Reid, 1837)) are found in coastal and inland forest, and where they are sympatric, *Presbytis melalophos* usually inhabits the lower elevations. Their distribution in Thailand today is restricted to the Kra isthmus. The silvered langur (*Presbytis cristata* (Raffles, 1821)) and

Presbytis obscura seem to prefer tall forests but are known to occur together in coastal lowland forests of Malaysia. Lekagul and McNeely (1977:302) note that the sub-species *Presbytis cristata ultima* can be found at the junction of coastal forest and mangrove swamp in west Malaysia. Medway (1970) believes that they are recent arrivals from Sumatra and Chivers (1980) thinks their restriction to this habitat could be a result of inter-specific competition. The two other sub-species of *P. cristata* are geographically separate from *P. c. ultima*, which encouraged Lekagul and McNeely to postulate a possible contact between them along the now submerged northern coast of Sundaland. Without identification to species, it is noted that the *Presbytis* genus is represented. Consideration will be given to its likely diet, behaviour and habitat range.

The most abundant primate genus is *Macaca*, which is consistently represented from the initial occupation to the uppermost layers. *Presbytis* is relatively uncommon throughout. In zone C the relative number of primates increases significantly, but the emphasis on the macaque continues. The frequency of langur rises in this zone but is still numerically inferior to the macaque. However, there is a significant proportional increase in langur as compared with macaque from their respective frequencies in zone B (Table 23).

TABLE 23: *The incidence by zone of Macaca sp. and Presbytis sp.*

Zone	<i>Macaca</i>	<i>Presbytis</i>
A	27	5
B	49	7
C	50	14
Individuals	126	26

The majority of the primates were sub-adult or adult at death. The method(s) of capture employed may have included trapping, bow and arrow, or blow-gun, the last of which is still used by 'aboriginal' peoples in the forests of Malaysia (Southwick and Cadigan 1972). *Macaca fascicularis* has a smaller body size than any of the other macaques. When we examine the changes in the size of the bones and tooth-row lengths from the different zones, it is noticeable that the macaque specimens in zones A and B are generally smaller than those in zone C. However, because of the small sample size and the existence of sexual dimorphism within this species, we can only infer that the crab-eating macaque is the most likely to be represented in zones A and B. In zone C, the environmental change postulated of a fall in sea level and a shift to a swamp-woodland community saw a rise in primate numbers. It is possible that both lowland macaque species (*Macaca fascicularis*) and *Macaca nemestrina* are represented. The pig-tailed macaque is more of an inland forest dweller and larger than its crab-eating congener. The adaptability of the latter and its ability to exploit disturbed habitats (conditions likely to have existed with increases in deer and bovids in this upper zone) also favour its presence.

TABLE 24: *The incidence of bones of Presbytis sp.*

	10:14	10:13	10:11	10:4	10:1	9:7	9:1	8:7	1.12	7:5	7:4
M ₁	-	-	-	1	-	-	-	-	-	-	-
Mandible	-	1	-	1	-	-	1	-	-	-	-
Scapula	1	-	-	-	-	-	-	-	-	-	-
Humerus	-	-	-	-	-	1	-	-	-	-	-
Radius	-	-	1	-	1	-	-	-	-	-	-
Ulna	-	-	-	-	-	-	-	-	-	1	-
Scaphoid	-	-	-	-	-	-	-	-	-	-	-
Metacarpal	-	-	-	-	-	-	-	-	-	-	1
Fibula	-	-	-	-	1	-	-	-	-	-	-
Metatarsal	-	-	-	-	-	-	-	1	-	-	-
Individuals	1	1	1	1	1	1	1	1	1	1	1
	6:1	6:1.2	4:3	4:2	4:1	3:5	3:4	3:3	3:2	3:1	2:2
Skull	-	-	1	2	-	-	-	-	-	1	-
Canine ¹	-	-	-	-	-	-	-	-	-	1	-
PM ²	-	-	-	-	-	-	-	1	-	-	-
M ¹	-	-	-	-	-	-	-	-	-	1	-
M ²	-	-	-	-	-	-	-	-	-	-	1
Incisor ₂	-	-	-	1	-	-	-	-	-	-	-
Canine ₁	-	-	-	1	-	-	-	-	-	-	-
PM ₁	-	-	-	-	-	-	1	-	-	1	-
Mandible	1	-	1	-	1	-	-	1	2	1	1
Maxilla	-	-	1	1	-	-	-	-	-	-	-
Scapula	-	-	-	-	-	1	-	-	-	-	-
Clavicle	-	1	-	-	-	-	-	-	-	-	-
Radius	-	-	-	-	-	-	-	-	1	-	-
Pelvis	-	-	-	-	1	-	-	-	-	-	-
Femur	-	-	-	-	-	-	-	-	1	-	-
Astragalus	-	-	-	-	-	-	1	1	-	-	1
Metatarsal	-	-	1	2	-	-	1	-	-	-	-
Individuals	1	1	2	2	1	1	1	2	2	2	1

TABLE 25: *The incidence of bones of Macaca sp.*

	11:1	10:1	10:26	10:16	10:14	10:13	10:12	10:11	10:10	10:9	10:8	10:6	10:5	10:4	10:3	10:1.2	10:2	10:1
Canine ¹	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-
Mandible	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	2	3
Maxilla	-	-	-	1	1	1	1	-	-	1	-	-	1	-	-	-	-	-
Scapula	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Humerus	2	-	-	-	-	-	-	-	-	-	-	-	-	1	1	3	3	-
Ulna	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	1	-	-
Scaphoid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	-
Metacarpal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
Pelvis	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	1	-
Femur	-	-	-	-	-	2	1	1	-	1	1	1	-	-	-	-	1	-
Tibia	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Calcaneum	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fibula	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Metatarsal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
Individuals	2	1	1	1	1	2	2	1	1	1	1	1	1	3	1	3	4	3
	9:7	9:6	9:1.9	9:3	9:1.6	9:2	9:1	8:1.12	8:7	8:6	8:5	8:1.7	8:4	8:3	8:1	7:7	7:6	
Skull	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Canine ¹	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Mandible	1	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-
Maxilla	2	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Clavicle	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Humerus	-	2	-	2	-	1	-	-	-	-	-	1	1	-	-	-	1	-
Radius	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulna	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Metacarpal	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	1	-
Pelvis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Femur	1	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Tibia	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-
Fibula	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Metatarsal	1	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-
Individuals	2	2	1	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1
	7:5	7:4	7:3	7:2	6:7	6:6	6:5	6:4	6:3	6:2	6:1.2	6:1	5:5	5:4	5:3	5:2	4:5	
Skull	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1
Canine ¹	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
PM ¹	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
M ¹	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M ²	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M ₂	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mandible	-	1	2	1	1	-	-	1	-	1	-	-	-	-	-	-	1	-
Maxilla	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The incidence of bones of Macaca sp. (cont.)

	7:5	7:4	7:3	7:2	6:7	6:6	6:5	6:4	6:3	6:2	6:1.2	6:1	5:5	5:4	5:3	5:2	4:5
Scapula	-	-	1	-	-	1	-	-	-	-	-	-	-	1	-	-	-
Humerus	2	2	-	4	-	1	-	3	2	-	1	-	-	-	2	-	-
Radius	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulna	-	1	-	-	-	-	-	1	1	-	-	-	1	-	-	-	1
Pelvis	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Femur	-	-	-	-	-	-	1	-	-	-	1	-	-	-	1	-	-
Tibia	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Metatarsal	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Individuals	2	3	2	3	1	1	1	3	2	2	1	1	1	1	2	1	2
	4:4	4:3	4:2	4:1	3:5	3:4	3:3	3:2	3:1	2:3	2:2	2:1					
Skull	-	1	-	5	-	-	-	-	-	1	1	-					
Incisor ¹	-	-	-	-	-	-	1	1	-	-	-	-					
Incisor ²	-	-	1	-	-	-	-	1	-	-	-	-					
Canine ¹	-	1	2	1	1	2	1	1	2	5	1	2					
PM ¹	-	1	2	1	-	-	-	-	1	-	-	-					
PM ²	-	-	1	1	-	-	-	-	-	-	-	-					
M ¹	-	-	-	1	-	-	-	1	-	-	2	-					
M ²	-	-	1	-	-	-	-	1	-	4	-	1					
M ³	-	-	2	1	1	-	-	1	1	3	-	1					
Incisor ₁	-	-	-	1	-	-	1	-	1	-	-	-					
Canine ₁	-	-	1	-	1	1	-	1	-	-	-	-					
PM ₂	-	-	-	1	-	-	1	1	-	-	-	-					
M ₁	-	-	-	2	-	-	1	1	-	-	-	-					
M ₂	-	-	-	-	-	-	1	1	1	-	-	1					
M ₃	-	-	-	2	-	1	-	2	-	1	-	2					
Mandible	3	1	3	3	1	1	3	3	5	1	1	5					
Maxilla	-	1	2	1	-	-	1	-	2	4	1	-					
Scapula	-	-	2	1	-	-	-	-	1	-	1	-					
Humerus	-	-	2	-	-	-	2	-	1	-	1	1					
Radius	-	-	-	1	1	1	1	2	-	1	-	-					
Ulna	1	-	1	1	-	-	2	1	2	-	-	4					
Metacarpal	-	1	-	-	-	1	-	-	-	1	-	-					
Fore phal. 1	-	-	-	1	-	-	-	-	-	-	-	-					
Pelvis	2	-	1	-	-	-	3	-	-	-	-	1					
Femur	1	-	4	7	-	1	1	-	3	2	4	-					
Astragalus	-	-	-	-	-	-	-	-	-	-	1	-					
Calcaneum	-	-	-	2	-	-	1	2	1	-	2	1					
Metatarsal	-	-	-	-	1	-	1	1	1	-	-	-					
Rear phal. 1	-	-	-	-	-	-	-	-	1	1	-	-					
Rear phal. 2	-	-	-	-	-	-	-	-	-	-	1	-					
Individuals	2	3	4	5	1	4	3	4	4	7	4	7					

TABLE 26: *The measurements of bones and teeth from Presbytis sp. *: alveolar*

Bone	Layer	GL	PW	DW	DPA	BPC	GLP	BG	LG
Scapula	10:14	-	-	-	-	-	19.6	9.6	15.4
Humerus	9:7	-	-	24.6	-	-	-	-	-
Radius	3:2	-	12.5	-	-	-	-	-	-
	10:1	-	-	14.7	-	-	-	-	-
	10:11	-	-	13.8	-	-	-	-	-
Ulna	7:5	-	-	-	(11.6)*	(7.7)	-	-	-
	3:1	-	-	-	-	17.0	-	-	-
Pelvis	4:1	-	-	-	-	-	-	-	-
Metacarpal 3	7:4	43.1	5.0	5.1	-	-	-	-	-
Fibula	10:1	-	10.6	-	-	-	-	-	-
Astragalus	3:3	20.5	-	-	-	-	-	-	-
	3:4	(26.5)	-	-	-	-	-	-	-
Metatarsal 1	4:3	-	-	6.6	-	-	-	-	-
2	3:4	-	5.9	-	-	-	-	-	-
2	4:2	-	(5.0)	-	-	-	-	-	-
2	8:7 1.12	-	5.1	-	-	-	-	-	-
4	4:2	-	5.3	-	-	-	-	-	-
Rear phal. 2	3:1	22.7	6.2	4.0	-	-	-	-	-

Bone	Layer	LPM ²	LM ¹	LM ²	LPM ¹⁻²	LM ¹⁻³
Maxilla	2:2	-	-	5.3	-	-
	3:1	-	5.1	-	-	-
	4:2	-	-	-	9.0	-
	4:3	-	-	-	7.1	16.5

Bone	Layer	LPM ₁	LPM ₂	LPM ₁₋₂	LM ₁	LM ₂	LM ₃	LM ₁₋₃	H vr.
Mandible	2:2	-	-	(9.5)	(4.8)	(5.9)	-	-	-
	3:1	(6.9)	-	-	-	-	-	-	-
	3:2	-	-	9.4	-	-	-	17.7	-
	3:3	-	4.7	-	(5.4)	(6.1)	-	-	-
	3:4	(6.1)	-	-	-	-	-	-	-
	4:3	-	-	-	-	-	6.8	-	-
	6:1	-	-	-	5.3	6.6	ue	-	-
	9:1	-	-	-	f	5.6	7.3	-	-
	10:4	-	dec.	(5.1)	dec.	dec.	-	-	31.7
	10:13	-	-	-	-	(7.3)	e	-	29.6

EXCAVATION OF KHOK PHANOM DI

The dimensions of bones and teeth from Macaca sp. (cont.)

Bone	Layer	LPM ₁	LPM ₂	LPM ₁₋₂	LM ₁	LM ₂	LM ₃	LM ₁₋₃	H vr.
Mandible	10:1	-	-	-	-	7.9	10.6	-	-
	10:1	-	-	-	-	7.1	9.5	-	-
	10:1	-	15.2	-	-	-	26.8	-	-
	10:2	-	-	-	-	-	-	23.5	-
	10:2	-	-	-	-	-	-	23.5	48.0
	10:3 1.2	-	e	-	(4.8)	(6.8)	ue	-	-
	10:3 1.2	-	-	9.3	(5.4)	(5.8)	ue	-	-
	10:4	-	-	(10.8)	-	-	-	(25.6)	-
	10:4	-	-	12.9	-	-	-	25.7	-
	10:8	-	-	10.9	-	-	-	23.5	-
	10:11	-	-	-	-	7.4	8.7	-	-
	10:12	-	-	13.4	-	-	-	26.1	-
	10:13	-	-	-	-	-	-	-	43.1
	10:14	-	-	-	-	-	8.3	-	-
Bone	Layer	PW	DW	GLP	BG	LG			
Scapula	2:2	-	-	20.3	10.4	17.2			
	3:1	-	-	-	11.4	-			
	3:5	-	-	18.4	9.4	-			
	4:1	-	-	21.1	11.7	-			
	4:2	-	-	17.8	12.2	-			
	6:7	-	-	-	11.4	13.6			
	7:4	-	-	-	(12.3)	-			
	10:	-	-	-	13.2	-			
Humerus	10:23 1.26	-	-	-	10.6	-			
	3:3	17.6	-	-	-	-			
	4:2	-	24.4	-	-	-			
	4:2	-	24.3	-	-	-			
	5:3	-	24.3	-	-	-			
	5:3	-	19.4	-	-	-			
	6:4	-	24.1	-	-	-			
	6:4	-	24.9	-	-	-			
	6:6	-	24.6	-	-	-			
	7:2	-	21.3	-	-	-			
	7:2	-	26.1	-	-	-			
	7:2	-	25.2	-	-	-			
	7:4	-	(23.0)	-	-	-			
	7:4	-	(20.6)	-	-	-			
	7:5	-	22.1	-	-	-			
	8:4	-	21.5	-	-	-			
	9:2	-	23.8	-	-	-			
	9:3	-	24.8	-	-	-			
	9:6	16.4	-	-	-	-			

The dimensions of bones and teeth from Macaca sp. (cont.)

Bone	Layer	PW	DW	GLP	BG	LG
Humerus	9:6	14.3	-	-	-	-
	10:2	21.6	-	-	-	-
Scapula	10:2	-	24.6	-	-	-
	10:3 1.2	-	25.7	-	-	-
	10:3 1.2	-	23.7	-	-	-
	10:4	15.7	-	-	-	-
	11:1	-	23.1	-	-	-
	11.1	-	(21.8)	-	-	-
Bone	Layer	GL	PW	DW	DPA	BPC
Radius	2:3	-	(11.5)	-	-	-
	3:2	-	12.2	-	-	-
	3:3	-	-	13.8	-	-
	3:4	-	11.1	-	-	-
	3:5	-	11.0	-	-	-
	4:1	-	11.0	-	-	-
	7:7	-	10.8	-	-	-
	9:3 1.6	133.8	14.9	11.6	-	-
Ulna	9:6 1.9	-	12.2	-	-	-
	2:1	-	-	-	-	(12.0)
	2:1	-	-	-	-	(14.5)
	2:1	-	-	-	-	10.9
	2:1	-	-	-	-	10.7
	3:1	-	-	-	-	17.6
	3:2	-	-	-	-	12.7
	3:3	-	-	-	15.4	13.6
	3:3	-	-	-	14.7	11.6
	4:1	-	-	-	14.8	12.2
	4:5	-	-	-	15.2	(11.3)
	5:5	-	-	-	-	10.0
	6:3	-	-	-	14.1	11.3
	6:4	-	-	-	-	11.6
	7:6	-	-	-	14.0	12.6
	9:3 1.6	-	-	-	15.3	14.3
	10:4	-	-	-	12.4	9.7
Metacarpal 2	2:3	-	-	6.1	-	-
	8:6	43.6	7.3	6.8	-	-
	8:7 1.12	48.4	7.8	7.5	-	-
	10:1	-	7.7	-	-	-
	10:2	50.3	7.1	6.5	-	-
Metacarpal 3	3:4	-	-	6.0	-	-
Metacarpal 4	4:3	-	5.0	-	-	-

The dimensions of bones and teeth from Macaca sp. (cont.)

Bone	Layer	GL	PW	DW	DPA	BPC				
Metacarpal 4	7:5	-	-	5.9	-	-				
	7:7	33.1	5.6	5.7	-	-				
Fore phal. 1	4:1	23.0	6.5	4.4	-	-				
Bone	Layer	GL	PW	DW	DC	LA	LAR	SH	SB	
Pelvis	3:3	-	-	-	-	18.8	(16.0)	17.5	8.4	
	7:2	-	-	-	-	-	-	14.5	6.3	
	7:4	-	-	-	-	14.7	17.1	-	-	
	7:4	-	-	-	-	19.7	17.3	18.1	8.4	
	8:1	-	-	-	-	15.5	13.4	-	-	
	10:2	-	-	-	-	18.8	(16.0)	17.3	7.2	
	10:9	-	-	-	-	15.7	14.2	13.2	7.0	
Femur	2:2	-	-	-	14.1	-	-	-	-	
	2:2	-	-	-	14.8	-	-	-	-	
	2:2	-	-	-	13.8	-	-	-	-	
	2:2	-	-	-	14.6	-	-	-	-	
	3:1	-	-	-	16.0	-	-	-	-	
	3:1	-	-	-	14.5	-	-	-	-	
	4:1	-	-	23.3	-	-	-	-	-	
	4:1	-	-	-	15.2	-	-	-	-	
	4:1	-	-	-	13.7	-	-	-	-	
	4:1	-	28.4	-	-	-	-	-	-	
	4:2	-	30.7	-	15.4	-	-	-	-	
	4:4	-	24.8	-	13.2	-	-	-	-	
	6:1 1.2	-	28.0	-	13.0	-	-	-	-	
	6:5	-	(26.0)	-	(15.0)	-	-	-	-	
	8:6	-	29.1	-	14.9	-	-	-	-	
	10:2	-	-	19.3	-	-	-	-	-	
	10:5	-	-	-	14.0	-	-	-	-	
	10:6	132.0	24.7	-	12.6	-	-	-	-	
	10:8	-	28.0	-	14.0	-	-	-	-	
	10:10	-	24.1	-	11.6	-	-	-	-	
	10:11	133.6	23.9	22.8	12.1	-	-	-	-	
	10:12	-	-	23.9	-	-	-	-	-	
Tibia	5:3	-	23.4	-	-	-	-	-	-	
	8:1	119.6	20.0	12.7	-	-	-	-	-	
	8:1	-	-	14.7	-	-	-	-	-	
	8:7 1.12	-	-	15.8	-	-	-	-	-	
	9:6	(144.9)	-	14.9	-	-	-	-	-	
	10:10	-	-	14.1	-	-	-	-	-	
	10:14	-	-	11.1	-	-	-	-	-	
Fibula	8:7 1.12	-	10.3	-	-	-	-	-	-	

The dimensions of bones and teeth from Macaca sp. (cont.)

Bone	Layer	GL	PW	DW	GB
Calcaneum	2:1	30.3	-	15.8	-
	2:2	-	-	13.4	-
	2:2	29.4	-	-	14.8
	3:1	32.2	-	-	18.3
	3:2	29.2	-	-	14.2
	3:2	28.9	-	-	15.7
	3:3	37.4	-	-	16.9
	4:1	30.9	-	-	15.0
	8:5	(23.3)	-	-	14.9
	8:7	32.7	-	-	(17.8)
	10:10	29.3	-	-	13.0
Metatarsal 1	3:3	32.7	9.6	7.7	-
	3:5	-	7.4	-	-
	7:3	27.2	8.0	5.2	-
	10:2	34.5	8:8	7.8	-
Metatarsal 2	8:3	-	-	5.7	-
	8:7	-	-	7.8	-
	10:3	-	-	6.2	-
Metatarsal 3	3:1	-	-	7.9	-
	3:2	-	-	7.5	-
	9:7	-	6.1	-	-
	10:1	44.3	7.8	5.8	-
Metatarsal 4	4:5	-	5.8	-	-
	7:5	-	-	5.9	-
Metatarsal 5	7:5	-	-	5.4	-
Rear phal. 1	2:3	-	5.2	-	-
	3:1	23.4	6.5	4.6	-
Rear phal. 2	2:2	15.6	5.6	4.1	-

SUS SCROFA

The remains of the pig, *Sus scrofa* Linnaeus, 1758, are present but rare throughout zones A and B, but became much more abundant with the decline in marine resources which occurred at the beginning of zone C (layers 2-4). The bones were fragmented, indicating that animals were butchered. The presence of pig remains from a mangrove habitat is not surprising. Lekagul and McNeely (1977:664) have noted that wild pig feed on the crabs, shellfish, fish and coconuts which are abundant in mangrove contexts.

An issue of some interest is the status of the pigs represented. It is immediately conceded that distinction between wild and domestic animals on the basis of fragmentary remains is virtually impossible. In the case of the remains from Non Nok Tha, Higham (1975b) was able to consider two mandibles from mortuary contexts. These, he claimed, were distinguishable from wild specimens due to a foreshortening of the face under domestication. If the same principle is applied to the one well-preserved mandible from Khok Phanom Di layer 9:7, then this specimen at least is probably from a wild animal. With reference to the material from zones A and B, perhaps the most significant point is their rarity. Secondly, given the fact that domestic pigs in Thailand often interbreed with wild animals, the ascription of bones to either of the conventional categories of wild or domestic becomes not only virtually impossible osteologically, but rather pointless culturally.

TABLE 28: *The values of t on comparing the upper and lower alveolar length of the first molar from Khok Phanom Di and other prehistoric Thai samples of Sus scrofa (*P ≥ 0.05). Samples 1-4 are the upper molar, and 5-9 for the lower molar*

Sample	Mean	S.D.	t cf. sample 2	sample 3	sample 4	sample 5
1. KPD zones A-B	14.2	0.57	0.33	3.39*	3.59*	-
2. KPD zone C	14.1	0.92	-	2.21	2.66	-
3. Ban Na Di	13.2	0.96	-	-	0.79	-
4. Ban Chiang	12.8	1.12	-	-	-	-
1. KPD zones A-B	14.3	0.57	0.91	2.98	3.88*	0.44
2. KPD zone C	14.6	0.88	-	1.66	2.61	1.20
3. Ban Chiang	15.4	0.91	-	-	0.63	3.03
4. Ban Tong	15.6	0.91	-	-	-	3.81*
5. Ban Na Di	14.1	0.75	-	-	-	-

Nevertheless, two variables will be considered. One is the age structure of the samples from zones A, B and C. The other is the size of the dentition compared with other prehistoric assemblages. An increase, or a very high proportion of young animals, is commonly seen as an indication of herd management whereby a given age group was culled. At Khok Phanom Di during zones A and B there was a preponderance of sub-adult animals, but with zone C this situation changed and adult animals became more common. Young pigs were not common and very young specimens were rare. A satisfactory sample of limb bones on which to judge the size of the Khok Phanom Di pigs is not available. The commonest specimens, and indeed the only specimens present in sufficient numbers to make up a reasonable sample size, are the teeth and, in particular, the first upper and first lower molar. This is not a particularly useful tooth. It is the smallest of the molars and the alveolar length is not an easy dimension to replicate consistently particularly when teeth are lodged in the mandible. It is therefore quite likely that different workers, even the same person, will produce variable estimates from the same specimen. This must be borne in mind when considering the results set out in Table 28.

The mean alveolar length of the first upper molar from zones A and B is statistically indistinguishable from zone C sample. With $P \geq 0.05$ however, the zone A and B sample appears to be rather longer than the specimens from Ban Na Di layers 6-8 and from early Ban Chiang. This result seems clear-cut, but is contradicted by the results taken from the same dimension for the mandibles. Here, it is seen that the Khok Phanom Di sample is the same size as the other prehistoric samples, save for that from Ban Tong, which at $P \geq 0.05$ is actually *bigger*. Given the near certainty that the samples from Ban Tong, Ban Na Di and Ban Chiang do include larger, wild animals, it is clear that little, if any, useful information can at present be drawn from these dimensions. This is further emphasized by the finding that the mean length of the lower first molar from Khok Phanom Di is virtually identical with a sample drawn from nine specimens of the wild pig *Sus scrofa jubatus*. The limb bones are also of little value, but it is noted that many of the first phalanges from Khok Phanom Di fall within the size range of the bearded pig, *Sus barbatus*.

TABLE 29: *The incidence of Sus scrofa bones*

[illegible]

The incidence of Sus scrofa bones (cont.)

	7:6	7:5	7:4	7:3	7:2	7:1.2	7:1	6:1.1	6:1.2	6:8	6:5	6:4	6:3	6:2	6:1	5:5
Skull	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Scapula	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Humerus	-	-	-	-	-	-	-	-	-	1	2	1	-	-	-	-
Radius	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-
Ulna	-	-	1	-	-	-	-	-	-	1	-	-	-	1	-	-
Metacarpal	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Phalanx 1	-	-	-	1	-	-	1	-	-	-	1	-	-	-	-	-
Pelvis	-	-	-	1	1	-	-	-	-	-	1	-	-	-	-	-
Femur	-	1	-	-	1	-	-	-	-	-	-	1	-	-	-	-
Tibia	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Metatarsal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calcaneum	-	-	1	1	-	-	1	-	-	-	-	-	-	-	1	-
Individuals	1	1	1	1	1	1	1	1	1	1	4	3	1	1	1	1

	5:4	5:3	5:2	5:1	4:5	4:4	4:3	4:2	4:1	3:5	3:4	3:3	3:2	3:1	2:3	2:2	2:1
Skull	-	-	-	-	1	-	-	-	1	-	-	-	-	-	1	-	-
Scapula	-	1	-	-	-	-	2	3	-	-	2	3	6	10	-	3	1
Humerus	-	-	-	-	-	1	-	-	2	-	-	1	4	-	4	4	4
Radius	-	-	-	-	-	-	-	2	1	1	1	3	4	3	1	2	3
Ulna	-	-	-	-	1	-	2	1	-	-	4	1	2	1	1	3	-
Metacarpal	-	-	1	-	1	2	3	1	-	-	7	3	3	7	-	2	2
Scaphoid	-	-	-	-	-	1	-	-	1	1	-	1	-	1	-	1	-
Unciform	-	-	-	-	-	-	-	1	-	-	1	-	2	-	-	3	-
Lunate	-	-	-	-	-	-	-	1	-	-	-	1	1	-	-	1	-
Cuneiform	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-
Phalanx 1	-	-	1	1	1	5	2	8	7	3	4	8	5	3	2	7	3
Phalanx 2	-	-	-	-	-	2	2	7	6	1	1	2	4	8	-	2	4
Phalanx 3	-	-	1	1	-	1	1	3	6	1	4	4	3	8	2	4	4
Pelvis	-	-	1	-	1	1	1	3	1	-	-	4	-	-	1	3	1
Femur	-	-	-	1	-	1	1	3	3	4	-	-	1	-	2	4	1
Patella	-	-	-	-	-	1	-	1	-	-	-	1	-	-	-	-	-
Tibia	-	-	-	-	1	2	2	2	4	-	2	4	1	5	1	1	2
Fibula	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
Cuboid	-	-	-	-	-	1	-	-	1	-	1	-	1	2	-	2	1
Navicular	-	-	-	-	-	-	-	1	1	-	1	1	-	1	-	-	-
Metatarsal	1	-	-	-	1	-	3	-	-	-	-	3	4	6	-	2	1
Astragalus	-	-	-	1	-	-	-	1	3	-	3	6	3	5	2	5	2
Calcaneum	-	1	-	-	1	1	1	-	2	-	3	1	4	6	2	4	3
Metapodial	-	-	-	3	-	-	-	2	4	3	-	3	5	4	2	6	2
Individuals	1	1	2	2	2	3	4	7	4	3	5	5	5	7	5	5	5

TABLE 30: *The dimensions of limb bones and teeth from Sus scrofa. The tooth length dimensions are all alveolar. * estimated measurement, + from an epiphysis*

	Layer	LM ¹	LM ²	LM ³	LM ¹⁻³	LPM ³⁻⁴	LPM ^{4-M} ²	LPM ¹⁻³
Maxilla	2:1	14.8	-	-	-	-	-	-
	2:2	14.2	-	-	-	-	-	-
	2:2	-	20.2	-	-	-	-	-
	2:2	-	21.0	-	-	-	-	-
	2:2	-	21.0	-	-	-	-	-
	2:2	-	-	34.8	-	-	-	-
	2:2	-	-	34.5	-	-	-	-
	2:3	15.0	-	-	-	-	-	-
	2:3	-	-	34.5	-	-	-	-
	3:1	15.0	-	-	-	-	-	-
	3:1	14.2	-	-	-	-	-	-
	3:1	-	19.2	-	-	-	-	-
	3:1	-	-	36.7	-	-	-	-
	3:2	13.5	-	-	-	-	-	-
	3:2	-	18.5	-	-	-	-	-
	3:2	-	-	36.1	-	-	-	-
	3:3	14.1	-	-	-	-	-	-
	3:3	15.5	-	-	-	-	-	-
	3:3	14.3	-	-	-	-	-	-
	3:3	13.8	-	-	-	-	-	-
	3:3	13.6	-	-	-	-	-	-
	3:4	-	-	-	26.5	-	-	-
	3:4	-	-	39.5	-	-	-	-
	3:5	-	20.0	-	-	-	-	-
	3:5	-	21.0	-	-	-	-	-
	3:5	14.1	-	-	-	-	-	-
	3:5	-	-	35.9	-	-	-	-
	4:1	15.0	-	-	-	-	-	-
	4:1	-	-	-	-	-	-	35.0
	4:1	-	19.6	-	-	-	-	-
	4:1	14.0	20.0	-	-	-	-	-
	4:1	-	20.0	35.0	-	-	-	-

The dimensions of limb bones and teeth from Sus scrofa (cont.)

	Layer	LM ¹	LM ²	LM ³	LM ¹⁻³	LPM ³⁻⁴	LPM ⁴ -M ²	LPM ¹⁻³
Maxilla	4:2	-	-	36.0	-	-	-	-
	4:2	-	-	36.0	-	-	-	-
	4:2	-	-	34.2	-	-	-	-
	4:2	-	-	38.0	-	-	-	-
	4:2	14.1	19.2	39.0	76.4	-	-	-
	4:3	14.1	-	-	-	-	-	-
	4:3	-	19.2	-	-	-	-	-
	6:5	14.8	19.5	-	-	-	-	-
	6:5	-	-	-	27.0	-	-	-
	7:1	12.1	19.0	-	-	-	-	-
	7:1	14.0	-	-	-	-	-	-
	7:1	13.8	-	-	-	-	-	-
	9:3	14.1	20.2	-	-	-	50.0	-
	10:3 l. 2	14.1	18.1	-	-	-	46.2	-
	10:4	14.1	19.3	-	-	25.8	-	-
	11:1	14.8	-	-	-	-	-	-
	11.1	15.0	-	-	-	-	-	-
	Layer	LM ₁	LM ₂	LM ₃	LM ₁₋₃	LPM ₂₋₄	LPM ₄ dec.	
Mandible	2:2	-	21.0	-	-	-	-	
	2:2	-	19.5	-	-	-	-	
	2:3	15.2	-	-	-	-	-	
	2:3	15.3	-	-	-	-	-	
	3:1	15.6	-	-	-	-	-	
	3:1	-	19.8	-	-	-	-	
	3:1	15.0	-	-	-	-	-	
	3:1	14.9	-	-	-	-	-	
	3:1	14.6	-	-	-	-	-	
	3:1	-	21.0	-	-	-	-	
	3:1	-	-	37.9	-	-	-	
	3:1	-	-	45.0	-	-	-	
	3:1	-	20.5	41.9	-	-	-	
	3:1	-	-	37.3	76.5	-	-	
	3:4	15.2	20.8	-	-	-	-	
	3:4	14.1	-	37.0	-	-	-	
	4:1	13.3	19.0	-	-	-	-	
	4:1	-	-	39.4	-	-	-	
	4:2	13.9	18.1	-	-	-	-	

	Layer	LM ₁	LM ₂	LM ₃	LM ₁₋₃	LPM ₂₋₄	LPM ₄ dec.		
Mandible	6:4	13.5	-	-	-	-	-		
	6:5	-	-	-	-	-	16.9		
	6:1.2	14.5	20.5	43.5	78.3	-	-		
	7:1	-	-	-	-	-	18.0		
	7:1	14.8	-	-	-	-	-		
	7:2 1.2	-	-	-	-	-	18.0		
	8:7 1.12	-	19.7	-	-	-	-		
	8:7	14.0	-	-	-	-	-		
	9:1	14.0	-	-	-	-	-		
	9:3 1.7	-	20.0	-	-	-	-		
	9:7	14.1	18.6	-	-	41.6	-		
	10:3 1.2	-	-	-	-	39.8	-		
	10:17	-	-	41.0	-	-	-		
	11:1	15.2	-	-	-	-	-		
	Layer	L	PW	Layer	L	PW	Layer	L	PW
Phalanx 1	2:3	44.5	14.0	3:3	46.6	18.5	3:5	42.2	18.0
	4:1	34.0	13.1	4:1	42.8	16.0	4:2	34.2	14.0
	4:2	40.0	19.0	6:5	41.0	17.3	-	-	-
Phalanx 2	2:1	24.5	15.0	2:1	27.0	16.5	2:1	25.0	14.0
	3:1	25.0	13.3	3:1	22.0	13.0	3:1	23.0	14.5
	3:1	25.0	15.5	3:1	24.0	16.0	3:2	23.5	14.0
	3:2	25.0	15.8	3:3	20.0	12.0	3:3	22.5	13.9
	3:4	21.2	12.0	3:5	23.4	13.6	4:1	-	12.8
	4:1	22.0	13.0	4:1	27.2	14.0	4:1	24.5	14.2
	4:2	20.4	12.0	4:2	21.0	12.0	4:2	23.2	12.6
	4:2	24.0	14.6	4:2	22.0	13.5	4:2	24.1	14.5
	Layer	L	MW	Layer	L	MW	Layer	L	MW
Astragalus	2:1	44.5	24.5	2:2	39.0	22.0	2:2	40.0	23.0
	2:2	42.0	26.0	2:3	41.5	25.0	2:3	42.5	24.0
	3:1	45.0	28.0	3:1	42.0	-	3:1	45.0	26.0
	3:1	40.0	23.5	3:2	43.0	24.5	3:2	39.5	23.0
	3:2	46.0	26.0	3:3	45.0	25.5	3:4	44.5	26.5
	4:1	42.5	25.2	4:1	45.2	27.0	5:1	40.1	24.0
	10:24	47.6	29.0	-	-	-	-	-	-

The dimensions of limb bones and teeth from Sus scrofa (cont.)

	Layer	PW	DW	Layer	PW	DW	Layer	PW	DW
Radius	2:1	30.6	-	2:3	31.0	-	3:1	24.3	-
	3:1	31.1	-	3:1	25.5	-	3:3	28.7	-
	3:5	24.4	-	4:2	26.0+	-	4:2	-	32.0+
	5:3	-	33.8	8:1	27.0	29.5	11:1	28.0	-
	Layer	L	MW	Layer	L	MW	Layer	L	MW
Calcaneum	3:1	71.8	17.0	2:2	86.0	24.0	-	-	-
	Cont.	A/P L	Cont.	A/P L	Cont.	A/P L	Cont.	A/P L	-
Cuboid	4:4	26.1	4:1	24.9	3:4	22.3	3:2	28.9	-
	Cont.	DW	Cont.	DW	Cont.	DW	Cont.	DW	-
Tibia	3:1	25.8	3:3	30.0	4:3	27.0	4:4	31.0	-
	9:1	27.0	9:7	26.2	-	-	-	-	-
	Layer	L	DW	PW	Layer	Bone	L	DW	PW
Metatarsal III	2:1	-	-	16.0	3:1	MT 3	-	-	13.0
	3:1	-	-	15.2	3:2	MT 3	-	-	12.5
	3:3	-	-	14.5	3:3	MT 3	-	-	14.5
	4:1	-	-	14.2	4:3	MT 3	-	-	13.5
	4:4	-	-	17.2	3:1	MC 3	-	-	14.0
Metacarpal III	3:2	-	-	16.0	3:5	MC 3	-	-	17.0
	3:5	-	-	17.2	3:5	MC 3	80.8	15.1	16.0
	4:5	-	-	17.9	6:4	MC 3	-	-	17.5
	10.6	84.0	19.1	-	2:1	MC 4	-	-	15.8
Metacarpal IV	2:2	-	22.5	14.0	3:1	MC 4	-	-	19.1
	3:2	-	-	15.3	3:5	MC 4	-	-	16.2
	3:5	-	-	18.2	4:3	MC 4	-	-	17.2
	4:4	-	14.5	-	8:1	MC 4	79.9	16.1	-

SUMMARY

The faunal spectrum from Khok Phanom Di has been expressed in two ways. Figure 39 portrays the incidence and relative stratigraphic abundance of individual animals and taxa. From this spectrum, it can be seen that in zones A and B large mammalian taxa are consistently represented but are uncommon. Four main groups make up the majority of the mammalian range – macaques, pigs, and the medium and large deer species. During this period of occupation, it is postulated that the site was located in a mangrove swamp/estuarine environment.

Certainly, pigs are known to enter into both the mangrove forest to eat aquatic fauna, and they also forage in the more terrestrial nypa palm zone. If, as suspected, the macaque species represented is *Macaca fascicularis*, then its presence in a mangrove coastal forest environment is not unusual. The mangrove would have provided an ideal habitat for the crab-eating macaque. The back swamps behind the mangrove would have provided grazing for the herbivorous *Cervus eldi* and *Cervus schomburgki*. Deer bones corresponding in size to sambar (*Cervus unicolor*) are also present. This is adapted to a wide variety of habitats, including woodland. However, these cervids are less abundant than are pigs and macaques and probably represent more opportunistic hunting than do the representation of the pig and macaques. The leaf monkey (*Presbytis* sp.) is relatively rare during these two zones as are canids, small deer and both the water buffalo and bovids. During this period, subsistence was marine orientated. Crabs, shellfish, crustacea, turtles and fish were widely exploited.

Figure 40 shows the relative abundance of marine fauna (represented here by *Anadara granosa*, a bivalve mollusc adapted to mud/sandflats on the seaward side of mangroves (Morton 1983:123) as compared with terrestrial mammalian fauna. As can be seen, during zones A and B the amounts of marine resources exploited were vastly disproportionate to that of mammals. Although the use of single valves of *Anadara* in this figure to represent marine remains is by no means accurate, it does signify the emphasis placed on exploiting marine resources during the period the site was located on or very near the coast. Most of the midden and lenses in these two zones contained shell and other marine remains. That mammals were not a significantly large part of the diet may be indicated by the lack of mammal bones represented here. The NISP (number of identified specimens per taxa) count is low for each species.

A contributory reason for the the relative rarity of economically exploited mammals in zones A and B would have been the use of the site as a cemetery. Certainly, during zone B the area was specifically used as a cemetery, and inhumations were set into the occupation contexts of zone A. Nevertheless, the biological evidence for the concentration on marine resources, the low NISP count, and the 'dominance' of mammal species that enter the mangal, that is pig and macaques, as against woodland/grassland species, would bespeak that mammals were not heavily (or easily) exploited, particularly during the accumulation of the zone A deposits.

Towards the end of the period represented by zone B, the sea level retreated. With zone C, an environmental change had clearly taken place, and this is represented in the faunal spectrum. The relative abundance of all mammalian taxa increase in zone C, particularly macaque, pig and both swamp and forest deer. There is an associated decline in exploited marine species.

The freshwater swamp forest and herbaceous swamplands postulated by Maloney from pollen evidence would have provided a preferred habitat for Schomburgk's, Elds, and pig deer, as well as water buffalo, whose frequencies increase in zone C, the period proposed for the establishment

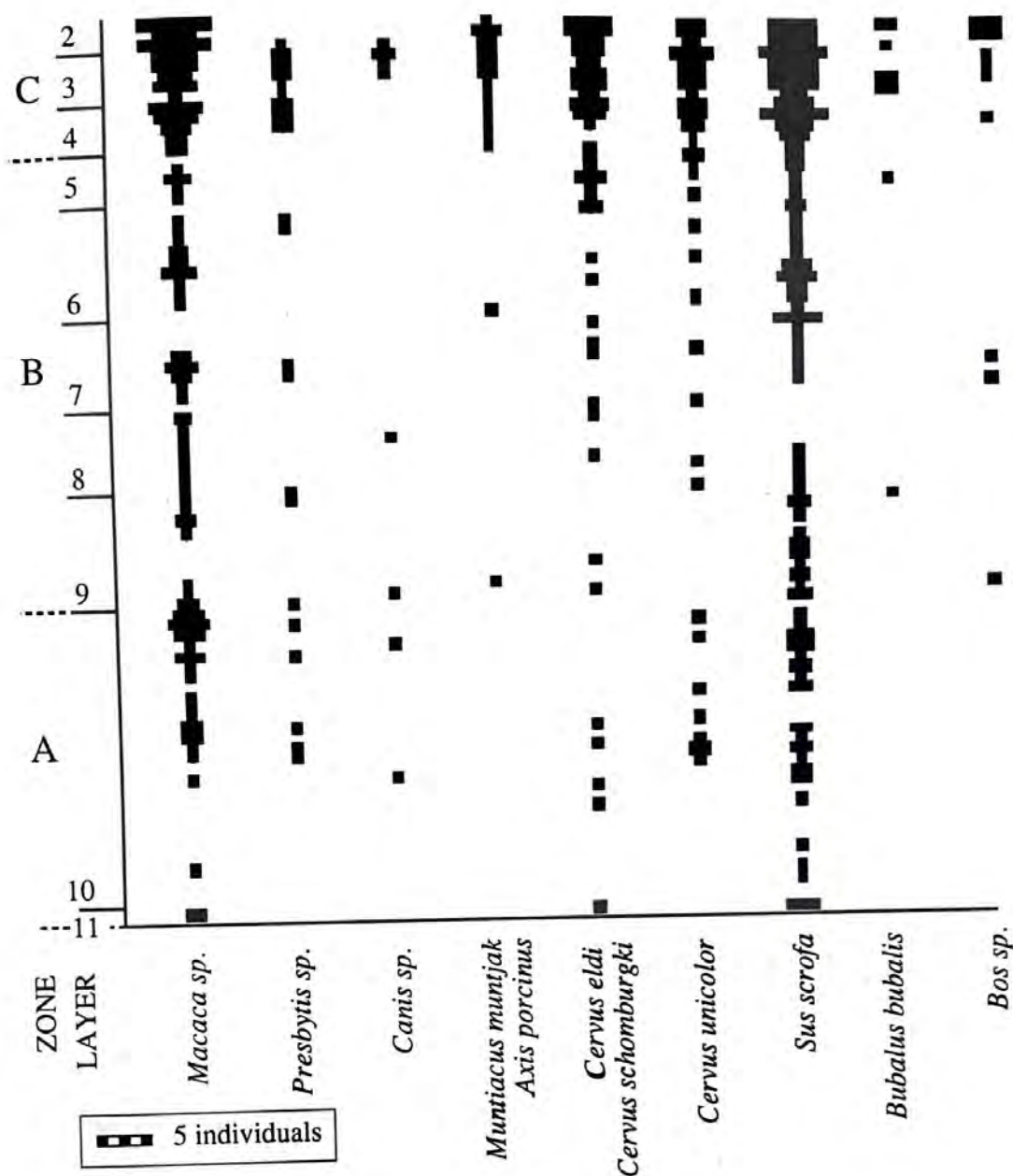


FIG. 39. The larger mammalian faunal spectrum. Each species is represented by the number of individual animals represented

and/or extension of swampy grasslands. The increase in deer identified as sambar (*Cervus unicolor*) and small deer, which probably contains specimens of the forest dwelling muntjac, seems to indicate the presence nearby of some type of forest vegetation. The concomitant rise in frequencies of arboreal primates (langurs and macaques) who require fruits and leaves for their diet also

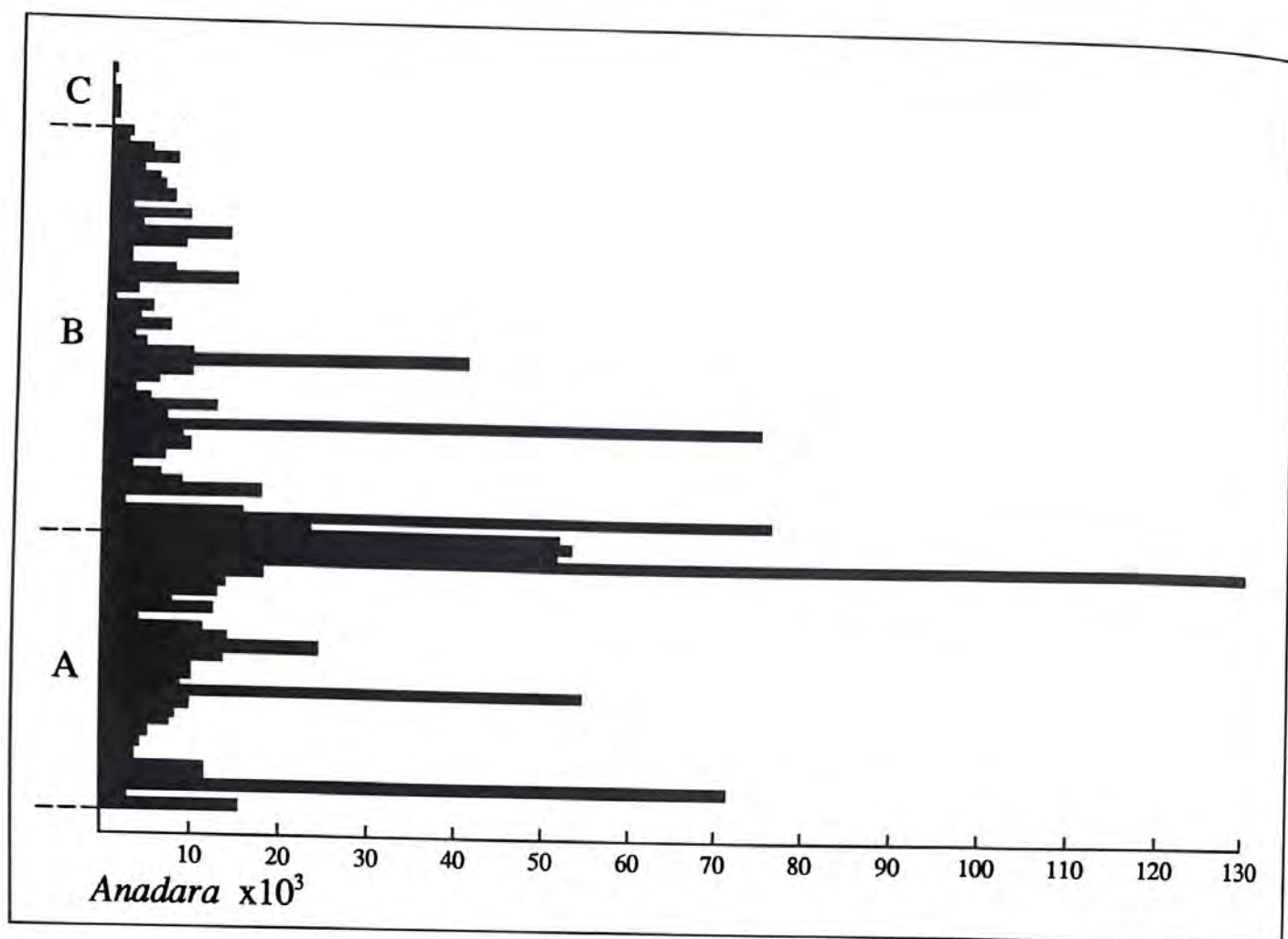


FIG. 40. The relative status of marine and mammalian faunas. The marine variable is represented by *Anadara*. The ratio represented was achieved by dividing the absolute number of single valves by 1000 for each spit incidence

supports the view that forest existed in the vicinity of the site. This was probably an evergreen type because deciduous forest is not a consistent source of food resources for these primates.

Not only is zone C characterized by a significant increase in the relative abundance of large mammal species, there is a concomitant increase in the amount of fractured bone, indicative of post-mortem butchery. The NISP count for all species rises in this zone. Although the NISP measure is affected by the degree of bone fragmentation, the fact that the number of individual animals identified also increases means that the same number of bones were not fractured more heavily than before. That a larger number of animals was exploited and butchered for food and bone material can be seen with the evidence from the deer. From layer 4, the incidence of deer increased, as did the representation and fragmentation of antler. Both shed and unshed antler are present, and, from artefactual evidence, it was cut and worked. Two polished deer ulnae were also found.

The NISP count for the layers below zone C is generally very low, that is, few bone specimens are represented. This phenomenon can be seen in the tables of skeletal part evidence for each taxon. A more representative range of anatomical bones is found in zone C. During the preliminary sorting procedure it was noticed that the larger animals were butchered more heavily than the mammals of smaller body size. For example, there was less diagnostic bone identifiable as primate in zone C than there was for bone deriving from pigs and deer. Monkeys are small and have robust, small and dense bones. They have little marrow value. The wide representation of skeletal elements, small body size and ease of transportation would probably indicate that the monkeys were returned to the site as complete carcasses. The larger mammals, such as deer, pig and bovids have undergone a greater degree of butchery, and this pre-depositional treatment may well discriminate against their relative frequencies by reducing the number of identifiable elements.

A noticeable difference between this site and Ban Chiang or Ban Na Di is the virtual absence of burnt or even charred bone. Butchering marks on some bone in zone C indicate fine score marks, possibly derived from the use of metal implements. Metal, however, was not recovered from the excavation.

As to the question of domestication, the results are inconclusive. The canids could possibly be domestic, but the sample size is so small and the absence of cranial material means speciation is problematical. The most notable feature of the canid remains is their scarcity. Higham has found the evidence for the domestication of the pig to be inconclusive, with wild animals certainly present. The water buffalo remains all indicate we are dealing with wild stock and the 'Bovidae' are not indicative of domesticates.

An inland mosaic of dry evergreen forest and swamp woodland interspersed by swampy grasslands could be proposed as a plausible environment for the area when zone C was deposited, based on the consideration of the larger mammalian fauna from the zone and the palynological data presented above. This environment succeeded the local presence of a mangrove community and back swamplands and swamp forest after a fall in the local sea level. Evidence for the exploitation of large mammals is consistent but limited during zones A and B. The relative abundance of all taxa increases in each successive zone. With the transition to zone C, which post-dates a significant marine regression and the reoccupation of the site, the representation of taxa and their relative frequencies increase. The mammals found within this zone are representative of a swamp woodland/grassland and forested environment.

The following abbreviations have been employed: a/pL: anterior/posterior length, BG: Scapula: breadth of the glenoid cavity, BPC: Ulna: greatest breadth across coronoid process, DC: greatest depth of the caput femoris, DE: Distal epiphysis, DPA: Ulna: depth across the processus anconaeus, DW: Distal width, e: erupting tooth, f: fragment, GB: Greatest breadth, GL: Greatest length, GLI: Astragalus: greatest length of the lateral half, GLm: Astragalus: greatest length of the medial half, GLP: Scapula: greatest length of the glenoid process, GW: greatest width, H mand: Mandible: height of the mandible behind M₃, from the most aboral point of the alveolus, measured at right angles to the basal border, LA: Pelvis: length of the acetabulum, LAR: Pelvis: length of the acetabulum on the rim, LdPM₄: length of the fourth lower deciduous premolar, LdPM₄¹: length of the fourth upper deciduous premolar, LG: Scapula: length of the glenoid cavity, LM₁: length of first lower molar, LM₁¹: length of first upper molar, LPM₁: length of first lower premolar, LPM₁¹: length of first upper premolar, MW: minimum width, PE: Proximal epiphysis, PW: Proximal width, SB: Pelvis: smallest breadth of the shaft of the ilium, SH: Pelvis: smallest height of the shaft of the ilium, ue: unerupted tooth, WPAS: Width of the proximal articular surface,

XIII. THE MICROFAUNA AND BIRD REMAINS

By Barbara West*

THIS section was initially restricted to the analysis of bird remains. It was then extended to include bones from species which were not represented in the small comparative collection available at the University of Otago. These species are set out in Table 31. Conclusions should be taken in conjunction with those obtained by Grant and Higham in the preceding chapter. The presentation and analysis in this section employs, in addition to the successive layers and features such as pits, burials and lenses, three broad groups of layers. Zone A represents layers 10–11, during which the sequence began with evidence for occupation and pottery making (layer 11), followed by a series of shell and ash lenses, and much ritual activity associated with the cemetery (layer 10). Zone B (layers 9–5) saw a continuation of burial activity but with a number of modifications in behaviour including a reduction in the number of lenses and shell middens. Zone C (layers 4–2) represents a period, probably after an episode of site abandonment, when the sea level had fallen and the river had moved its channel away from the site. The principal activity represented again appears to have been pottery manufacture.

A total of 2590 bones were identified during the initial sorting as belonging to small mammals or birds, and these have been analysed in conjunction with the large mammalian fauna. Evidence from the large mammalian fauna, sediment stratigraphy, and pollen spectra indicates a coastal mangrove environment during the early occupation levels (zones A and B), and a marine regression resulting in freshwater swamp conditions, forest and grassland in later levels (zone C).

SKELETAL ELEMENTS, AGE AND SEX

The identifications were made using the osteological collections of the British Museum (Natural History), and the species in question are given in Table 36. Of the total 2590 bones, 25 per cent were from zone A, 17 per cent from zone B, and 58 per cent from zone C. Rats comprised more than half of the identified bones, with proportions decreasing steadily through time from zone A to zone C.

The great predominance of mandibles identified as otters and civets is unmatched by maxillae or post-cranial bones, even amongst the unidentified carnivores. This cannot be explained by preservation or size bias, as the tiny bones of rats were well represented. The rats also showed an interesting anomaly in zone B: whereas femora were the most frequently occurring bones in zones A and C, and outnumbered tibiae by 2:1, in zone B femora and tibiae were of roughly equivalent numbers (Table 35).

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TABLE 31: *The bird, small mammal and rare mammalian, amphibian and reptilian species identified at Khok Phanom Di*

<i>Crocodylus porosus</i> (Schneider, 1801)	saltwater crocodile or
<i>Crocodylus siamensis</i> (Schneider, 1801)	Siamese crocodile
frog sp.	
<i>Rhinoceros sondaicus</i> Desmarest, 1822	Javan rhinoceros
<i>Panthera tigris</i> (Linnaeus, 1758)	tiger
<i>Felis viverrina</i> Bennett, 1833	fishing cat
<i>Felis temmincki</i> Vigors and Horsfield, 1827	Asian golden cat
<i>Felis bengalensis</i> Kerr, 1792	leopard cat
<i>Felis marmorata</i> Martin, 1837	marbled cat
<i>Viverra zibetha</i> Linnaeus, 1758	large Indian civet
<i>Viverra megaspila</i> Blyth, 1862	large-spotted civet
<i>Paradoxurus hermaphroditus</i> (Pallas, 1777)	common palm civet
<i>Paguma larvata</i> (Hamilton-Smith, 1827)	masked palm civet
<i>Nycticebus coucang</i> (Boddaert, 1785)	slow loris
<i>Hystrix brachyura</i> Linnaeus, 1758	Malayan porcupine
<i>Hystrix hodgsoni</i> (Gray, 1847)	crestless Himalayan porcupine
<i>Aonyx cinerea</i> (Illiger, 1815)	small-clawed otter
<i>Lutra sumatrana</i> (Gray, 1865)	hairy-nosed otter
<i>Bandicota indica</i> (Bechstein, 1800)	great bandicoot
<i>Rattus rattus</i> (Linnaeus, 1758)	roof rat
<i>Grus antigone</i> Linnaeus, 1758	Sarus crane
<i>Ciconia</i> sp. Brisson, 1760	stork
<i>Phalacrocorax carbo</i> (Linnaeus, 1758)	cormorant
<i>Pelecanus</i> sp. Linnaeus, 1758	pelican
Threskiornithidae Richmond, 1917	ibis/spoonbill
<i>Phalacrocorax pygmaeus</i> Pallas, 1773	pygmy cormorant
<i>Mycteria leucocephala</i> (Pennant, 1769)	painted stork
<i>Anhinga</i> sp. Brisson, 1760	Oriental darter
<i>Limosa limosa/lapponica</i> Linnaeus, 1758	godwit
<i>Anas crecca</i> Linnaeus, 1758	teal
<i>Gallus gallus</i> Linnaeus, 1758	junglefowl/domestic fowl
<i>Corvus</i> sp. Linnaeus, 1758	crow
<i>Corydon sumatranus</i> Lesson, 1828	dusky broadbill
<i>Ardea sumatrana</i> (Raffles, 1822)	great-billed heron

Table 36 shows the minimum number of individuals for each species in the three zones, as well as information on age and sex (which could only be determined for a female leopard cat). Minimum numbers were calculated simply by the most frequently occurring element of left or right side (also taking age into account), age was estimated using dental attrition and epiphyseal fusion, and sex was

determined using the dimorphism exhibited by specimens in the British Museum (NH) collections.

The majority of mammals, birds and crocodiles were adults, advanced old age being evident only in the civets. Juveniles were represented amongst the fishing cat, civets and rats. Although juvenile and sub-adult rats outnumbered adults in all three zones, the relative proportions were similar in zones A and B, contrasting with the very high proportion of juveniles in zone C (Table 32).

TABLE 32: *Percentage of the number of rat specimens for which age was estimated in each zone*

	zone A	zone B	zone C
Adults	41	44	30
Juveniles and sub-adults	59	56	70

BUTCHERY, BURNING AND GNAWING

Obvious butchery marks were recorded on only three specimens, all in zone C: two chopped mandibles (one common palm civet and one hairy-nosed otter) and one tiger ulna apparently smashed for marrow extraction (Earl of Cranbrook, pers. comm.). Microscopic examination of all the bones would no doubt reveal more evidence of butchery, such as delicate knife marks, but this was not undertaken.

Only two species showed signs of burning: one small-clawed otter mandible in zone C was burnt black, and burnt rat bones were found in all three zones. Burnt black were:

1. zone A: 4 femora, 1 tibia, 1 mandible
2. zone B: 1 femur
3. zone C: 4 femora, 5 tibiae, 1 humerus, 1 mandible, 1 mandibular tooth.

White charring only occurred on rat bones in zone C: 1 femur, 4 tibiae, 1 humerus, 1 mandibular tooth.

Evidence for gnawing was noted in only one specimen: a civet calcaneus from zone C. The species responsible for it was not determined.

PATHOLOGY

Four instances of pathology were recorded: 3 civets and 1 roof rat.

1. Layer 10:2 *Rattus rattus* skull: the left maxillary first molar had been lost ante-mortem and the alveolus had become infected, as shown by the large area of resorption.

2. Layer 10:22 Civet species mandible: all the molars had been lost ante-mortem, with the alveoli badly healed, indicating periodontal disease and advanced age.
3. Layer 11:1 Civet species tibia: considerable deposition and resorption around the proximal shaft indicates a badly healed fracture.
4. Layer 5:2 *Paradoxurus hermaphroditus* mandible: the left mandibular first molar had been lost ante-mortem, with the alveolus partially healed. Deposition and resorption along all the alveoli suggests periodontal disease and advanced age (also severe attrition on the second molar).

MEASUREMENTS

Only the *Rattus rattus* skulls and mandibles were measured (see Fig. 41 for measurement positions, some of which are taken from Armitage *et al.* 1984). Measurable skulls were found only in zones

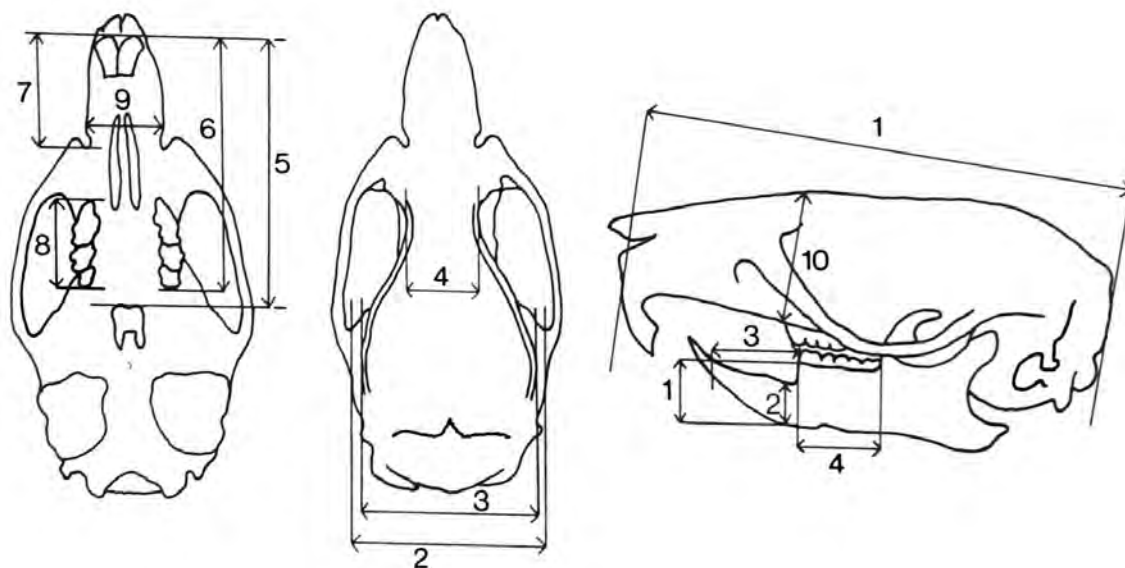


FIG. 41. *Rattus rattus* measurements for the skull and mandible

A and B (Table 33), and the means and range of mandibular measurements are listed in Table 34.

Although Table 34 shows an apparent decrease through time in the height of the mandible in front of the first molar (measurement 1), Fig. 42 shows that almost all the outlying points of both lower and upper ends of the scale are in zone C. Since this pattern is reflected in graphs of the other measurements, it suggests an extension in the range of sizes of rat hunted during the latest occupation represented by zone C, rather than a general size decrease. Comparative statistical studies using modern specimens and principal components analysis were beyond the scope of this report, but it is hoped that these may be undertaken in future by other researchers.

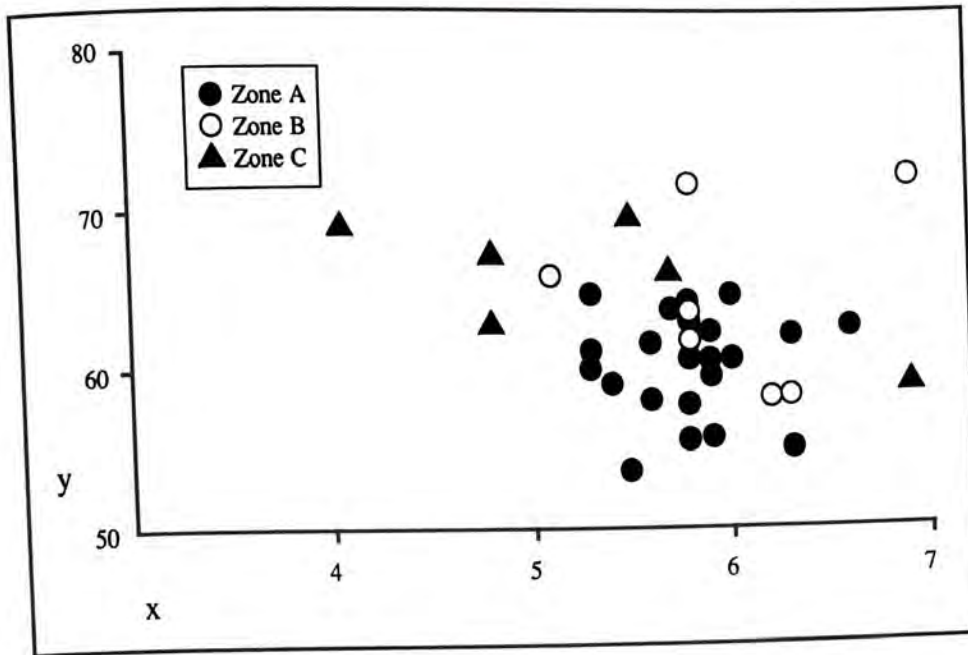


FIG. 42. The dimensions of *Rattus rattus* mandibles. X axis, measurement 1; Y axis, diastema index (measurement 2/measurement 3) x 100. See Fig. 41 for positions

ENVIRONMENTAL INDICATORS

Occurring exclusively in zones A and B are crocodile, slow loris, Sarus crane, stork, great-billed heron, pelican, ibis/spoonbill, cormorant, Oriental darter, ducks (including teal) and godwit. Figure 43 shows the changes through time of species and groups as distinct from all the others in a particular zone. For example, of all the crocodile bones recovered from the site, 83 per cent occurred in zone A and 17 per cent in zone B. The information on these species given below is taken from the following sources:

1. *Mammals*: Lekagul and McNeely 1977
2. *Birds*: Lekagul 1968; King *et al.* 1975; Thompson 1964; Campbell and Lack 1985
3. *Crocodiles*: Groombridge 1982

The largest extant crocodilian known is *Crocodylus porosus*, the estuarine or saltwater crocodile, attaining lengths of over 7m. Although it prefers brackish water such as coastal mangrove swamp-forest, some individuals have been known to swim hundreds of miles out to sea. One feeding tactic in estuaries is to swim close to the bank and curl the tail inwards to block the passage of fish, which are then caught by a sideways snap of the jaws.

The smaller Siamese crocodile (*Crocodylus siamensis*) attains lengths of up to 4m, preferring freshwater swamps off the main river course, and slow-moving streams with muddy banks. Unlike *C. porosus*, it is not aggressive and presents no danger to man, at least when fish are plentiful. The slow loris (*Nycticebus coucang*) is almost entirely arboreal, seldom being found on the ground, and

TABLE 33: *Rattus rattus* skull measurements. See Fig. 41 for positions

Layer	1	2	3	4	5	6	7	8	9	10
10:15 B107	-	-	-	-	-	-	-	6.9	-	-
10:12 B109	42.5	-	-	6.6	-	21.8	10.4	6.7	-	10.7
10:7	-	-	-	6.9	24.2	22.9	11.0	7.6	7.9	10.8
10:6 F38 B	-	-	-	-	-	-	-	6.7	-	-
10:6 B74	-	-	-	-	-	-	-	6.7	-	-
10:6	-	-	-	-	-	20.9	-	6.8	-	-
10:3 B56	42.0	-	-	6.8	-	20.8	9.0	-	8.0	10.1
10:3 B58	-	-	-	6.7	-	-	-	-	-	-
10:2	-	-	-	6.0	-	21.2	-	7.0	-	10.0
10:1	41.9	17.5	14.1	6.6	23.1	21.8	10.5	7.6	7.9	10.4
9:4	-	-	-	6.2	21.2	21.6	10.3	6.6	8.1	10.3
7:7 F1	-	-	-	-	-	21.4	10.9	6.7	7.8	9.9
6:2 F2	-	-	-	6.5	-	22.8	11.8	6.7	8.4	10.7

lives in primary or secondary forest, or in bamboo groves. Its diet consists of fruit, birds (especially nestlings), small mammals, lizards, large molluscs and insects. Although generally climbing slowly and deliberately, a loris can strike at insects with amazing speed, and climbs considerably faster when it is windy, thus giving rise to its Thai name 'wind monkey'.

The very large Sarus crane (*Grus antigone*) is found in swamps and marshy ground, probing for rhizomes in addition to taking crabs, insects, etc. It also browses on sedges and cereal crops. Storks (*Ciconia* sp. and others) prefer to hunt fish, frogs, snakes, etc. at ponds, marshes, river edges, and wet and dry fields. The painted stork (*Mycteria leucocephala*) is a very large bird bearing a striking plumage of pink, white and black, and the great-billed heron (*Ardea sumatrana*), another large fish eater, prefers mangroves, coastal islands and swamps. Pelicans (*Pelecanus* sp.) are fishing birds, frequenting lakes, rivers and sea coast. Ibis and spoonbills (*Threskiornithidae*) prefer shallow, calm, slow-moving waters in swamps, marshes and mangroves. Cormorants are aquatic fishing birds, catching fish by underwater pursuit. The cormorant (*Phalacrocorax carbo*), found only in zone A, prefers the open sea coast, unlike its much smaller relative, the pygmy cormorant (*Phalacrocorax pygmaeus*), found only in zones B and C, which prefers rivers, marshes and mangroves. The Oriental darter (*Anhinga* sp.) is also called the snakebird, because it swims with the body under and very long neck and head above water, appearing like a swimming snake. Fish and other prey are pursued underwater, speared in the flank, brought to the surface, tossed high in the air and then swallowed head first. Darters prefer sheltered inland, tidal and marine waters with no waves, and wooded shores for perching in trees. Two species of duck were found at Khok Phanom Di, one large (species undetermined) and one very small: the teal (*Anas crecca*) frequents marshes, estuaries and sea coasts. Godwits (*Limosa limosa/lapponica*) are tall long-legged waders inhabiting mudflats, marshes, estuaries and sea coasts.

TABLE 34: *Rattus rattus* mean mandible measurements. See Fig. 41 for positions

Measurement	N specimens measured	$\bar{X}$	Range	S.D.
zone A				
1	36	5.8	5.3-6.7	0.37
2	30	3.8	3.5-4.2	0.20
3	35	6.3	5.4-7.1	0.41
4	45	6.8	5.8-7.4	0.34
zone B				
1	9	5.9	5.1-6.9	0.53
2	7	4.0	3.8-4.9	0.41
3	7	6.2	5.3-6.7	0.53
4	14	6.9	6.6-7.2	0.24
zone C				
1	11	5.6	4.1-6.9	0.83
2	10	3.9	3.2-4.5	0.41
3	11	6.2	5.3-7.6	0.92
4	17	6.8	6.0-7.8	0.55

Occurring primarily in zone C (but also in small numbers in zones A and B) are cats, civets and otters, while tiger, porcupine, great bandicoot, crow and dusky broadbill are found only in zone C. Tigers (*Panthera tigris*), although found in a wide variety of habitats, are good swimmers and fond of water. They will eat almost any animal, including fish, insects, porcupines, other tigers and humans, but prefer deer and wild boar. The fishing cat (*Felis viverrina*) is a medium-sized cat frequenting river-banks, where it lies in wait on branches or rocks overhanging the water, using its partially webbed front paws to flip small fish out of the water and onto the bank behind. They also eat a variety of other animals, such as crabs, birds, freshwater molluscs and small mammals. Rather surprisingly, fishing cats are not particularly fond of swimming. The Asian golden cat (*Felis temmincki*) is slightly larger than the fishing cat, and is often found in drier habitats, such as dry deciduous forests. Also found in rainforests, it feeds upon birds, small deer, hares, lizards and other small animal prey. As can be seen from Table 36, at least eleven individuals of *Felis viverrina* were found at Khok Phanom Di, and the remaining eight *F. viverrina/temmincki* specimens probably also represent *F. viverrina*. The leopard cat (*Felis bengalensis*) commonly occurs in a wide variety of habitats, including the vicinity of villages. Small deer and other animals such as birds, rodents, lizards and amphibians form the regular diet of this small cat, which is so capable a swimmer that it has colonized offshore islands. In contrast, the marbled cat (*Felis marmorata*), is a rare jungle-dweller whose habits are very little known. Slightly smaller than the leopard cat, the marbled cat is thought to be nocturnal and arboreal, taking a variety of small animals. Since the only small cat identified to species was *F. bengalensis* (see Table 36), the four *F. bengalensis/marmorata* specimens probably also represent *F. bengalensis*.

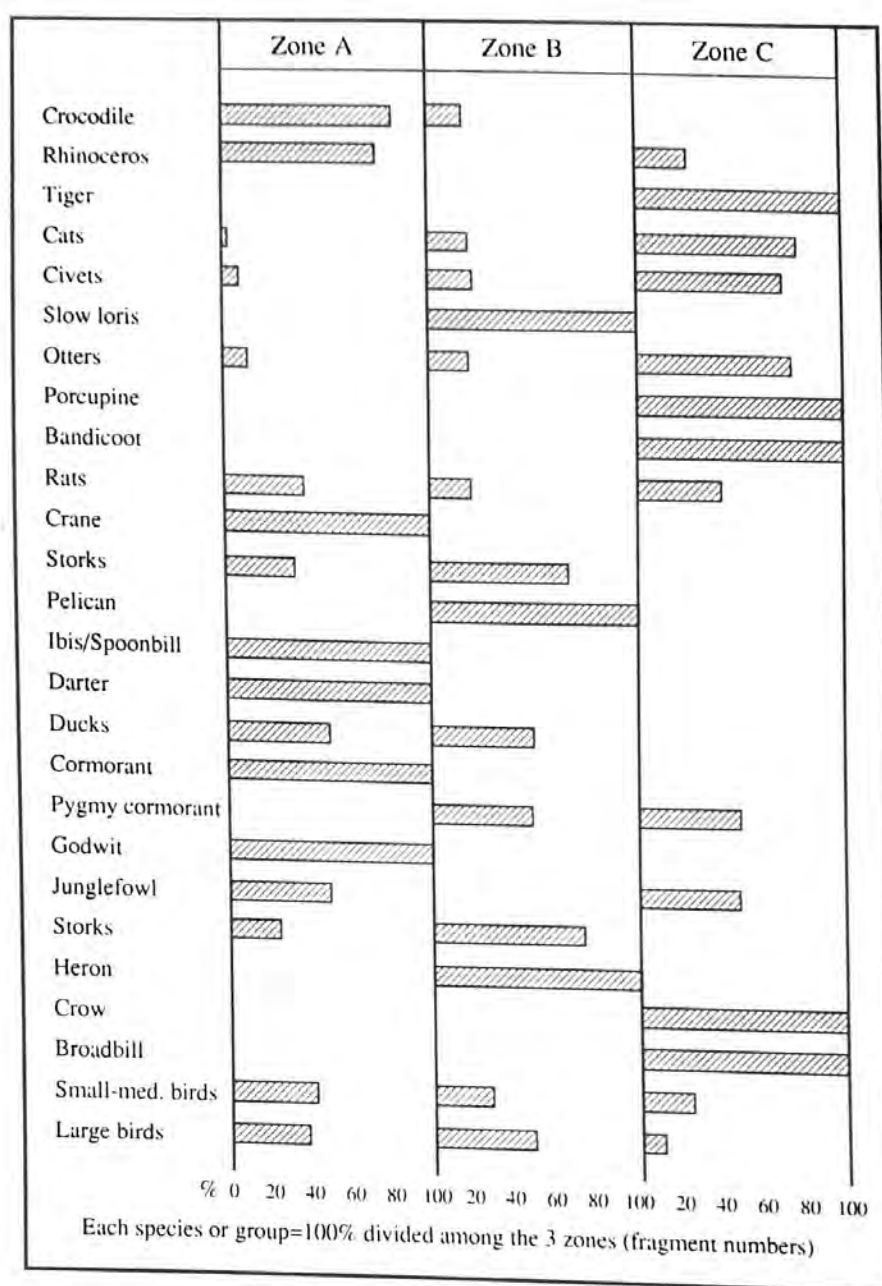


FIG. 43. The incidence of the different mammalian and bird species by zone

Turning to the civets, which are primarily forest-dwellers, both the large Indian civet (*Viverra zibetha*) and large-spotted civet (*Viverra megaspila*) are common in Thailand and frequently found near human dwellings, but knowledge of their habits is scanty. Prey includes small animals such as fish, crabs, amphibians, insects, lizards and birds.

Although only one individual masked palm civet (*Paguma larvata*) was identified (in zone C), the common palm civet (*Paradoxurus hermaphroditus*) was the most frequently occurring civet

from the site (see Table 36). Both these medium-sized civets have similar habits, being generally arboreal, with a diet of fruit, leaves, insects, molluscs and rodents.

Two species of otter were identified: two individuals of the hairy-nosed otter (*Lutra sumatrana*) and twenty-five individuals of the small-clawed otter (*Aonyx cinerea*). Although all otters are gregarious and chiefly aquatic, feeding on fish, frogs and invertebrates, they also hunt on land for rodents, rabbits and birds. Little information is available on the habits of the medium-sized *Lutra sumatrana*, except for reported sightings in coastal waters.

Much more is known of *Aonyx cinerea*, the smallest, stoutest otter in Thailand. Frequenting rivers, estuaries and sea coasts, they consume less fish and more crabs and molluscs than do other otters. They are sometimes trained by Malay fishermen to catch fish, and their consumption of destructive freshwater crabs is welcomed by rice farmers.

Porcupines (*Hystrix brachyura/hodgsoni*) are large, stout rodents widespread in all types of forest. Sometimes gnawing elephant tusks and animal bones for their mineral content, porcupines eat fruit, bark, tubers and roots.

A large, stout, blunt-nosed, commensal burrowing rat that is delicious to eat, the great bandicoot (*Bandicota indica*) has never been found in a purely natural habitat in Thailand. Although indigenous wild populations of the lesser bandicoot (*Bandicota savilei*) occur in forests and grasslands, no truly wild populations of great bandicoot have ever been discovered. This being the case, Lekagul and McNeely (1977) have concluded that it may have been brought to Thailand by humans at a comparatively recent date.

Two bird species were found only in zone C: crow and broadbill. Although crows are found in woodlands of all types, the crows of *Corvus* sp. generally prefer more open fields and grasslands (with the exception of the jungle crow (*Corvus macrorhynchos*)). Most crows are omnivorous, with a diet including insects, seeds, fruit, eggs, nestlings and carrion.

The dusky broadbill (*Corydon sumatranus*) is the only broadbill species known to be permanently gregarious, in noisy whistling groups of up to ten individuals. Strictly a forest canopy bird (unlike other broadbills which forage at mid-levels), it builds large untidy nests suspended from branches overhanging forest streams.

ENVIRONMENTAL INDICATORS: ANOMALIES

Whereas most species and groups were concentrated in either the early zones A and B, or the latest zone C, some were anomalous. Rats, for example, were present in roughly equal amounts in zones A and C, decreasing sharply in zone B (Fig. 43). Junglefowl were also present in equal amounts in zones A and C, disappearing altogether in zone B. Since all of the 104 rat mandibles and skulls were roof rat (*Rattus rattus*), the post-cranial bones are likely to represent roof rat as well. As the most abundant mammal in Thailand, occupying all habitats except mountain moss forest, roof rats are also present on all the islands and are excellent climbers and swimmers. Lekagul and McNeely (1977) emphasize that roof rat was the *only* rat species they could trap in mangrove swamps, where it was common.

Junglefowl, on the other hand, avoid alluvial plains and wet areas (Beebe 1921; Delacour 1977) and would not be expected to occur in either the mangroves of zones A and B or the swamp forest

areas of zone C, unless they were domesticated. Even the dry evergreen forest areas postulated for zone C might be too close to alluvium for the comfort of junglefowl.

The Javan rhinoceros (*Rhinoceros sondaicus*) also occurred only in zones A and C, and was represented only by teeth. This animal prefers dense rainforests with an abundance of water and mud wallows, and actively modifies the environment to suit its dietary needs. Its habit of uprooting trees (by leaning a shoulder against the tree and then walking over it as it gives way) slows down forest regeneration, creating suitable forage areas. The significance of these rhinoceros teeth is discussed in the conclusions.

Another interesting anomaly was found in the distribution of small-to-medium birds compared to very large birds in all zones (Fig. 43). The highest proportion of small-to-medium birds occurred in zone A, decreasing steadily in zones B and C. Although a substantial proportion of large birds occurred in zone A, the highest occurred in zone B, decreasing very sharply in zone C.

NATURAL DEPOSITS OR FOOD ITEMS ?

The fauna described previously begs the question: were these reptiles, mammals and birds actually eaten by the occupants of Khok Phanom Di, or were they naturally deposited on the site as part of the background fauna? In an attempt to answer this question, a search was made through the ethnographic literature on South-East Asia in the library of the British Museum's Department of Ethnography (Museum of Mankind), concentrating particularly on 'tribal' peoples of Malaysia, Thailand, Cambodia and Burma in a variety of habitats, rather than modern village settlements in which diet is more restricted. Although ritual and kinship structures were described in great detail in all these studies, precise information on species hunted and eaten was unfortunately patchy or non-existent. Different groups had different sets of animals considered taboo, but apart from these, the ethnographers' general implication was: 'They eat everything'.

Marshall (1922) did provide a few species names in explaining that the Karen people of Burma ate every sort of meat with relish, from elephant to rat, and all birds including crow. By far the most detailed descriptions were by Lewis (1970) on the Akha of Burma, in which he explains that they eat every sort of animal and bird except vulture and house swift (elephants, hornbills and big snakes are taboo). The variety of hunting methods is remarkable: different types of weapons, traps, nets, snares, decoys, birdlime and blinds. For example, they use several types of box traps for rats and mice; dead-fall traps for rodents large and small; spear traps for bear, deer and porcupine; snap-traps along tree branches frequented by squirrels, civets, monkeys and wild cats. Turtles are hunted by ramming metal poles into the lake mud. They will only kill and eat tigers or leopards if the animals attack them first. Not only do they hang the mandibles of all the wild animals they kill on the walls of their houses, but they also reassemble the bones of the animal as it was when alive, several times: after eating it in the forest, then again while placing it under the ancestral altar back in the village, etc.

No mention of crocodile hunting was found in any of these ethnographic studies. Medway (1959) also found no precedent for the eating of crocodiles in Indonesia or Malaya, although he pointed out that modern Dayaks occasionally eat crocodiles as a medicine, particularly for asthma.

Although no one can presume to impose the customs of modern tribal peoples on the inhabitants of Khok Phanom Di, these comparisons do at least serve to illustrate that the early inhabitants would

probably also have fully exploited their potential food resources, and that these faunal remains represent food debris rather than natural background deposits.

CONCLUSIONS

The habitat preferences of the fauna described above correlate very well with the evidence from the large mammalian fauna and the palynological data from Khok Phanom Di. Occurring exclusively in zones A and B are crocodile, slow loris, Sarus crane, stork, great-billed heron, pelican, ibis/spoonbill, cormorants, Oriental darter, duck (including teal) and godwit. As well as eating these birds, they may also have bartered the feathers, since bird plumage is a likely item within exchange networks in South-East Asia (Higham pers. comm.). The large feathers of birds such as the stork and the Sarus crane may have been highly prized, particularly for the beautiful pink, white and black plumage of the painted stork. All these species are associated with rivers, estuaries, marshes and coastal mangrove swamps. Cranes, storks, herons, ibis/spoonbills, Oriental darters and pygmy cormorants particularly prefer sheltered, slow-moving waters with no waves, rather than the open sea-coast. Occurring exclusively in zone C are tiger, porcupine, great bandicoot, crow and dusky broadbill – all species associated with drier conditions. Although the tiger is fond of water and is found in a wide variety of habitats, the porcupine and dusky broadbill are strictly creatures of the forest. The crow (except the jungle crow) and great bandicoot are found in more open areas such as rice paddies and grasslands.

Occurring primarily in zone C (but also in small numbers in zones A and B) are fishing cat, leopard cat, large Indian civet, common palm civet, masked palm civet, hairy-nosed otter and small-clawed otter. Although the palm civets are, as their name implies, generally arboreal, the large Indian civet is mainly terrestrial and includes fish in its diet. The leopard cat, hairy-nosed otter and small-clawed otters are all fond of water and excellent swimmers, but the fishing cat prefers to fish from above the water rather than actually in it.

Thus the habitat preferences of all these species suggest a local environment of sheltered, slow-moving waters in marshes and coastal mangrove swamp for zones A and B, and for zone C forest with at least one river or large stream nearby, and a few open areas such as paddy fields or grassland in the vicinity.

There were, of course, a few species which did not fit quite so neatly into the pattern hitherto described. These were the Javan rhinoceros, roof rat, junglefowl and the great bandicoot.

The Javan rhinoceros was represented only by teeth: in zone A, three teeth were placed with burial 120 and covered by ochre (unlike any other faunal remains from the site). In contrast, the single tooth in zone C was neither covered with red ochre, nor placed in a burial. Rhinoceros remains have been ritually associated with human burials elsewhere in South-East Asia, for example, at Niah in Sarawak the teeth of a Sumatran rhinoceros (*Dicerorhinus sumatrensis*) were found in one ochre-painted burial, and a rhinoceros radius had been placed as a pillow under the skull of another (Medway 1958, 1959). Although the Sumatran rhinoceros has previously been found in swamps and even swimming in the ocean, the Javan rhinoceros has not. Thus it must be assumed either that this animal was hunted further inland during the earliest phase at the site (zone A), and the teeth ritually deposited with the human burial, or that the teeth were obtained as talismans or symbolic items through an exchange network.

The roof rat was anomalous in that it appeared in roughly equal proportions in zones A and C, but decreased sharply in zone B. As discussed previously the roof rat is the most abundant mammal in Thailand and occupies all habitats including mangroves, so its presence in all three zones is no surprise. However, the sharp decrease in zone B was echoed in other categories of data: (1) whereas femora outnumbered tibiae by 2:1 in zones A and C, roughly equal proportions occurred in zone B; (2) whereas of all the rat bones with evidence of burning, zones A and C contained 27 per cent and 68 per cent respectively, while zone B contained only 5 per cent. This suggests that rats were exploited differently as a food source in zone B than in zones A and C.

The problem with junglefowl, on the other hand, is that they should not be on the site at all. As explained, junglefowl avoid alluvial plains and wet areas and would not be expected to occur in either the mangroves of zones A and B, or the swamp forest areas of zone C, and perhaps not even in the dry evergreen forest areas of zone C – unless they were either domesticated or hunted very much further inland, well away from the alluvium. Unfortunately, the bones are insufficiently complete to ascertain domestication positively. Fowl domestication at such an early date in Thailand is entirely feasible, given recent evidence presented by West and Zhou (1988).

The occurrence of great bandicoot in zone C is very interesting, in the light of Lekagul and McNeely's (1977) conclusion that it must have been brought to Thailand by humans at a comparatively recent date, because no truly wild populations of great bandicoot have ever been found in Thailand. It appears to be entirely commensal.

HUNTING PATTERNS

Having established from ethnographic parallels that the early inhabitants of Khok Phanom Di would probably have exploited their potential food resources as fully as their modern counterparts, and that these faunal remains represent food debris rather than natural background deposits, we can attempt to postulate some of their hunting patterns.

Zone A: during the earliest period of occupation represented by zone A, the inhabitants hunted a variety of birds of all sizes, in addition to very large birds of marsh and mangrove such as Sarus crane, stork, ibis/spoonbill, Oriental darter, and smaller ones such as duck and godwit. In the mangrove area, crocodiles, along with large numbers of roof rats, were obtained. Juvenile rats were preferred to adults, and the lower hind legs were often apparently discarded off the site. From a nearby river, they occasionally obtained fishing cat and small-clawed otter and, either by travelling further inland or exchange, they obtained remains of the rhinoceros (also used in burial rites), civets and possibly junglefowl in very small numbers. There is evidence that they kept domestic dogs and possibly chickens.

Zone B: during the next phase of occupation represented by zone B, they continued to exploit birds of all sizes, including marsh, mangrove and coastal birds such as painted stork, great-billed heron, pelican, pygmy cormorant and teal. The greatest exploitation of very large birds occurred at this time. In the mangrove area, there was a sharp decrease in crocodile (found only in the earliest level of zone B) and roof rats. Proportions of juvenile to adult rats were similar to that in zone A, and the lower hind legs were apparently no longer discarded. In the latest phases of zone B, there was a definite shift toward greater exploitation of animals from the river and from the forest further inland (unless the forest was advancing with the marine regression), such as the slow loris,

fishing cat, leopard cat, common palm civet and small-clawed otter. The large Indian civet and hairy-nosed otter make their first appearance during this phase of the site. Chicken/junglefowl are undetectable in this zone.

Zone C: a dramatic change in hunting patterns occurred during the latest levels represented by zone C. There is a decrease in the hunting of small-to-medium sized birds, and a marked decrease in large birds. Large birds of marsh and mangrove disappear from the site (along with crocodile), to be replaced by birds of the forest, such as chicken/junglefowl and dusky broadbill, and birds frequenting more open areas of field and grassland, such as crow.

Tiger, porcupine and great bandicoot now appear on the site, and there is a great increase in not only animals which enter the mangrove, but also forest, riverine and grassland animals such as fishing cat, leopard cat, common palm civet and small-clawed otter. Rat trapping also greatly increases, and is similar to that practised in zone A, in that the lower hind legs are often apparently discarded; however, the extremely high proportion of juvenile rats contrasts with the patterns in zones A and B. Measurements indicate that the range of sizes of rats hunted was greatly expanded. Of the smaller mammals, the favourite prey of hunters during this phase are fishing cat, common palm civet, small-clawed otter and roof rat.

In conclusion then, the evidence for environment and diet gained from the small mammalian and avifauna correlates remarkably well with the evidence from the large mammalian, shellfish, fish, crab, ostracode, phytolith and pollen remains.

TABLE 35: *The distribution of bones by species and zone*

Zone A	Sku	Max	Man	Tee	Scp	Cla	Cor	Hum	Rad	Uln	Inn
<i>Crocodylus porosus/</i> <i>siamensis</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Rhinoceros sondaicus</i>	-	-	-	3	-	-	-	-	-	-	-
Frog sp.	-	-	-	-	-	-	-	1	-	-	-
<i>Felis viv./temmincki</i>	-	-	1	-	-	-	-	-	-	-	-
Civet sp.	-	-	2	1	-	-	-	2	-	-	-
<i>Aonyx cinerea</i>	-	-	3	-	-	-	-	-	-	-	-
<i>Rattus rattus</i>	13	2	50	-	-	-	-	-	-	-	-
<i>Rattus</i> sp.	1	11	2	4	-	-	-	14	1	-	19
<i>Grus antigone</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Ciconia</i> sp.	-	-	-	-	-	-	-	-	-	-	-
Threskiornithidae	-	-	-	-	-	-	-	-	-	-	-
<i>Anhinga</i> sp.	-	-	-	-	-	-	-	1	-	-	-
<i>Gallus gallus</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Limosa limosa/lapponica</i>	-	-	-	-	-	-	1	-	-	-	-
Duck sp.	-	-	-	-	-	-	-	-	-	1	-

Zone A	Fem	Tib	Fib	Mtc	Cal	Ast	Mtt	Mtp	Pha	Ver
<i>Crocodylus porosus/</i> <i>siamensis</i>	-	-	-	1	-	-	2	-	1	1
<i>Rhinoceros sondaicus</i>	-	-	-	-	-	-	-	-	-	-
<i>Felis viv./temminki</i>	-	-	-	-	-	-	-	-	-	-
Civet sp.	-	1	-	-	-	-	-	-	-	-
<i>Aonyx cinerea</i>	-	-	-	-	-	-	-	-	-	-
<i>Rattus rattus</i>	-	-	-	-	-	-	-	-	-	-
<i>Rattus</i> sp.	159	64	-	-	-	-	-	-	-	-
<i>Grus antigone</i>	-	3	-	-	-	-	-	-	-	-
<i>Ciconia</i> sp.	1	-	-	-	-	-	-	-	-	-
Threskiornithidae	-	-	-	-	-	-	2	-	-	-
<i>Anhinga</i> sp.	-	-	-	-	-	-	-	-	-	-
<i>Gallus gallus</i>	1	-	-	-	-	-	-	-	-	-
<i>Limosa limosa/lapponica</i>	-	-	-	-	-	-	-	-	-	-
Duck sp.	-	-	-	-	-	-	-	-	-	-
<i>Phalacrocorax carbo</i>	-	-	-	-	-	-	1	-	-	-

The distribution of bones by species and zone (cont.)

Zone B	Sku	Max	Man	Tee	Scp	Cla	Cor	Hum	Rad	Uln	Inn
<i>Crocodylus porosus/</i>											
<i>siamensis</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Felis viverrina</i>	-	-	-	-	-	-	-	1	-	-	-
<i>Felis viv./temminki</i>	-	-	-	1	-	-	-	1	-	1	-
<i>Felis beng./marmorata</i>	-	-	-	-	-	-	-	1	-	-	-
<i>Felis sp.</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Viverra zibetha/megaspila</i>	-	-	-	2	-	-	-	-	-	-	-
<i>Paradoxurus hermaphroditus</i>	-	-	3	1	-	-	-	-	-	-	-
<i>Civet sp.</i>	-	-	1	1	1	-	-	-	-	-	1
<i>Aonyx cinerea</i>	-	2	2	1	-	-	-	-	1	1	-
<i>Lutra sumatrana</i>	-	-	-	1	-	-	-	-	-	-	-
<i>Nycticebus coucang</i>	1	-	-	-	-	-	-	-	-	-	-
<i>Rattus rattus</i>	3	-	14	-	-	-	-	-	-	-	-
<i>Rattus sp.</i>	-	5	2	5	-	-	-	18	4	1	7
<i>Ciconia sp.</i>	-	-	-	-	-	-	1	-	-	-	-
<i>Stork sp.</i>	-	-	-	-	-	-	-	1	-	-	-
<i>Pelecanus sp.</i>	-	-	-	-	-	-	1	-	-	-	-
<i>Phalacrocorax pygmaeus</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Anas crecca</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Mycteria leucocephala</i>	-	1	-	-	-	-	-	-	-	-	-

Zone B	Fem	Tib	Fib	Mtc	Cal	Ast	Mtt	Mtp	Pha	Ver	Uni
<i>Crocodylus porosus/</i>											
<i>siamensis</i>	-	-	-	-	-	-	-	-	1	-	-
<i>Felis viv./temminki</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Felis beng./marmorata</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Felis sp.</i>	-	1	-	-	-	-	-	-	-	-	-
<i>Viverra zibetha/megaspila</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Paradoxurus hermaphroditus</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Civet sp.</i>	1	-	-	-	-	-	-	-	-	-	-
<i>Aonyx cinerea</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Lutra sumatrana</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Rattus sp.</i>	56	47	-	-	-	-	-	-	-	1	-
<i>Ciconia sp.</i>	-	-	-	-	-	-	1	-	-	-	-
<i>Stork sp.</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Pelecanus sp.</i>	-	-	-	-	-	-	-	-	-	-	-
<i>Phalacrocorax pygmaeus</i>	1	-	-	-	-	-	-	-	-	-	-
<i>Anas crecca</i>	-	-	-	1	-	-	-	-	-	-	-
<i>Ardea sumatrana</i>	-	-	-	-	-	-	1	-	-	-	-

The distribution of bones by species and zone (cont.)

[illegible][illegible]

TABLE 36: The species identified, showing the number of individuals (N), ages and sexes

Species	zone A	zone B	zone C	N
<i>Crocodylus porosus/siamensis</i>	3 ad	1	-	4
<i>Rhinoceros sondaicus</i>	2 (1 ad)	-	1 ad	3
frog sp.	-	-	1	1
<i>Panthera tigris</i>	-	-	1 ad	1
<i>Felis viverrina</i>	-	2 (1 ad)	9 (6 ad, 1 j)	11
<i>Felis viverrina/temmincki</i>	1	1	6	8
<i>Felis bengalensis</i>	-	-	1 ad fe	1
<i>Felis bengalensis/marmorata</i>	-	1	3	4
<i>Felis</i> sp.	-	1	2 (1 ad)	3
<i>Viverra zibetha</i>	-	1 j	-	1
<i>Viverra zibetha/megaspila</i>	-	1	-	1
<i>Paradoxurus hermaphroditus</i>	-	3 (1 j, 1 old ad)	18 (2 ad)	21
<i>Paguma larvata</i>	-	-	1	1
Civet sp.	5 (1 ad, 1 old ad)	5 (2 ad, 1 ya)	11 (5 ad, 1 j)	21
<i>Nycticebus coucang</i>	-	1	-	1
<i>Hystrix brachyura/hodgsoni</i>	-	-	1 ad	1
<i>Aonyx cinerea</i>	3 ad	6 ad	16 (13 ad)	25
<i>Lutra sumatrana</i>	-	1 ad	1 ad	2
<i>Lutra</i> sp.	-	-	2 (1 ad)	2
Otter sp.	-	-	1	1
<i>Bandicota indica</i>	-	-	6 (1 ad, 3 ya)	6
<i>Rattus rattus</i>	58 (41 ad, 14 ya, 1 j)	17 (11 ad, 6 ya)	16 (9 ad, 3 ya)	91
<i>Rattus</i> sp.	140 (19 ad, 30 sa, 77 j)	90 (23 ad, 1 ya, 9 sa, 43 j)	67 (7 ad, 44 j)	297
<i>Grus antigone</i>	2 ad	-	-	2
<i>Ciconia</i> sp.	1 ad	1 ya	-	2
Stork sp.	-	1 ad	-	1
<i>Pelecanus</i> sp.	-	1 ad	-	1
Threskiornithidae	1 ad	-	-	1
<i>Mycteria leucocephala</i>	-	1	-	1
<i>Phalacrocorax pygmaeus</i>	-	1 ad	1 ad	2
<i>Phalacrocorax carbo</i>	1	-	-	1
<i>Anhinga</i> sp.	1 ad	-	-	1
<i>Limosa limosa/lapponica</i>	1 ad	-	-	1
<i>Anas crecca</i>	-	1 ad	-	1
Duck sp.	1 ad	-	-	1
<i>Gallus gallus</i>	1 ad	-	1 ad	2
<i>Corvus</i> sp.	-	-	1 ad	1
<i>Corydon sumatranus</i>	-	-	1 ad	1
<i>Ardea sumatrana</i>	-	1 ad	-	1

TABLE 37: *The post-cranial bones identified, showing their provenance, age and anatomical details*

layer	No.	Bone	Part	Age	Side	Fusion prox. dist.	layer	No.	Bone	Part	Age	Side	Fusion prox. dist.		
<i>Crocodylus porosus/siamensis</i>															
10:17	1	cdv	-	-	-	-	10:22	1	mtt	p	-	-	-		
10:22	1	mtt	d	-	-	-	10:22	1	mtc	p	-	-	-		
10:3	1	pha	-	-	-	-	9:7	1	pha	-	-	-	-		
Frog sp.															
4:3	1	hum	-	a	l	f	-								
Duck sp.															
10:4	1	uln	p	a	r	f	-								
<i>Anas crecca</i>															
8:2	1	mtc	-	a	r	f	f								
<i>Gallus gallus</i>															
10:9	1	fem	p	a	l	f	f	2:2	1	fem	p	a	l	f	-
<i>Anhinga sp.</i>															
10:13	1	hum	d	a	r	-	f								
<i>Corydon sumatranus</i>															
5:1	1	uln	p	a	r	f	-								
<i>Limosa limosa/lapponica</i>															
10:13	1	cor	-	a	l	f	f								
<i>Corvus sp.</i>															
4:1	1	fem	-	a	l	f	f								
<i>Phalacrocorax pygmaeus</i>															
9:4	1	fem	-	a	r	f	f								
4:1 F7	1	mtt	d	l	-	f	-	4:1 F7	1	mtt	-	a	r	f	f
4:1 F7	1	tib	d	a	l	-	f	4:1 F7	1	tib	-	a	r	f	f
4:1 F7	1	scp	d	a	r	-	f	4:1 F7	1	uln	p	a	l	f	-
4:1 F7	1	cor	-	a	l	f	f	4:1 F7	1	hum	p	a	l	f	-
4:1 F7	1	hum	d	a	l	-	f	4:1 F7	1	fem	-	a	l	f	f
<i>Phalacrocorax carbo</i>															
10:21 F25	1	mtt	d	-	r	-	f								
Threskiornithidae															
10:13	1	mtt	p	a	-	f	-	10:13	1	mtt	d	a	r	-	f
<i>Pelecanus sp.</i>															
9:5	1	cor	p	a	r	f	-								
Stork															
9:7	1	hum	d	-	r	-	-								

The post-cranial bones identified (cont.)

Layer No.	Bone	Part	Age	Side	Fusion prox. dist.	Layer No.	Bone	Part	Age	Side	Fusion prox. dist.
<i>Ciconia</i> sp.											
10:13	1	fem	d	a	r - f	7:5	1	cor	-	a	l f f
7:5	1	mtt	p	ya	r vc -						
<i>Grus antigone</i>											
10:18 F3	1	tib	p	a	l f -	10:17	1	tib	d	a	l - f
10:15	1	tib	d	a	r - f						
cf. <i>Ardea sumatrana</i>											
8:3 B47	1	mtt	d	a	r - f						
<i>Aonyx cinerea</i>											
6:4	1	uln	-	a	- f -	6:4	1	rad	-	a	- f f
4:2	1	uln	p	a	r f -	4:1	1	hum	d	a	r - f
<i>Civet</i> sp.											
3:4	2	hum	d	-	l - f	5:2	1	inn	-	a	l - -
4:2	1	hum	d	-	r - f	4:2	1	cal	-	a	l f -
4:5	1	fem	-	a	r f f	10:26	1	hum	d	-	r - f
5:1	1	scp	d	a	l - f	3:1	1	hum	d	-	r - f
3:1	1	cal	-	j	l vo -	7:6	1	fem	p	ya	r vc -
4:1	1	uln	p	-	l - -	11:1	1	hum	d	-	r - f
11:1	1	tib	-	-	l - f	3:4	1	hum	d	-	r - f
3:4	2	cal	-	a	r f -						
<i>Felis</i> sp.											
5:1	1	tib	d	-	l - f	3:4	1	hum	d	-	r - f
3:4	1	hum	s	-	r - -	2:2	1	cal	-	a	r f -
<i>Felis bengalensis</i> or <i>Felis marmorata</i>											
3:3	1	hum	s	-	r - -	7:7	1	hum	d	-	r - f
<i>Felis viverrina</i> or <i>Felis temmincki</i>											
2:2	2	ast	-	-	b - -						
<i>Felis viverrina</i>											
3:2	1	hum	d	a	l - f	7:2	1	hum	s	a?	r - -
4:2	1	uln	s	-	l - -	2:2	1	tib	d	j	r - vo
2:2	1	hum	s	-	r - -	2:2	1	scp	d	a	l - f
3:1	1	hum	d	-	r - f	3:2	1	hum	s	-	r - -
6:7	1	uln	p	-	r - -	6:8 F3	1	hum	d	-	r - f
<i>Panthera tigris</i>											
4:1	1	uln	ps	a?	l - -						

The post-cranial bones identified (cont.)

Layer No.	Bone	Part	Age	Side	Fusion prox. dist.	Layer No.	Bone	Part	Age	Side	Fusion prox. dist.				
<i>Rattus sp.</i>															
10:22	1	tib	p	j	l	u	-	10:22	1	fem	-	a	l	f	f
10:22	1	fem	-	j	r	-	-	10:21	1	tib	p	j	l	u	-
10:21	1	fem	d	j	-	-	u	10:21	1	fem	d	sa	-	-	vc
10:21	1	fem	s	-	l	-	-	10:21	1	fem	p	sa	l	vc	-
10:21	1	fem	-	sa	r	-	vc	10:21	1	hum	-	j	-	u	f
10:20	1	fem	d	sa	l	-	vc	10:19	1	fem	-	a	r	f	f
10:19	1	tib	-	j	l	u	f	10:18	117	inn	-	-	r	-	-
10:18	1	fem	d	j	-	-	u	10:18	1	fem	-	sa	l	vc	vc
10:18	1	fem	-	j	r	u	u	10:18	1	fem	d	sa	r	-	vc
10:17	1	fem	p	j	l	u	-	10:17	1	fem	-	j	l	vo	u
10:17	2	tib	-	j	r	u	f	10:16	1	fem	-	sa	r	vc	vc
10:15 B128	1	tib	p	j	r	u	-	10:15 B128	1	hum	p	sa	r	vc	-
10:15	1	tib	p	j	r	u	-	10:15	1	fem	p	sa	-	vc	-
10:15	1	fem	p	sa	l	vc	-	10:15	1	fem	d	sa	l	-	vc
10:15	1	fem	p	sa	l	vc	-	10:15	1	fem	-	sa	l	-	vc
10:15	1	fem+pat	d	sa	r	-	vc	10:15	1	fem	-	sa	r	-	vc
10:15	1	fem	-	j	r	u	u	10:15 B131	1	fem	p	a	l	f	-
10:15 B107	1	fem	-	j	r	f	u	10:15 B107	1	fem	p	j	l	vo	-
10:15 B107	1	fem	-	a	l	f	f	10:14	1	tib	p	j	r	u	-
10:14	3	tib	p	j	l	u	-	10:14	2	fem	d	j	-	-	u
10:14	1	fem	p	sa	l	vc	-	10:14	2	fem	-	sa	l	vc	vc
10:14	1	fem	s	-	r	-	-	10:14	1	fem	d	sa	r	-	vc
10:14	1	fem	p	sa	r	vc	-	10:14	1	fem	-	j	r	vc	u
10:14	2	fem	-	j	r	u	u	10:14	2	inn	-	-	l	-	-
10:14	2	inn	-	-	r	-	-	10:14 B120	1	fem	d	j	-	-	u
10:14 B120	1	hum	-	j	l	u	f	10:14	1	tib	d	-	-	-	f
10:13 F30	1	fem	-	sa	l	vc	f	10:13	1	fem	-	sa	l	f	vc
10:13	1	inn	-	-	l	-	-	10:13	1	hum	-	sa	r	vc	f
10:13	1	tub	s	-	-	-	-	10:13	1	tib	-	j	l	u	f
10:13	1	tib	p	j	r	u	-	10:13	1	tib	pe	j	r	u	-
10:13	2	fem	d	j	-	-	u	10:13	2	fem	d	a	r	-	f
10:13	1	fem	-	sa	r	vc	vc	10:13	1	fem	-	j	r	vc	u
10:13	1	fem	-	sa	l	vc	vc	10:13	1	fem	p	j	l	u	-
10:13	1	fem	s	-	l	-	-	10:13	1	fem	-	j	l	u	u
10:13 B112	1	fem	d	sa	r	-	vc	10:13 B112	1	fem	p	sa	l	vc	-
10:13 B112	1	tib	p	j	l	u	-	10:13 B112	1	hum	d	-	l	-	f
10:13 B112	1	tib	d	-	-	-	f	10:13 B112	1	hum	p	j	r	u	-
10:12 B87	1	fem	-	j	l	u	u	10:12 B87	1	inn	-	a	l	-	-
10:12 B87	1	tib	d	-	l	-	f	10:12 B87	1	fem	-	a	l	f	f
10:12 B109	1	fem	-	j	r	-	vo	10:12	1	fem	-	j	l	f	u

The post-cranial bones identified (cont.)

Layer No.	Bone	Part	Age	Side	Fusion prox. dist.	Layer No.	Bone	Part	Age	Side	Fusion prox. dist.				
10:12 B109	1	fem	-	j	r	-	vo	10:12	1	fem	-	j	l	f	u
10:12	1	fem	p	sa	l	vc	-	10:12	1	inn	-	-	l	-	-
10:12	1	hum	d	-	r	-	f	10:12	2	tib	d	-	-	-	f
10:12	1	tib	p	j	l	u	-	10:12	1	tib	p	j	r	u	-
10:12	1	tib	p	j	r	u	-	10:12	2	fem	d	sa	-	-	vc
10:12	1	fem	p	sa	r	vc	-	10:12	1	fem	p	j	r	u	-
10:12	1	fem	d	j	r	-	u	10:12	1	fem	d	j	r	-	u
10:12	1	fem	-	j	r	vc	vo	10:12	1	fem	d+e	j	l	-	u
10:12	1	fem	d	a	l	-	f	10:12	1	fem	-	j	l	u	u
10:11 B102	1	fem	-	sa	l	vc	vc	10:11 B102	1	fem	d	a	r	-	f
10:11 B97	1	fem	p	a	r	f	-	10:11 B102	1	tib	p	j	r	u	-
10:11 B97	1	tib	-	a	r	f	f	10:11 B97	1	fem	d	a	r	-	f
10:11	1	rad	p	-	-	f	-	10:11	1	inn	-	j	r	-	-
10:11	1	tib	-	-	r	-	u	10:11	1	fem	d	j	-	-	u
10:11	2	fem	d	sa	-	-	vc	10:11	1	fem	p	j	r	u	-
10:11	1	fem	p	sa	r	vc	-	10:11	3	fem	-	j	l	vc	u
10:11	1	fem	-	sa	l	vc	vc	10:10	1	fem	p	sa	r	vc	-
10:10	1	fem	-	a	r	f	f	10:10	2	fem	-	j	r	f	u
10:10	2	fem	-	j	l	u	u	10:10	2	fem	-	sa	l	f	vc
10:10	3	tib	d	-	-	-	f	10:10	1	tib	s	-	-	-	-
10:10	3	tib	p	j	l	u	-	10:10	2	tib	p	j	r	u	-
10:10	2	hum	-	j	l	u	f	10:10	1	hum	d	-	l	-	f
10:10	2	inn	-	-	l	-	-	10:10	1	inn	-	-	l	-	-
10:10	2	inn	-	-	r	-	-	10:10	1	hum	p	j	r	u	-
10:10 F1	1	fem	p	a	r	f	-	10:10 F25	1	tib	-	j	l	vo	f
10:10 B123	1	fem	d	a	-	-	f	10:9	1	fem	-	a	l	f	f
10:9	1	fem	-	j	l	u	u	10:9	1	fem	p	-	r	f	-
10:9	1	fem	d	j	r	-	u	10:8	1	fem	-	a	l	-	f
10:8	1	fem	-	sa	l	vc	vc	10:8	1	hum	-	sa	l	vc	f
10:8	1	fem	-	j	r	-	u	10:8	1	hum	-	sa	l	vc	f
10:8	1	fem	-	j	r	-	u	10:8	1	fem	-	j	r	vc	u
10:8 B90	1	fem	-	j	r	vc	u	10:8	1	fem	-	j	r	vc	u
10:7	1	tib	d	-	l	-	f	10:7	1	fem	-	j	l	u	u
10:7	1	fem	d	sa	r	-	vc	10:7	1	fem	-	j	r	u	u
10:7 B72	1	fem	p	j	r	u	-	10:7 B72	1	fem	d+e	j	l	-	u
10:7 B72	1	tib	-	j	l	u	f	10:7	1	hum	-	sa	r	vc	f
10:7	1	fem	-	j	l	u	-	10:7	1	fem	d	j	-	-	u
10:7	1	inn	-	-	l	-	-	10:7 B74	1	tib	p	j	r	u	-
10:7	1	fem	-	sa	l	vc	vc	10:6	1	inn	-	-	r	-	-
10:6	1	inn	-	-	l	-	-	10:6	1	tib	d	-	-	-	f

The post-cranial bones identified (cont.)

Layer	No.	Bone	Part	Age	Side	Fusion prox.	dist.	Layer	No.	Bone	Part	Age	Side	Fusion prox.	dist.
10:6	2	tib	p	j	l	u	-	10:6	1	tib	p	j	r	u	-
10:6	1	tib	-	j	r	u	f	10:6	1	fem	d	sa	l	-	vc
10:6	1	fem	d	sa	r	-	vc	10:6	1	fem	-	j	l	f	u
10:6	1	fem	p	j	r	u	-	10:6	1	tib	p	j	l	u	-
10:6	1	tib	-	j	r	u	f	10:6	1	fem	-	j	l	vo	vo
10:6 B64	1	fem	-	j	r	u	u	10:5	1	fem	-	j	r	u	u
10:5	1	fem	s	-	r	-	-	10:5	1	fem	-	j	l	u	vc
10:5	1	tib	p	j	r	vo	-	10:4	1	fem	-	sa	l	-	vc
10:4	1	fem	d	sa	r	-	vc	10:4	1	fem	p	a	r	f	-
10:4	1	fem	-	sa	r	vc	vc	10:4	2	tib	p	j	l	u	-
10:4	2	tib	-	j	r	u	f	10:4 B57	1	fem	-	j	l	vc	vo
10:4	1	tib	p	j	r	u	-	10:4 B57	1	fem	-	sa	r	vc	vc
10:4 B57	1	fem	p	sa	l	vc	-	10:4 B60	1	tib	p	j	l	u	-
10:4 B60	1	fem	-	j	l	vc	u	10:4	1	fem	d	j	-	-	u
10:4 B60	1	fem	d	j	-	-	u	10:3	1	tib	-	j	l	u	f
10:3 B58	1	fem	d	sa	l	-	vc	10:3	1	inn	-	-	l	-	-
10:3	1	tib	-	j	l	u	f	10:3	1	fem	p	j	r	u	-
10:3	1	fem	-	sa	r	vc	vc	10:3 L2	1	hum	p	j	-	u	-
10:3	1	fem	p	sa	l	vc	-	10:3 L2	1	fem	-	j	l	u	u
10:3 L2	1	fem	d	sa	r	-	vc	10:3 B58	1	tib	d	-	r	f	-
10:3 B58	1	tib	p	j	l	u	-	10:3 B58	1	tib	p+e	u	l	u	-
10:3 B58	1	fem	d	j	r	-	vo	10:2	1	tib	p+e	j	r	u	-
10:2	1	tib	p	j	r	u	-	10:2	1	fem	-	sa	r	f	vc
10:2	2	fem	-	j	r	u	u	10:2	1	fem	p	j	r	u	-
10:2	1	fem	d	j	-	-	u	10:1	1	fem	-	sa	l	f	vc
10:1	1	fem	d+e	j	r	-	vo	10:1	1	fem	d	a	-	-	f
10:1	1	fem	d	j	-	-	u	10:1	2	tib	p	j	r	u	-
10:1	1	lfem	p	a	l	f	-	10:1 F41	1	fem	d	j	-	-	u
10:1 B57	1	fem	-	sa	r	-	vc	9:7	1	tib	-	a	l	f	f
9:7	1	fem	-	j	l	vc	u	9:7	1	inn	-	-	r	-	-
9:7	1	hum	d	-	r	-	-	9:7	1	hum	-	j	l	u	f
9:6	1	tib	-	j	l	u	f	9:6	1	fem	p	a	l	f	-
9:5	1	fem	d	sa	l	-	vc	9:5	1	tib	p	j	r	u	-
9:5	1	tib	d	-	-	-	f	9:4	1	fem	d	j	-	-	u
9:4	1	fem	-	sa	l	vc	vc	9:4	1	hum	-	j	r	u	f
9:4	1	rad	-	j	-	f?	u	9:4 F37	1	fem	-	j	r	u	u
9:4	1	fem	-	j	r	vc	u	9:3	1	tib	d	-	l	-	f
9:3	1	fem	d	j	-	-	u	9:3	1	inn	-	-	l	-	-
9:2	11	tib	-	j	l	u	-	9:2	1	fem	-	j	r	vc	u
9:1	1	tib	-	j	l	u	f	8:7	1	rad	-	j	-	f	u

The post-cranial bones identified (cont.)

Layer No.	Bone	Part	Age	Side	Fusion prox. dist.	Layer No.	Bone	Part	Age	Side	Fusion prox. dist.			
8:7 F4	1	fem	-	a	l	f	8:7 B38	1	fem	d	a	r	-	f
8:7	1	hum	p	sa	r	vc	8:7	1	uln	p	a	l	f	-
8:7	1	rad	d	j	-	-	8:7	1	fem	-	j	l	vc	u
8:7	1	fem	d	sa	l	-	8:7	1	axi	-	-	-	-	-
8:5 B130	1	fem	-	j	r	u	8:4	1	fem	-	sa	l	vc	vc
8:3	1	tib	d	-	l	-	8:2 B45	1	fem	p	sa	r	vc	-
8:2 B45	1	fem	d	j	-	-	8:1	1	fem	p	-	l	f	-
8:1	1	fem	-	a	r	f	8:1	1	inn	-	-	l	-	-
8:1	1	rad	p	j	-	u	8:1	1	hum	d	-	l	-	f
8:1	1	hum	p	a	l	f	8:1	1	tib	p+e	j	r	u	f
8:1	1	tib	d	-	r	-	8:1	1	tib	p	a	r	f	-
8:1	1	fem	s	-	l	-	7:7 F1	1	fem	-	a	r	f	f
7:6 B21	1	fem	d	j	r	-	7:6 B21	1	fem	p	sa	r	vc	-
7:6 F13	1	hum	d	-	l	-	7:6 B36	1	fem	p	j	l	u	-
7:5	1	tib	p	j	r	u	7:5	1	fem	p	a	l	f	-
7:5 F35	1	fem	-	sa	r	vc	7:5	1	fem	d	a	-	-	f
7:5	1	fem	-	j	l	u	7:4	2	fem	-	a	r	f	f
7:4	2	inn	-	-	r	-	7:4	1	hum	-	j	r	u	f
7:2 B15	1	fem	d	a	l	-	7:2 B15	1	fem	d+e	j	l	-	u
7:2	1	fem	-	a	r	f	7:1	1	fem	-	a	l	f	f
7:1	1	fem	-	j	r	f	7:1	1	hum	d	-	r	-	f
6:8	1	hum	-	j	r	u	6:7 F19	1	tib	-	j	l	u	f
6:5 B13	1	hum	p	a	l	f	6:5 B13	1	fem	d	a	l	-	f
6:5 B13	1	fem	-	j	r	u	6:5 F45	1	fem	-	a	l	f	-
6:4	1	tib	p	j	l	u	6:4	1	tib	p	a	r	f	-
6:4	1	tib	p	j	r	u	6:4	1	hum	d	-	l	-	f
6:4 F2	1	tib	d	-	-	-	6:4	1	fem	d	j	-	-	u
6:4 F13	1	fem	p	j	l	u	6:4 F2	1	tib	d	-	-	-	f
6:4 F13	1	fem	d	j	-	-	6:3 F60	1	fem	-	a	r	f	f
6:3 B9	1	hum	-	j	r	u	6:3 F23	1	fem	p	a?	l	f?	-
6:3 F23	1	fem	d	j	-	-	6:3 B3	1	tib	p	j	l	u	-
6:2	2	hum	-	j	r	u	6:2	1	tib	p	j	l	u	-
6:2	1	tib	s	-	-	-	6:2	1	fem	-	j	l	f	u
6:2	1	fem	-	j	r	f	6:2 B4	1	tib	d	-	l	-	f
6:2	1	fem	-	j	r	f	6:2 F2	1	fem	-	sa	r	f	vc
6:1	1	inn	-	-	r	-	6:1	1	fem	-	j	r	u	u
6:1	1	inn	-	-	r	-	6:1	1	fem	-	j	r	u	u
5:5	1	fem	d	a	l	-	5:4	1	fem	-	a	r	f	f
5:4	1	tib	p	j	l	u	5:4	1	tib	-	a	r	f	f
5:2	1	fem	p	j	l	u	5:2	1	hum	-	j	l	u	f

The post-cranial bones identified (cont.)

Layer	No.	Bone	Part	Age	Side	Fusion prox. dist.	Layer	No.	Bone	Part	Age	Side	Fusion prox. dist.
5:2	1	fem	de	j	l	- u	5:2	1	hum	p	sa	l	vc -
5:2	1	tib	d	-	-	- f	5:1	1	tib	p	j	l	u -
5:1	2	tib	s	-	-	- -	5:1	1	hum	s	-	-	- -
5:1	1	tib	p	j	r	u -	5:1	1	fem	p	j	r	u -
5:1	1	fem	-	a	r	f f	4:5	1	fem	+de	j	l	f u
4:5	1	inn	-	-	l	- -	4:5	1	hum	d	-	l	- f
4:5 F5	1	hum	d	-	l	- f	4:4	1	fem	-	j	l	u u
4:4	1	fem	-	j	l	j u	4:4	1	fem	s	-	l	- -
4:4	1	tib	p	j	r	u -	4:3	1	inn	-	-	l	- -
4:3	1	hum	-	j	r	u f	4:3	1	hum	-	j	l	u f
4:3	1	hum	-	a	l	f f	4:3	1	fem	d+e	j	-	- u
4:3	1	fem	-	j	r	- u	4:3	1	fem	-	j	l	u u
4:3	1	fem	p	-	l	f -	4:3	2	fem	-	j	l	f u
4:2	2	tib	s	-	r	- -	4:2	2	tib	s	-	r	- -
4:2	1	inn	-	-	r	- -	4:2	1	hum	-	j	l	u f
4:2	1	hum	s	-	r	- -	4:2	1	hum	d	-	r	- f
4:2	1	fem	d	a	-	- f	4:2	1	fem	p	j	r	u -
4:2	1	fem	s	-	r	- -	4:2	1	fem	p	-	r	f -
4:2	1	fem	p	a	l	f -	4:2	3	fem	s	-	l	- -
4:2	1	fem	s	-	l	- -	4:2	1	fem	-	j	l	u u
4:2	4	fem	p	j	l	u -	4:2	1	tib	p	j	l	u -
4:2	1	uln	p	a	-	f u	4:2	1	inn	-	-	r	- -
4:1	1	fem	d	a	-	- f	4:1	1	tib	d	-	-	- f
4:1	1	tib	p	j	l	u -	4:1	1	hum	d	-	-	- -
4:1	1	fem	p	j	r	u -	4:1	1	fem	s	-	r	- -
4:1	1	tib	s	-	r	- -	4:1	1	tib	p	j	r	u -
4:1	1	fem	s	-	l	- -	4:1	1	fem	d	j	-	- u
4:1	1	fem	p	j	r	u -	4:1	2	fem	p	j	r	u -
4:1 F1	1	fem	-	j	l	u u	4:1 F1	1	fem	p	j	l	u -
4:1 F1	1	hum	d	-	l	- f	4:1 F1	1	hum	d	-	r	- f
4:1	1	hum	p	j	-	u -	4:1	1	hum	d	-	r	- f
4:1	1	hum	-	j	l	u f	4:1	1	fem	p	a	l	f -
4:1	1	fem	p	j	l	u -	4:1	1	fem	-	j	l	u u
4:1	1	fem	-	j	r	u u	4:1	1	fem	s	-	r	- -
4:1	1	tib	-	j	r	u f	4:1	1	tib	d	-	l	- f
4:1 F7	1	fem	-	j	l	u u	4:1	2	inn	-	-	l	- -
4:1	1	cal	-	a	-	- f	4:1	1	fem	de	j	l	- u
4:1	1	fem	p	j	l	u -	4:1	1	fem	p	a	l	f -
4:1	1	scp	d	-	l	- -	4:1	1	scp	d	-	r	- -
4:1	1	uln	p	a	r	f -	4:1	1	fem	p	j	l	u -

The post-cranial bones identified (cont.)

Layer No.	Bone	Part	Age	Side	Fusion prox. dist.			Layer No.	Bone	Part	Age	Side	Fusion prox. dist.		
3:5	1	fem	s	-	l	-	-	3:4	1	hum	-	j	r	u	f
3:4	1	tib	p	j	r	u	-	3:4	1	fem	-	j	r	vo	u
3:4	1	tib	d	-	-	-	f	3:4	1	inn	-	-	l	-	-
3:4	1	fem	d	a	-	-	f	3:3	1	hum	d	-	-	-	-
3:3	1	tib	p	j	l	u	-	3:3	1	tib	p	j	r	u	-
3:3	1	fem	p	j	r	u	-	3:3	2	fem	p	j	l	u	-
3:3	1	fem	d	j	-	-	u	3:3	2	fem	p	j	l	u	-
3:3	1	fem	d	j	l	-	u	3:3	1	fem	-	j	l	f	u
3:3	3	fem	p	j	r	u	-	3:3	2	fem	-	j	r	u	u
3:3	2	hum	d	-	r	-	f	3:3	1	tib	p	j	l	u	-
3:3	1	fem	d	a	r	-	f	3:3	3	fem	d	j	-	-	u
3:2	1	fem	s	-	l	-	-	3:2	2	fem	p	j	l	u	-
3:2	2	fem	p	j	l	u	-	3:2	1	fem	p	j	r	u	-
3:2	5	fem	p	j	r	u	-	3:2	2	fem	p	-	r	f	-
3:2	2	hum	d	-	r	-	f	3:2	3	hum	d	-	l	-	f
3:2	1	hum	-	j	l	u	f	3:2	1	tib	p	j	l	u	-
3:2	1	tib	p	j	r	u	-	3:2	1	tib	p	j	r	u	-
3:2	1	tib	s	-	-	-	-	3:2	1	fem	d	a	-	-	f
3:1	1	tib	p	j	l	u	-	3:1	1	tib	d	-	r	-	f
3:1	1	hum	s	-	l	-	-	3:1	1	uln	p	j	r	u	-
3:1	1	tib	d	-	r	-	f	3:1	2	tib	p	j	r	u	-
3:1	1	tib	s	-	r	-	-	3:1	2	fem	d	j	-	-	u
3:1	1	fem	d	j	-	-	u	3:1	2	fem	s	-	l	-	-
3:1	1	fem	d	j	l	-	u	3:1	1	fem	-	j	l	u	u
3:1	3	fem	s	-	r	-	-	3:1	1	fem	p	-	r	-	-
3:1	1	fem	-	j	r	u	u	3:1	2	inn	-	-	l	-	-
3:1	3	inn	-	-	r	-	-	3:1	2	fem	p	a	l	f	-
3:1	1	fem	p	j	l	u	-	3:1	2	fem	-	j	l	u	u
3:1	1	hum	s	-	-	-	-	3:1	1	hum	d	-	l	-	f
3:1	1	hum	d	-	r	f	-	3:1	1	hum	d	-	r	-	f
3:1	1	inn	-	-	l	-	-	3:1	1	tib	d	-	-	-	f
3:1	4	tib	d	-	-	-	f	3:1	1	tib	s	-	-	-	-
3:1	1	tib	s	-	r	-	-	3:1	1	tib	p	j	r	u	-
3:1	1	tib	-	j	r	u	f	3:1	4	tib	p	j	l	u	-
3:1	1	tib	s	-	l	-	-	3:1	1	fem	p	j	-	u	-
3:1	2	fem	p	j	r	u	-	3:1	1	fem	p	a	r	f	-
2:2	2	tib	d	-	-	-	f	2:2	1	tib	p	j	r	u	-
2:2	1	tib	p	j	r	u	-	2:2	1	hum	s	-	l	-	-
2:2	1	fem	d	j	-	-	u	2:2	1	fem	p	j	l	u	-
2:2	1	fem	d	j	-	-	u	2:2	1	fem	-	j	r	u	u
2:2	1	fem	s	-	l	-	-	2:2	1	fem	-	j	l	u	u

TABLE 38: *The mandibular and maxillary dentition of small mammals*

Layer No.	Bone	Age	Side	Tooth eruption	Layer No.	Bone	Age	Side	Tooth eruption		
<i>Felis viverrina</i>											
10:3	1	man	-	r	C ₁ , P ₃ , P ₄ , M ₁	8:3 F28	1	man	a	l	C ₁ , P ₃ -M ₁
6:1	1	mnt	-	r	P ₁	4:3 F7	1	mnt	a	l	M ₁
4:3	1	man	a	r	P ₃ , P ₄ , M ₁	4:1	1	max	a	r	C ¹ , P ³ , P ⁴
3:5	1	man	-	r	-	3:5	1	mnt	-	-	P
3:2	1	man	-	r	P ₄	3:2	1	man	-	r	-
3:1	1	mnt	-	l	C ₁	3:1	1	man	-	r	P ₄
3:1	1	max	a	l	P ⁴	2:2	1	man	a	l	P ₃ , P ₄
<i>Felis viverrina</i> or <i>Felis temminki</i>											
10:3	1	man	-	r	C ₁ , P ₃ -M ₁	6:1	1	mnt	-	r	P ₁
3:5	1	man	-	r	-	3:5	1	mnt	-	-	P
3:2	1	man	-	r	-	3:2	1	man	-	r	P ₄
3:1	1	man	-	r	P ₄	3:1	1	mnt	-	l	C ₄
<i>Felis bengalensis</i>											
4:1	1	man	a	l	M ₁	-	-	-	-	-	-
<i>Felis bengalensis</i> or <i>F. marmorata</i>											
3:3	1	man	-	l	-	3:2	1	man	-	r	-
2:2	1	man	-	l	M ₁	2:2	1	man	-	l	P ₃ , P ₄
<i>Viverra zibetha</i>											
7:1	1	mnd	j	l	P ₄ dec.	-	-	-	-	-	-
<i>Viverra zibetha</i> or <i>V. megaspila</i>											
9:2	1	mxt	-	l	P ⁴	-	-	-	-	-	-
<i>Paradoxurus hermaphroditus</i>											
5:5	1	mnt	-	r	M ₁	5:3	1	man	-	-	-
5:3	1	man	j	l	P ₄	5:2	1	man	o	l	P ₃ , M ₂
4:3 F5	1	man	a	r	P ₃₋₄	4:3 F7	1	man	-	l	-
4:3	1	man	-	l	-	4:3 F7	1	man	-	r	-
4:2	1	man	-	l	-	4:2	1	max	-	r	-
4:1	1	man	-	l	P ₄ , M ₁	4:1	1	man	-	r	P ₃
3:4	1	man	-	r	-	3:3	1	mnt	-	r	P ₄
3:3	1	man	a	l	P ₄ , M ₂	3:3	1	man	-	r	P ₃ , P ₄ , M ₁
3:3	1	man	-	l	P ₂	3:3	1	man	-	r	-
3:2	1	man	-	l	-	3:2	1	man	-	r	-
3:2	1	man	-	l	-	3:2	1	man	-	r	-
3:1	1	man	-	l	-	3:1	5	man	-	r	-
2:3	1	man	-	l	-	2:2	1	man	-	l	-
2:2	2	man	-	r	-	-	-	-	-	-	-
<i>Paguma larvata</i>											
3:1	1	man	-	r	-	-	-	-	-	-	-

The mandibular and maxillary dentition of small mammals (cont.)

Layer No.	Bone	Age	Side	Tooth eruption	Layer No.	Bone	Age	Side	Tooth eruption
<i>Nycticebus coucang</i>									
5:3 B12	1	skl	a	- P ³⁻⁴	-	-	-	-	-
<i>Paradoxurus hermaphroditus</i> or <i>Paguma larvata</i>									
4:2	1	mxt	a	r P ⁴	4:2	2	man	a	l -
2:2	1	man	-	l -	-	-	-	-	-
<i>Paradoxurus hermaphroditus</i> or <i>Cynogale bennetti</i>									
5:4	1	man	-	r -	4:1	1	man	-	l -
<i>Civet sp.</i>									
10:6	1	mnt	a	l P ₄	5:3 B12	1	mxt	-	l M ¹
11:1	1	man	-	r -	10:22	1	man	o	l -
4:2	2	tth	-	- -	4:1	1	tth	-	- -
<i>Hystrix brachura</i> or <i>Hystrix hodgsoni</i>									
3:3	1	mxt	a	- P ⁴ or M ³	-	-	-	-	-
<i>Aonyx cinerea</i>									
10:13	1	man	a	r M ₁ , M ₂	10:12	1	man	a	l P ₃₋₄ , M ₁
10:3	1	man	a	l C ₁ , P ₄ , M ₁ , M ₂	7:5	1	man	a	r M ₁
6:3	1	max	a	b C ₁ , P ₁₋₃ , M ¹	6:1 L1	1	man	a	l I ₂ - M ₂
5:4	1	mnt	a	r M ₁	5:3	1	max	a	r P ⁴ , M ¹
4:4	1	man	a	l M ₁	4:3 F7	1	mnt	a	r M ₁
4:2 F2	1	man	-	r -	4:2	2	man	-	l -
4:2	1	max	a	r P ³ , M ¹	3:4	1	man	a	l P ₃₋₄
3:3	1	man	-	l -	3:3	1	mnt	a	r M ₁
3:3	1	man	-	l P ₄	3:2	2	man	a	l -
3:2	1	man	a	l P ₄ , M ₁	3:1	1	man	-	l -
3:1	2	man	a	r -	3:1	1	mnt	a	l M ₁
2:3	1	man	a	l -	2:3	1	man	a	l -
2:3	1	man	a	r P ₃	2:3	1	man	a	r -
2:2	1	man	-	l -	2:1	1	man	-	- -
2:2	1	man	-	r M ₁	2:2	1	max	a	l P ₄ , M ₁
<i>Lutra sumatrana</i>									
6:3	1	mnt	a	r M ₁	3:5	1	man	a	l C ₁ , P ₂ - M ₁
<i>Lutra sp.</i>									
4:2	1	pmx	a	r I ¹⁻²	2:2	1	man	-	- -
<i>Otter sp.</i>									
3:3	1	man	-	- -	-	-	-	-	-

The mandibular and maxillary dentition of mammals (cont.)

Layer No.	Bone	Age	Side	Tooth eruption	Layer No.	Bone	Age	Side	Tooth eruption
<i>Bandicota indica nemorivaga</i>									
4:3	1	mnt	-	r I	4:1	1	man	ya	l I ₁ , M ₁₋₃
3:3	1	mnt	-	l I	3:3	1	mxt	-	l I
3:1	1	man	ya	l M ₁₋₂	2:3	1	man	a	r M ₁
2:3	1	mxt	-	r I	2:3	1	mnt	-	l I
2:3	1	mnt	-	r I	2:3	1	max	ya	r M ²
<i>Rhinoceros sondaicus</i>									
10:14 B120	1	mnt	-	r M ₁ or 2	10:14 B120	1	mnt	-	r M ₃
4:4 F1	1	mxt	a	r p ³	-	-	-	-	-
<i>Rhinoceros sondaicus</i> or <i>Dicerorhinus sumatrensis</i>									
10:14 B120	1	tth	-	-	-	-	-	-	-
<i>Rattus</i> sp.									
10:15 B107	1	max	-	b I ₁ , I ₁	10:13	1	tth	-	-
10:12 B87	1	man	a	r I ₁	10:12 B87	1	skl	a	b L ¹ , M ¹⁻³
10:10	1	skl	-	b I ¹ -I ¹	10:6	1	max	a	r M ¹⁻²
10:6	1	mxt	-	- I ¹	10:6	1	man	-	l I ₁
10:6	1	max	a	r M ¹⁻³	10:6	1	pmx	-	r I ¹
10:6	1	mxt	-	l I ¹	10:6	1	skl	-	b I ₁ , I ₁
10:5	1	max	-	r I ₁	10:4	1	max	-	r I ¹
10:3	1	max	a	r M ¹⁻²	10:3	1	pmx	-	l I ¹
10:3	1	pmx	-	r I ¹	10:3 B58	1	mnt	-	- I ₁
10:3	1	man	-	r I ₁	10:3 B56	1	max	-	l I ₁
10:1	1	pmx	-	r I ¹	10:1	1	max	a	r M ¹⁻³
8:7	1	max	a	r M ¹	8:7	1	pmx	-	r I ¹
8:7	1	tth	-	- I	8:7	1	max	a	l M ¹⁻³
8:3	1	max	a	l M ¹⁻³	8:2	1	man	ya	l M ₂₋₃
7:5	1	man	a	r M ₁	7:2	1	max	-	r I ₁
5:3	1	mxt	-	- I ₁	4:5 F5	2	mnt	-	- I
4:5	1	man	a	r M ₁₋₂	4:5	1	man	ya	l M ₁
4:5 F5	1	mxt	-	l M ¹	4:4	1	mnt	-	- I
4:3	1	man	-	l -	4:2	1	mnt	-	- I
4:2	1	mnt	-	r I	4:1 F7	1	man	a	r I ₁ , M ₂₋₃
4:1	7	mnt	-	- I	4:1	1	mnt	-	- I
4:1	4	mnt	-	- I	3:5	1	man	a	r M ₁₋₂
3:5	1	mnt	-	- I	3:4	1	man	a	r M ₁
3:4	3	mxt	-	- I	3:4	6	mnt	-	- I
3:3	1	mxt	-	- I	3:3	9	mnt	-	- I
3:3	1	man	-	- M ₁	3:3	2	mnt	-	-
3:2	1	man	-	r I	3:2	1	mxt	-	- I
3:2	4	mnt	-	- I	3:1	4	mxt	-	- I
3:1	11	mnt	-	- I	2:3	1	mxt	-	- I
2:3	4	mnt	-	- I	2:2	3	mxt	-	- I
2:2	2	mnt	-	- I					

TABLE 39: *The Rattus mandibles and dimensions. See Fig. 41 for positions*

Layer	Age	Side	1	2	3	4	Layer	Age	Side	1	2	3	4
10:22	a	r	5.9	4.0	6.7	7.2	10:18	a	l	6.3	4.1	6.6	6.8
10:18	ya	r	6.0	-	5.9	6.5	10:17	ya	l	5.6	-	6.2	6.8
10:5 B100	a	r	-	-	-	5.8	10:14	a	l	6.0	3.7	6.1	7.0
10:14	a	r	-	-	-	7.0	10:14	a	r	6.5	4.0	-	7.0
10:14	a	r	6.6	4.0	-	7.3	10:14 B120	ya	l	5.8	-	6.2	6.9
10:14 B120	ya	r	5.8	-	6.2	6.9	10:14 B132	a	r	-	4.0	5.9	6.8
10:13	a	r	5.7	-	5.7	-	10:13	a	r	5.7	3.9	6.1	7.1
10:13	a	r	-	-	6.6	-	10:13	a	r	5.9	3.8	6.1	7.0
10:13	a	r	5.6	3.5	5.7	6.4	10:13 B113	ya	r	-	-	-	6.9
10:13 B112	ya	l	-	-	-	6.8	10:13 B112	ya	r	-	-	-	6.5
10:13 B112	ya	l	-	3.9	-	6.9	10:12	a	r	6.0	4.0	6.2	7.1
10:12	a	l	-	-	6.9	-	10:12	ya	l	5.4	3.9	6.6	7.3
10:12 B109	a	r	5.4	-	-	6.4	10:11	j	r	5.3	3.6	6.0	6.8
10:10	ya	l	5.6	3.6	6.2	6.6	10:10	ya	r	5.8	3.9	6.1	7.1
10:10	a	l	-	-	6.4	7.2	10:10	a	l	-	-	6.3	6.8
10:10	a	r	5.8	3.7	6.1	6.7	10:10	a	r	-	3.9	5.9	7.1
10:8	a	l	6.6	4.2	6.7	6.7	10:8	ya	l	5.9	3.8	6.8	7.0
10:7 B72	ya	l	5.3	3.6	5.9	6.3	10:7	a	r	5.4	3.5	-	6.3
10:7	ya	l	5.8	4.2	6.6	7.4	10:6	a	r	5.8	3.7	-	6.4
10:6	a	r	6.0	-	6.2	6.5	10:5	a	l	5.3	3.5	5.4	6.8
10:5	ya	r	5.7	-	5.4	6.9	10:3 B58	a	l	5.5	3.7	6.9	7.0
10:3 B58	a	r	5.4	-	-	7.0	10:3 L2	a	l	6.7	3.9	-	7.4
10:3 L2	a	r	6.3	3.9	7.1	6.2	10:3	a	l	5.8	3.8	6.6	7.0
10:2 B77	a	l	5.9	4.0	6.6	6.5	10:1	a	r	5.8	3.5	6.3	6.6
9:7	ya	l	5.7	3.8	-	7.2	8:7	ya	l	6.2	3.9	6.7	7.1
8:1	a	r	5.8	-	6.1	6.9	7:7	ya	l	-	-	-	6.6
7:6	a	r	-	-	-	7.4	7:5	a	r	6.2	3.9	-	6.8
7:2	ya	l	5.1	3.7	5.6	7.0	7:2	a	r	5.8	3.9	6.3	7.0
7:2 B15	a	r	-	-	-	6.6	7:2 B15	a	r	5.8	3.8	5.3	6.7
6:4	ya	l	-	-	-	7.2	6:2 F2	a	r	-	-	6.5	7.0
5:3	a	r	6.9	4.9	6.6	6.7	5:2	j	l	5.3	-	-	6.9
4:5	ya	r	6.3	4.2	7.2	7.8	4:1	a	l	-	-	-	6.0
4:1 F7	a	l	5.8	3.8	6.0	6.6	4:1	a	l	-	-	-	6.5
4:1	a	r	-	-	6.5	-	4:1	a	r	6.5	-	7.3	7.1

The Rattus rattus mandibles and dimensions (cont.)

Layer	Age	Side	1	2	3	4	Layer	Age	Side	1	2	3	4
4:1	-	r	-	-	-	6.0	3:1	a	l	4.8	4.1	6.1	7.4
4:1 F7	-	r	-	4.1	5.5	6.6	3:1	a	r	5.5	3.5	-	6.6
3:1	-	r	-	-	-	6.8	3:1	a	r	5.5	3.7	5.3	7.0
3:1	ya	r	4.8	3.4	5.4	6.3	3:1	a	l	-	-	-	6.8
3:1	a	l	-	-	-	6.7	3:1	ya	l	4.1	3.2	4.7	6.4
2:2	a	l	6.9	4.5	7.6	7.5	2:2	-	r	6.2	-	-	7.8
2:2	-	r	5.7	4.1	6.2	-							

The following abbreviations have been used: ad, adult; ast, astragalus; axi, axis; b, both; C, canine, followed by number; cal, calcaneus; cdv, caudal vertebra; cla, clavicle; cor, coracoid; d, distal; de, distal epiphysis; d+e, distal shaft and detached epiphysis; fe, female; fem, femur; fib, fibula; hum, humerus; I, incisor; inn, innominate; j, juvenile; l, left; M, molar, followed by number; man, mandible; max, maxilla; mnd, mandibular deciduous tooth; mnt, mandibular tooth; mtc, metacarpal; mtp, metapodial; mtt, metatarsal; mxt, maxillary tooth; o, old; P, premolar, followed by number; p+e, proximal shaft and detached epiphysis; pe, proximal epiphysis; pha, phalanges; pmx, premaxilla; r, right; rad, radius; S.D., standard deviation; s, shaft; sa, sub-adult; scp, scapula; sku, skull; tee, teeth; tib, tibia; tth, tooth; u, unfused; uln, ulna; uni, unidentified; ver, vertebrae; f, fused; vc, epiphyseal line visible but closed; vo, epiphyseal line visible and open; ya, young adult.

XIV. THE REMAINS OF FISH, CRABS AND TURTLES

By Amphan Kijngam

THE analysis of the fish remains from Khok Phanom Di was undertaken in the laboratory of the Anthropology Department, University of Otago. A small comparative collection was assembled from Bang Pakong Valley sources to assist in the identification of the bones to species.

PLOTOSIDAE

Plotosus canius Hamilton, 1822

Only two species of the genus *Plotosus* are found in Thailand, *Plotosus lineatus* (Thunberg, 1791) and *Plotosus canius* Hamilton, 1822. They are known in the vernacular as *Pla duk*. They are primarily marine dwellers, but are particularly common in estuarine situations and are occasionally found in fresh water. In the Bang Pakong Valley, *Pl. canius* is found in the estuary, the lower reaches of the river and high enough to be adaptive to freshwater conditions. They are currently caught by net or line, specimens of *Pl. canius* attaining up to 75cm in length (Smith 1945:354). In addition to the bones set out in Table 40, there are the following dorsal spines: layer 10, 227; layer 9, 54; layer 8, 34; layer 7, 8; layer 6, 23; layer 5, 23, layer 4, 97; layer 3, 176 and layer 2, 27.

TABLE 40: *The distribution of the remains of Plotosus canius*

Bone	Layer	n (right)	n (left)	Layer	n (right)	n (left)
Dentary	11	1	4	10	191	214
	9	105	112	8	24	29
	7	15	15	6	5	5
	5	2	3	4	23	13
	3	16	21	2	5	4
Pectoral spine	11	1	1	10	213	197
	9	75	65	8	46	41
	7	19	17	6	14	26
	5	22	23	4	65	71
	3	120	111	2	25	26

CENTROPOMIDAE

Lates calcarifer (Bloch, 1790)

This anadromous species, known as *Pla kapong*, is adapted to marine conditions, entering estuaries in March and April up to and including fresh water to spawn. This movement occurs prior to the onset of the monsoon. Smith (1945:478) has recorded specimens weighing between 1 and 30kg, but it is now unusual, perhaps due to over fishing, to encounter fish weighing over 6kg in the Bang Pakong River. They are caught by line or trap, nets being of little use because the sharp fins of these fish damage them. Because the smaller fish feed in coastal waters, the fishery in southern Thailand is active for ten months of the year. The distribution of this species throughout the site is shown in Table 41.

OPHICEPHALIDAE

Channa sp.

There are eight species of *Channa* in Thailand, with habitats ranging from mountain streams to lakes, ponds and swamps. All are edible, the commonest in the diet being *Ophicephalus striatus* Bloch, 1797 (*Pla chon*). This species can attain a length of about a metre, and is usually caught with a hook or in a bamboo trap. During the dry season, as the surface water dries out, this species has the capacity to bury itself in soft mud and thereby survive until the following wet season commences. *Channa* are still caught in the vicinity of Khok Phanom Di by hooks, nets and traps.

CLARIIDAE

Clarias sp.

Catfish of the genus *Clarias* are widespread in mainland South-East Asia, *Clarias batrachus* (Linnaeus, 1758) (*Pla duk dam*) and *C. macrocephalus* Günther, 1864 (*Pla duk uey*) being among the commonest food fish in the area. They can survive for lengthy periods without water provided their respiratory apparatus remains moist. The former has been found in rivers, canals, lakes, swamps and ricefields, the latter is particularly adaptive to ricefields. The villagers of Khok Phanom Di employ hooks, nets and traps to obtain them. The specimens set out in Table 43 are probably *C. macrocephalus*, a species which grows to about 30cm in length.

ANABANTIDAE

Anabas testudineus (Bloch, 1792)

The anabantids are widespread in such fresh-water habitats as large streams, canals, ditches, lakes, ponds, swamps and ricefields. Again, they are able to survive dessication through possession of a suprabranchial cavity. *Anabas testudineus* (*Pla mor*) is one of the staple food fish of Thailand

TABLE 41: *The distribution of the remains of Lates calcarifer*

Bone	Layer	n (right)	n (left)	Layer	n (right)	n (left)
Dentary	11	7	6	10	244	249
	9	67	58	8	69	60
	7	26	36	6	10	10
	5	7	9	4	13	15
	3	29	20	2	4	7
Premaxilla	11	0	1	10	107	120
	9	18	18	8	20	31
	7	15	19	6	4	14
	5	3	3	4	10	14
	3	31	25	2	7	13
Maxilla	11	6	1	10	98	97
	9	26	28	8	32	21
	7	15	15	6	2	4
	5	3	3	4	11	5
	3	14	17	2	6	4
Articular	11	14	12	10	194	167
	9	47	47	8	52	57
	7	23	25	6	6	14
	5	2	5	4	7	9
	3	12	19	2	5	2
Quadrate	11	3	1	10	107	104
	9	25	18	8	29	26
	7	13	22	6	11	5
	5	7	4	4	5	8
	3	13	17	2	1	4

and is today caught in the vicinity of the site with nets, traps and sometimes with hook and line. It is rare in prehistoric contexts at the site (Table 44).

BAGRIDAE

There are four genera and fifteen species of this catfish family. Most are found in canals, streams and rivers. Some species particularly favour estuarine conditions. The adult sizes range from 10 to 60 cm. The distribution set out in Tables 45 and 46 includes all bagrid catfish identified, as ascription of individual bones to species is not always possible.

TABLE 42: *The distribution of the remains of Channa sp.*

Bone	Layer	n (right)	n (left)	Layer	n (right)	n (left)
Dentary	11	-	-	10	18	17
	9	10	14	8	10	6
	7	3	3	6	1	2
	5	2	2	4	1	1
	3	3	2	2	1	2
Premaxilla	11	1	1	10	1	1
	9	1	3	8	3	1
	7	-	-	6	2	-
Articular	11	-	-	10	1	2
	9	3	2	8	-	1
	7	-	-	6	-	1
	5	2	-	3	-	2

TABLE 43: *The distribution of the remains of Clarias sp.*

Bone	Layer	n (right)	n (left)	Layer	n (right)	n (left)
Pectoral spine	11	-	-	10	18	10
	9	20	38	8	35	30
	7	8	9	6	12	20
	5	12	11	4	21	27
	3	39	33	2	4	2

TABLE 44: *The distribution of the remains of Anabas testudineus*

Bone	Layer	n (right)	n (left)	Layer	n (right)	n (left)
Articular	11	-	-	10	6	5
	9	4	1	7	1	-
	4	1	1	3	-	-

TACHYSURIDAE

The tachysurid catfish particularly prefer to occupy the lower courses of rivers and estuaries, where today they are usually caught with nets and traps. There are five genera and eighteen species, adult

TABLE 45: *The distribution of the remains of the dorsal spine of bagrid catfish*

Bone	Layer	n	Layer	n	Layer	n	Layer	n
Dorsal spine	10	11	9	4	8	9	7	3
	4	16	3	23	2	7		

sizes varying in length between 12 and 50cm. The remains of dorsal fin spines from this variety of catfish are particularly abundant. From 17 specimens in layer 11, the figure rises to 1139 in layer 10 and 122 in layer 9. Layer 8 has yielded 150, layer 7, 61; layer 6, 63 and layer 5, 37. Numbers began to climb again in layers 2-4, with 148 in layer 4, 288 in layer 3 and 95 in layer 2. The numbers of pectoral spines are set out in Table 46.

TABLE 46: *The distribution of the remains of pectoral spines of tachysurid and bagrid catfish*

Species	Layer	n (right)	n (left)	Layer	n (right)	n (left)
Tachysuridae	11	10	12	10	700	709
	9	134	120	8	157	192
	7	85	94	6	99	89
	5	59	60	4	157	182
	3	299	300	2	84	97
Bagridae	10	226	230	9	530	548
	8	919	850	7	477	495
	6	118	126	5	75	113
	4	310	300	3	491	464
	2	64	72			

CARCHARINIDAE

Sharks (*Pla chalam*) are common along the coasts of the Gulf of Siam. A small species, *Scoliodon walbeehmi* (Bleeker, 1856), commonly enters fresh water. Some of the sharks' teeth recovered may belong to this species, but further investigations are necessary before more definitive conclusions can be made due to the lack of an available comparative collection. Sharks' teeth were recovered as follows: Layer 10, 67; layer 9, 11; layer 8, 10; layer 7, 9; layer 6, 3; layer 5, 2; layer 4, 18; layer 3, 30 and layer 2, 11.

DASYATIDAE

There are two species of the genus *Dasyatis* which frequently enter fresh water while also living in salt or brackish-water conditions. They are *Dasyatis sephen* (Forskåal, 1775) and *Dasyatis bleekeri* (Blyth, 1860). The former has a large caudal spine, giving rise to the local Thai name *pla kaben tong* (flag ray). The latter is called *pla kaben nam chuet* or 'freshwater ray'. The freshwater ray is found in the Bang Pakong River in water over 3m deep and with a strong current. Both species are commonly caught by hook or net in the river during the rainy season. The distribution of spines and molariform teeth ascribed to the dasyatidae are set out in Table 47.

TABLE 47: *The distribution of the remains of dasyatid stingrays*

Layer	spines	molariform teeth	Layer	spines	molariform teeth
11	1	1	10	53	108
9	6	20	8	17	6
7	7	4	6	8	1
5	6	-	4	23	9
3	82	28	2	41	25

PORTUNIDAE AND POTAMIDAE

Two families of crabs are represented by body and chela fragments. The former are very hard if not impossible to ascribe to a species because of their fragmentary condition, but the chelae have been identified as belonging to *Scylla serrata* Forskåal, 1775 and *Portunus pelagicus* Linnaeus, 1758. Both belong to the family Portunidae. The former inhabits muddy-bottomed estuarine situations and is still caught in numbers at the estuary and along the banks of the Bang Pakong River. The latter prefers a sandy or sandy/mud habitat. Their distribution in the site is seen in Table 48. Land crabs of the family *Potamidae* are adapted to clear streams. Further work on this specimen is under way in Thailand.

TURTLES

Identifying fragmentary turtle remains to species on the basis of the carapace and plastron is not easy, particularly in the absence of a good comparative collection. It is held likely that the majority of the specimens from Khok Phanom Di prior to layer 4 are *Batagur baska* (J.E. Gray, 1830–2) while those from layers 2–4 are more likely to come from species which are not adapted to a marine habitat. *Batagur baska* is an aquatic species, preferring tidal marshes, estuaries and sluggish rivers. According to Goin *et al.* 1978, egg laying among communities occupying the mouth of the Irrawaddy River takes place from January to February:

TABLE 48: *The distribution of the chelae of Portunus pelagicus, Scylla serrata and potamid crabs*

Layer	<i>Portunus pelagicus</i>	<i>Scylla serrata</i>	<i>Potamidae</i>
11	5	79	-
10	1233	4177	30
9	12	1294	26
8	6	900	67
7	-	490	105
6	-	208	85
5	-	184	8
4	-	27	16

TABLE 49: *The distribution of the remains of turtle*

Layer	carapace	plastron	femur	humerus	mandible
11	7	7	-	-	-
10	97	88	2	14	5
9	57	29	-	5	3
8	133	68	2	14	7
7	38	32	-	1	1
6	28	5	-	-	-
5	45	7	-	-	2
4	360	143	1	3	2
3	680	720	2	4	2
2	555	645	-	4	2

'Every afternoon, the turtles come ashore, gather in large herds, and sun themselves on the sand. At night, the females dig holes 45 to 60 centimetres deep in the sand above the high-tide mark and deposit 10 to 30 eggs, each about 75 millimeters long. Each female lays between 50 and 60 eggs, in three batches, over a period of about six weeks. The incubation period is about 70 days.' (Goin *et al.* 1978:259).

The carapace length in *Batagur baska* reaches 46.3cm, making it the largest of the Emydidae (Wilbur and Morin 1988).

XV. THE SIZE FREQUENCY DISTRIBUTION OF *SCYLLA SERRATA* CRABS

By D. Cassaidy

INTRODUCTION

THE species *Scylla serrata*, family Portunidae, is commonly known as the mud or mangrove crab. It is the largest estuarine crab across its range in the Indo-Pacific area, with males reaching a maximum size of 190mm carapace width. The corresponding figure in females is 165mm. It lives in mangrove mudflat conditions, burrowing into banks at mid tide level. It also frequents muddy estuaries and upstream waters of marginal salinity (McLay 1988:230). *Scylla serrata* is an active, aggressive, nocturnal crab and often feeds on the surface at night. It has large, powerful dimorphic chelae, which are adapted to crushing hard-shelled prey such as mussels. At 170mm carapace width, the chelae account for 45 per cent of male weight, but only 22 per cent in the case of females. The larger chela is modified for crushing, the smaller for biting with conical rather than molariform teeth (McLay 1988:230-1).

The purpose of this study is to ascertain whether there is a temporal trend in the mean size of *Scylla serrata*. It is held that a decrease in size over time would indicate over-exploitation. The converse is that, in the absence of a significant size reduction, the crabs were not over-exploited.

Crab chelae contain two elements, the propodus (or fixed finger) and the dactylus. Separation of these was undertaken. In addition, each element was divided into left and right sides, because of the dimorphic nature of *Scylla serrata* chelae. There are four groups: left and right dactyli and right and left propodi. Much of the material is fragmentary, which restricted the number of measurements to two, the complete length and estimated length (Fig. 44). Use of the former is restricted to complete specimens. In the case of the dactylus, there is one distinctively large 'tooth'. The proximal end point for mensuration was from the distal end of this tooth to the true proximal end of this element. The complete dimension was taken from the distal to the proximal end of the dactylus. The propodus is a large endopod appendage of which only the strong distal end which opposed the dactylus survives well and is identifiable. The interior surface contains a number of molariform teeth. The four most proximal of these were observably larger than the rest and were used to give a proximal end measurement. The complete measurement was taken from the point at the distal end to the proximal end of the toothed surface. In order to increase the sample size, given the relatively few number of incomplete chelae, an estimated length value was calculated. The ratio between the proximal end length and the length in complete chelae was first taken, and then applied to fragmentary specimens (Fig. 45).

Measurements were made on 1520 specimens. Wherever possible, both measurements were taken on each chela. The mean size and standard deviation for each measurement were taken by layer in order to assess changes in size for statistical significance.

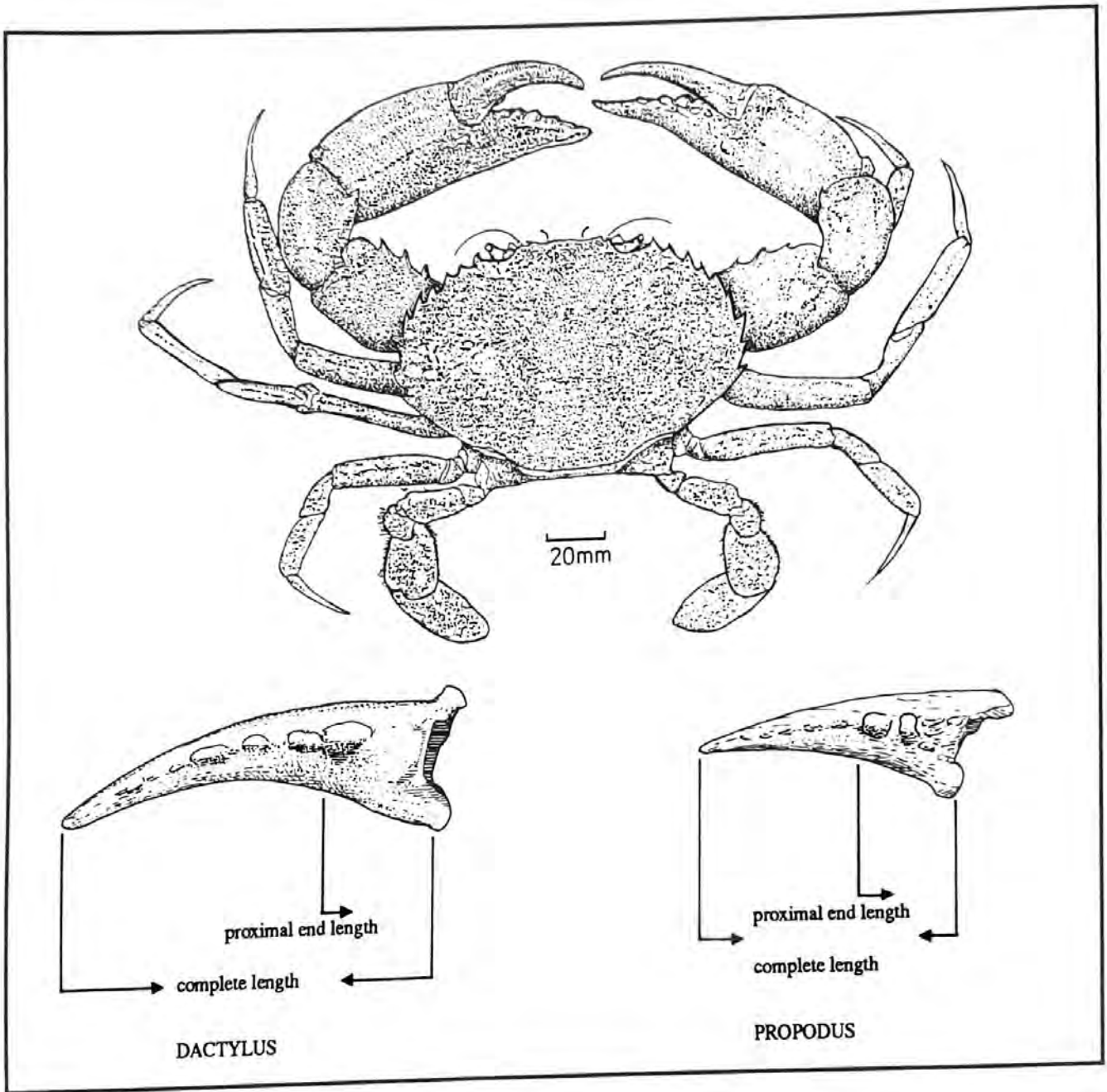


FIG. 44. *Scylla serrata*, and the measurements taken

In embarking on this study, it is appreciated that both age and sexual dimorphism will affect the composition of the sample and nature of the results based on measurements alone. It is felt likely that collectors of these crabs are unlikely to have selected on the basis of sex, unless they preferred the larger and older males. Inspection of the raw data, however, did not reveal any evidence for a bimodal distribution. Inclusion of young specimens might well account for the large element of variation in the sample. Again, however, it is not possible to exclude immature crabs from the

collection under study. These factors are expected to cloud the clarity of any results, but, rather than discontinue the size analysis, it was resolved to continue and consider the findings within a broad frame of reference.

RESULTS

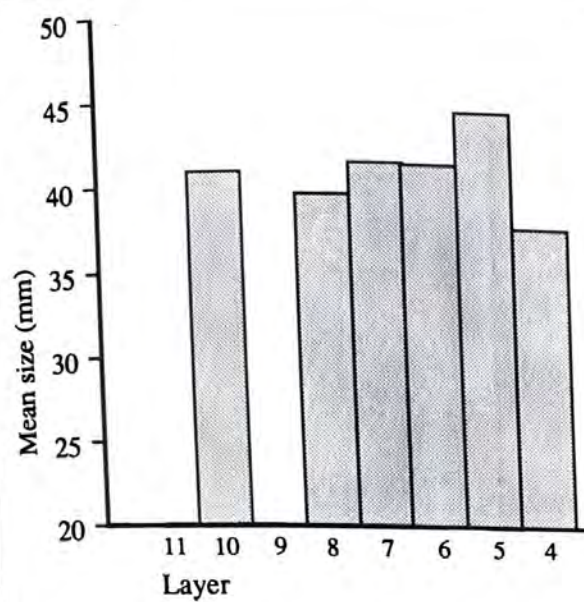
The data obtained are set out in Table 50. Since *Scylla serrata* has large, dimorphic chelae, four different sets of results are available, two for complete and the others for incomplete specimens. There is no immediately obvious size trend in the group of left dactyli (Fig. 45a). The Student's *t* tests failed to reveal any statistically significant changes. The greatest change, between layers 8 and 7, has a probability of only 0.337. In the data incorporating the estimated length dimensions, the size trend appears to increase to layer 7, and decrease thereafter (Fig. 45b). Curiously, the opposite situation obtains for the right dactylus (Fig. 45c). For the left propodus there a gradual increase in size with time is evident, although the changes are not sufficient to reveal statistical significance. The size increase for the right propodus, however, is significant between layers 10 and 7, and 8 and 7 ($P \geq 0.10$). There is no observable trend in the estimated length data (Fig. 46a-d).

It is evident that the working hypothesis of this section, that there was a decline in the size of the crabs due to over-exploitation, cannot be sustained. There are, however, some trends which require explanation. If a general trend is apparent at all, it is that particularly large crabs were taken during the initial settlement phase, that is, layer 11. There followed a decline in size during layers 9-7, followed by an increase. This trend is particularly apparent on the basis of the right dactylus. It is also seen on the basis of the right propodus. Naturally, this situation may not have statistical significance. If, on the other hand, we can identify the impact of human predation, it could be that, after an initial thinning of numbers, the size rebounded due to less competition within a smaller population.

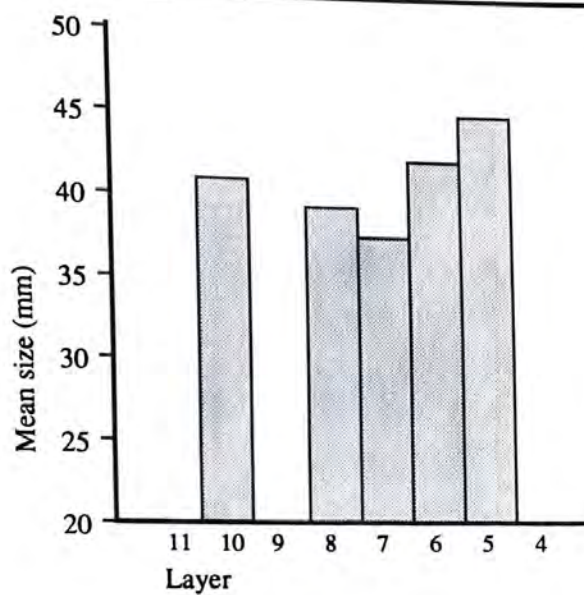
TABLE 50: *The mean size by layer of the Scylla serrata chelae*

Layer	n	Mean length	SD	SE	Layer	n	Mean length	SD	SE
Left complete propodus									
10	68	36.2	8.2	1.0	8	49	36.4	6.7	1.0
7	18	35.9	8.6	2.0	6	5	37.7	4.8	2.2
5	7	39.7	2.9	1.1	4	5	41.0	3.6	1.6
Right complete propodus									
11	6	36.1	3.8	1.5	10	103	35.6	6.3	0.6
9	3	36.1	6.0	3.5	8	87	35.0	7.3	0.8
7	26	38.1	6.6	1.3	6	15	37.0	5.6	1.5
5	11	37.8	6.3	1.9	4	7	38.8	7.6	2.9
Left complete dactylus									
11	1	41.7	-	-	10	63	40.9	8.3	1.0
8	50	39.7	8.9	1.3	7	42	41.4	9.8	3.1
6	10	41.4	9.8	3.1	5	2	44.5	0.4	0.3
4	2	37.7	7.3	5.2					
Right complete dactylus									
11	1	59	-	-	10	112	41.1	8.6	0.8
8	72	39.5	9.0	1.1	7	42	37.7	10.0	1.5
6	12	42.3	8.2	2.4	5	11	45.1	7.4	2.2
Layer	n	Mean est. length	SD	OR	Layer	n	Mean est. length	SD	OR
Left propodus									
11	5	46.9	3.5	42.0–51.2	10	121	38.9	8.7	42.0–51.2
9	1	27.8	-	27.8–27.8	8	82	39.7	8.5	23.6–58.3
7	26	38.8	8.8	19.7–51.7	6	20	41.5	6.7	29.4–51.2
5	13	41.9	7.6	24.9–54.3	4	10	43.9	6.0	35.3–51.9
Right propodus									
11	14	41.6	9.8	30.0–63.6	10	189	40.9	9.5	20.0–67.3
9	6	39.2	7.9	29.7–53.2	8	126	38.5	9.5	18.5–64.0
7	52	42.0	9.2	25.6–62.9	6	25	38.2	7.2	26.5–62.9
5	18	41.4	8.1	27.0–56.5	4	13	39.3	9.0	29.8–58.1
Left dactylus									
11	9	34.7	3.3	30.9–41.2	10	140	38.7	8.7	18.8–63.8
9	5	41.8	9.8	32.2–54.1	8	109	37.7	8.6	19.2–57.9
7	67	39.7	8.2	19.4–55.0	6	21	35.7	9.8	24.1–54.3
5	14	37.0	6.3	26.9–48.6	4	8	34.3	5.1	27.6–42.8
Right dactylus									
11	9	44.6	9.1	34.2–59.0	10	180	40.5	8.7	18.2–61.8
9	6	38.6	8.1	27.6–47.0	8	116	39.7	9.0	17.9–66.5
7	65	38.2	10.4	17.0–60.1	6	26	41.4	9.2	25.8–56.1
5	20	43.5	7.4	25.4–54.0	4	4	45.0	10.0	34.9–58.7

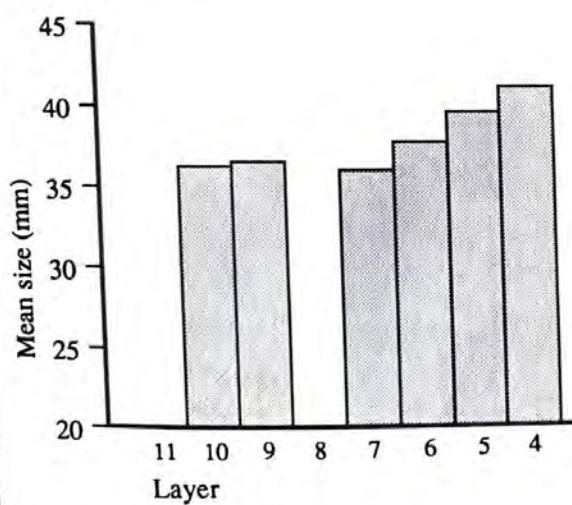
n, number of specimens; SD, standard deviation; SE, standard error; OR, observed range



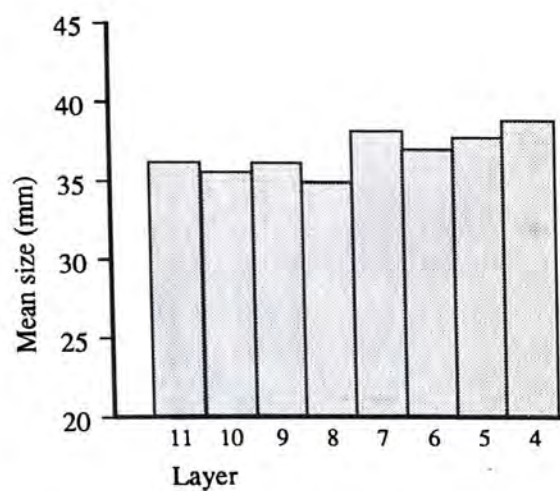
A. Left dactylus



B. Right dactylus

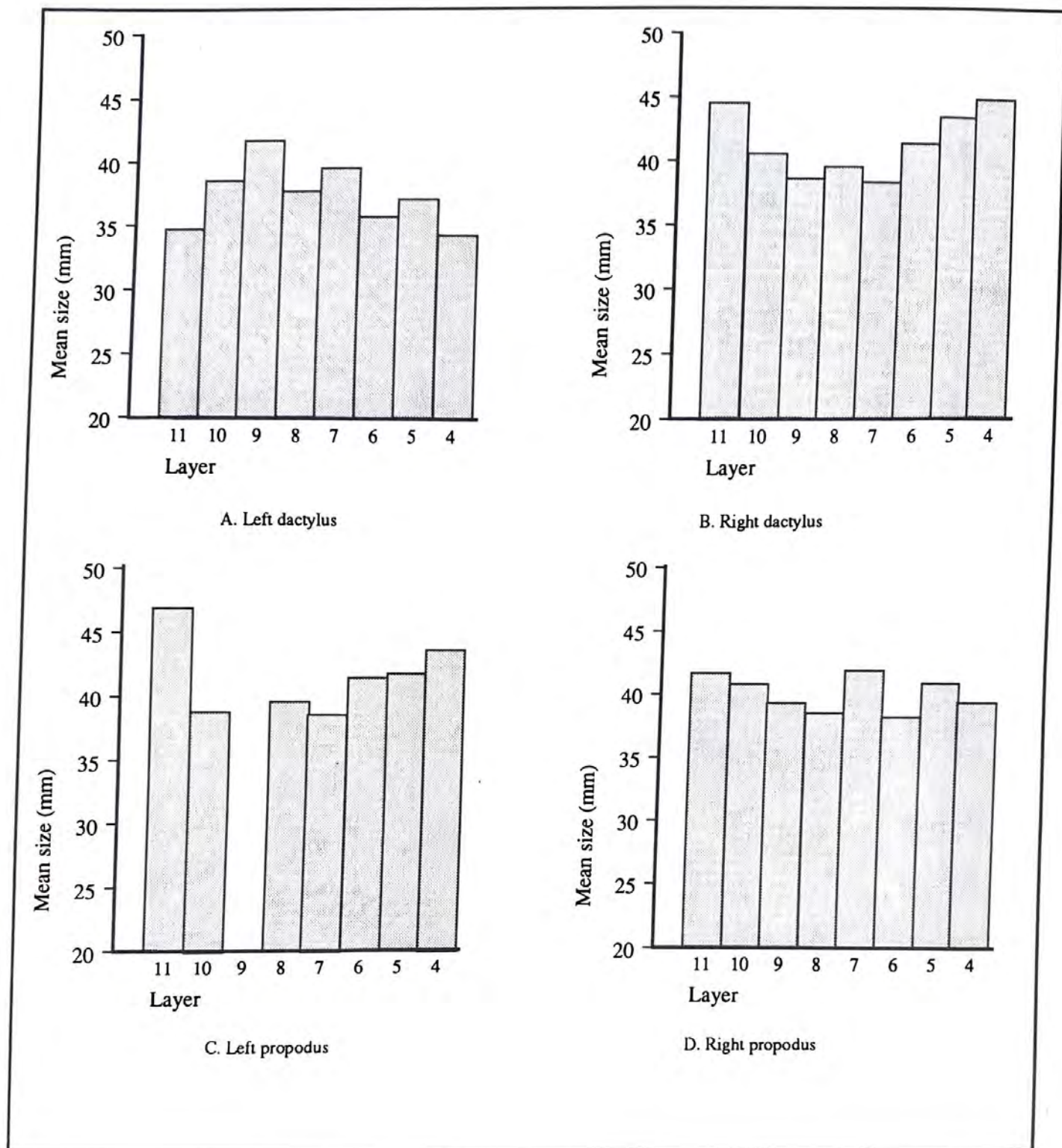


C. Left propodus



D. Right propodus

FIG. 45. The size distribution of the *Scylla serrata* chelae

FIG. 46. The estimated size distribution of the *Scylla serrata* chelae

XVI. THE CORAL, MITE, INSECTS, HAIR AND STOMACH CONTENTS

THE CORAL REMAINS

By Niphon Phongsuwan, J. Hylleberg and Anuwat Nateewathana

Three specimens of coral were recovered from the excavation. These are as follows:

1. 9:7 feature 32, cat. 1569. This specimen, which weighs 61.1gm is assigned to the family Faviidae. Its poor condition, however, makes this a tentative identification only.
2. 7:1 feature 14, cat. 514. This specimen has been ascribed to *Goniopora* sp. It weighs 88.4gm.
3. 6:5, cat. 463. This specimen has been ascribed to *Porites*. It weighs 17.8gm.

In general, the three types of coral represented can tolerate rather turbid water. They may grow near the mouth of mangrove canals if a hard substrate such as rocks or pebbles is available and the water is not too brackish or silty. These corals do not form coherent reefs, but grow as individual colonies under these circumstances. Such colonies are found in Phang Nga Bay and the Tarutao Islands near mangroves.

THE MITE REMAINS

By G. Ramsay

The remains of this mite come from the mass of food remains, thought to represent stomach contents, found in the pelvic area of burial 56. The specimen represents an oribatid mite, Cryptostigmata, family Lioididae, probably of the genus *Liodes*. Such mites are neither parasites nor associated with humans or any other animal. They live on or among leaf litter or the trunks of trees. The most that can be said, assuming the remains are partially digested food, is that the eating habits of the subject were not very hygienic and that food could have been placed on the ground or on rough twigs prior to eating. From the condition of the specimen, death probably occurred not long after the meal, as the specimen probably would not have survived the digestion process in this state. On the other hand, the mite could have entered the food remains after death during decomposition.

THE INSECT REMAINS

By A. Harris

Three insect fragments were identified in a probably human coprolite found in association with burial 67. The beetle has been assigned to the species *Oryzophilus surinamensis* Linnaeus, 1758, family Silvanidae of the order Coleoptera. The remains comprise the elytra, mesothorax, metathorax and abdomen. It is a cosmopolitan species, a pest of stored products including rice.

Two ant remains were also identified. The first comprises the head capsule and an isolated first gastral segment of an ant ascribed to *Monomorium pharaonis* Linnaeus, 1758. The second includes the articulated petiole, postpetiole and gaster of *Monomorium destructor* Jerdon, 1852. Both species belong to the sub-family Myrmicinae, family Formicidae, and are widely associated with human communities. The identification of both has been checked by Dr B. Bolton, British Museum (Natural History).

A second beetle was found among the stomach contents associated with burial 56. It comprises the elytra, mesothorax, metathorax and abdomen of *Formicomus* sp. (Coleoptera: Anthicidae). This small beetle would have fed in both its larval and adult stages on dead plant material, such as dried fragments of stalks and leaves of rice, as well as on fungi growing on such matter.

THE FISH REMAINS FROM THE FOOD RESIDUE, BURIAL 56

by P.H. Greenwood

During the excavation of burial 56, a tightly compacted mass of small bone was identified lying within the pelvis. Examination under a low-powered microscope revealed many small fish bones, fish scales and a few very fragile fragments of rice chaff and the oribatid mite reported on above. The bones examined include the right lower and part of an upper pharyngeal bone, probably the third pharyngobranchial, of *Anabas testudineus* the freshwater climbing perch. The smallest bone submitted is indeterminate, but is likely to be part of the upper pharyngeal series of an *Anabas*. Both of the larger bones could well be from the same fish, c. 7.0–8.0cm long.

The scales which show diagnostic features are almost certainly from *Anabas testudineus* since they show the large ctenii characteristic of the genus *Anabas*, as well as ornamentations which strongly suggest derivation from that taxon. Fragmentary scales show no contra-indications to their being from *Anabas*. Since no scale is entire, and because the size of fish scales varies on different parts of an individual's body, this material cannot be used to substantiate or refute the size estimation made on the pharyngeal bones. However, there are no clear indications of any scales being from fishes larger than 8.0–8.5cm in length.

Anabas testudineus seems to occupy almost any available freshwater habitat, but is commonest in canals, ditches, ponds and swamps. It has also been found rarely in brackish water. There is a record of its occurrence in rice paddy fields in Bengal. That *Anabas* can tolerate habitats unsuited for other fishes seems closely to be associated with the fact that it is an air-breather and thus not restricted to aquatic respiration. Indeed, it could well be an obligatory air-breather. Like all members of the family Anabantidae, it has a complex suprabranchial organ which, as long as

it is left moist, enables the fish to breathe in air for long periods of time. Because of that ability, *Anabas* is often carried for some distance from water, serving as a source of fresh fish for the traveller, and ensuring that it is fresh when taken to market. Also, *Anabas testudineus* is capable of moving overland, and has often been seen leaving drying pools and moving to better-watered areas. That habit would make it easily caught by man. Because of this mobility (both natural and human-assisted) and its eurytopicality, it would be difficult to speculate on the habitat from which this material stemmed.

It seems that sexual maturity in *A. testudineus* is reached at a length of between 10 and 15cm. Thus, the fish represented are probably sub-adults. It would be difficult to convert the estimated length of the fish to an estimated season of birth. Some authors claim that the species spawns throughout the year, others that it is an annual event taking place between mid-April and mid-July (the latter observation being based on populations in Bengal).

THE STINGRAY REMAINS FROM THE FOOD RESIDUE, BURIAL 56

By C. Patterson

The remains of pavement molariform teeth from the stingray (*Dasyatis* sp.) were identified in the stomach contents from burial 56 (Fig. 47).

HAIR FROM THE BURIAL 67 COPROLITE

By L. Moore

This coprolite was recovered from the grave of burial 67. It contained hair. The purpose of this investigation has been to compare these specimens with examples from Thai mammals in order to identify their likely origin.

The hair shaft consists of four structural units: the medulla, cortex, pigment granules and the cuticle. The cuticle is the thin outer layer of the hair shaft, and it consists of thin, imbricated, hyaline colourless scales of varying forms and dimensions. The scales are made to overlap during growth by complicated differential forces involving an upward movement of the inner sheath which drags the outer part of each cuticle over the one above it in the follicle. Overlapping edges of the scales point toward the tip of the hair. The thickness of the cuticle depends on the degree of overlap of the scales. The scale arrangement and patterns vary. Three characteristics are used in describing the scale.

1. The form of the scale margin which can be smooth/flattened, crenate with shallow indentation or rippled with a deep indentation.
2. The distance apart of the margin which can be close, near (intermediate) or distant.
3. The overall pattern, which might fall into one of the following: mosaic, regular or irregular depending on the visible parts of the scale; regular or irregular; chevron, regular V-shaped waves, acuminate; pectinate, comb like; petals, like overlapping flower petals or elongate.

Patterns formed by the external margins of the cuticular scales are most important aids to identifying mammalian hair. Speciation involves the examination and comparison of these structures

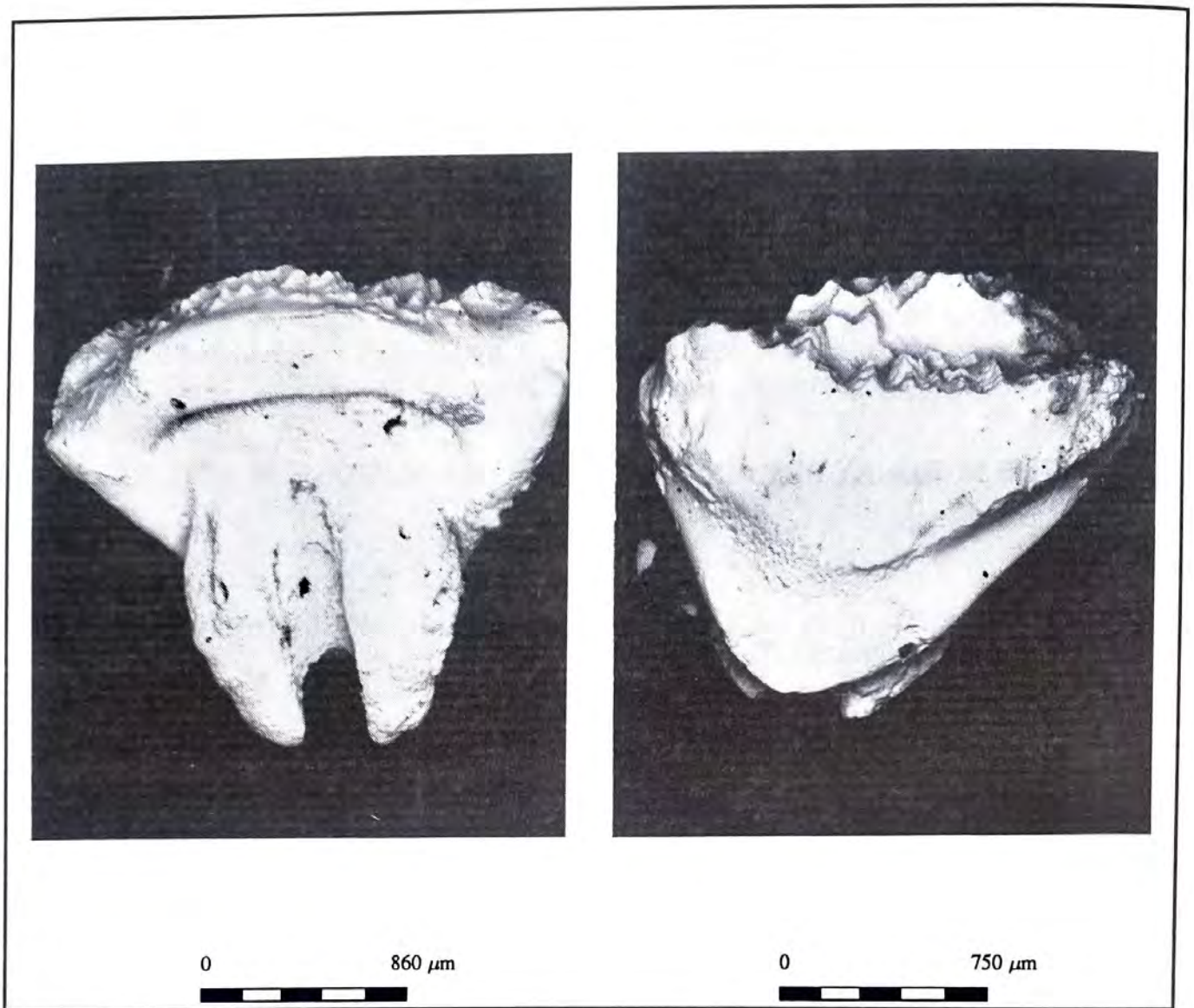


FIG. 47. A pavement molariform tooth from the stingray *Dasyatis* sp. from burial 56 stomach contents. SEM photograph by Gary Jones, British Museum (Natural History)

to determine a diagnostic pattern of each species. An example of this is the cuticle of the human hair, which consists of 5-10 overlapping cell layers. The mature cells are thin scales consisting of compact keratin which shows outer and inner zones of different densities. The outside surface of these is a flattened imbricate. It is proposed to examine the various unknown hair samples in order to determine which species are in question.

Untreated hairs were mounted on aluminium alloy stubs using double-sided adhesive tape. A uniform coating of metallic gold was applied to the hair surface to minimize bright spots and reduce image resolution due to the tendency for an electron charge to build up on the hair surface. The coated specimens were then examined under a Cambridge Scanning Electron Microscope.

TABLE 51: *The dimensions and characteristics of mammalian hair from Thailand*

Species	Diameter	Characteristics
<i>Rattus rattus</i> Linnaeus, 1758	18.0 μ m	acuminate elongate crenate
<i>Rattus rattus</i>	45.2 μ m	mosaic flattened
<i>Felis marmorata</i> Martin, 1837	82.6 μ m	waved flattened
<i>Felis viverrina</i> Bennet, 1833	49.8 μ m	mosaic crenate
<i>Felis temmincki</i> Vigors and Horsfield, 1827	30.0 μ m	waved flattened
<i>Felis bengalensis</i> Kerr, 1792	43.2 μ m	mosaic crenate
<i>Lutra sumatrana</i> Gray, 1865	48.7 μ m	irregular waved flattened
<i>Aonyx cinerea</i> Illiger, 1815	51.3 μ m	petal flattened
<i>Macaca fascicularis</i> Raffles, 1821	67.0 μ m	waved/mosaic flattened
<i>Cuon alpinus</i> Pallas, 1811	67.8 μ m	waved flattened
<i>Muntiacus muntjak</i> Zimmerman, 1780	96.1 μ m	waved flattened
<i>Panthera tigris</i> Linnaeus, 1758	88.0 μ m	irregular waved flattened
<i>Paradoxurus hermaphroditus</i> Pallas, 1777	65.6 μ m	waved flattened
<i>Paguma larvata</i> Hamilton-Smith, 1827	27.0 μ m	acuminate crenate
<i>Bandicota indica</i> Bechstein, 1800	70.3 μ m	mosaic flattened
<i>Presbytis cristata</i> Raffles, 1821	48.9 μ m	waved, slightly crenate

Hair diameters were measured and recorded and the hair was photographed at 1000 magnification (Figs. 48–50).

In the analysis of the modern hair, it was found that there are significant differences in the appearance of the overlapping imbricated scales according to the site from which the hair was sampled. This would make it difficult to be sure as to the species in question. These differences may reflect the hair diameter, rate of growth, anagen time, nutrition, temperature or even end organ response to normal levels of circulating hormones. The cuticular scale may also vary regularly and progressively in loss of normal cuticular pattern from root to tip from that of regularly edged to that of crenellated edges. Broken, split or general degradation of some hairs stripped away the hair of the cuticle so that no pattern was evident.

The analyses on the modern Thai material revealed a considerable range of cuticular pattern. However, as may be seen in Fig. 50, the same rat provided hair with both an acuminate elongate crenate and a mosaic flattened pattern. Sizes and patterns for the range of species considered are given in Table 51.

It is not possible to identify the prehistoric specimens with any degree of certainty, but some observations may be made. Stub 1 sample 1 from Khok Phanom Di has a similar pattern to modern human hair, and the diameter is not dissimilar (66.4 μ in *Homo sapiens*, 70 μ in the prehistoric specimen). Stub 5 sample 4 is similar to modern rat hair. Stub 1 sample 3 stands out from the other prehistoric specimens on account of its small size. In this respect, it resembles the modern mouse, *Mus musculus*. Numbers stub 3 sample 1, sample 2, stub 4 sample 3, stub 5 samples 1–

3 all have a similar waved, flattened scale. This pattern and their size is similar to that of *Lutra sumatrana*.

The diet of the people at Khok Phanom Di included fish, shellfish, turtle and rice. If rice was stored, and the presence of the beetle *Oryzophilus surinamensis* in the same coprolite supports this conclusion, then rodent remains too might have found their way into the human diet from a context of stored food. An oribatid mite was also found in the digestive tract of burial 56. This mite probably reached the stomach as a result of food being placed on the ground or rough twigs during preparation or consumption. The ground would be a ready source of hairs. The presence of human hair is easily explained through a lack of hygiene during food preparation. *

THE PARASITE EGGS FROM THE BURIAL 67 COPROLITE

By D.J. Morseth

The remains of a helminth egg found in a coprolite from burial 67 was identified from Fig. 51 as belonging to the Class *Trematoda*. The identification was based on several factors:

1. The suggestion of a missing operculum at one end (arrows).
2. Its large size.
3. The site of recovery.

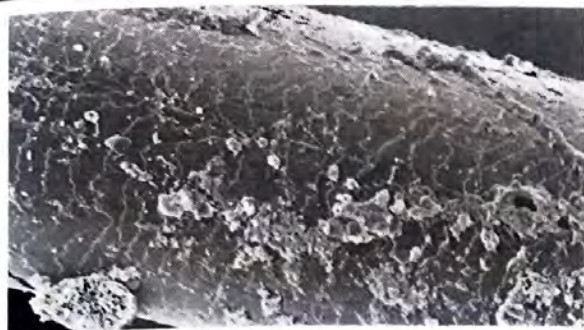
While a more specific identification cannot be made with certainty, a likely possibility might be the large intestinal fluke, *Fasciolopsis buski* Lankester, 1857 (Odhner, 1902), which is a common parasite of man and pigs throughout the Orient. Its eggs are passed in the faeces. It is endemic in areas of Thailand. Snails of the family *Planorbidae* act as intermediate hosts. The infective form of the parasite is shed by the snails and encysts on the aquatic vegetation.

Endemicity is associated with:

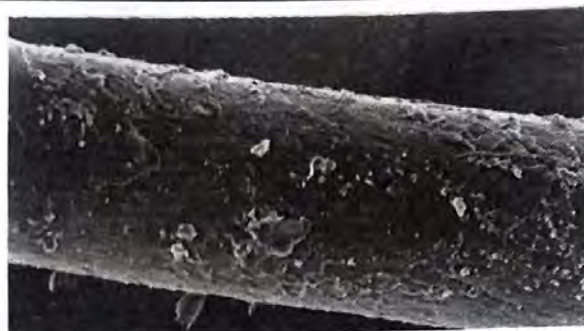
1. The cultivation of aquatic plants such as the water caltrop (*Trapa bicornis* in Thailand), the water chestnut (*Eleocharis tuberosa*), water bamboo (*Zizena aquatica*) and the lotus. Parts of these plants are consumed raw or peeled with the teeth by the native population (Sadun and Maiphoom 1953).
2. The use of untreated human excreta containing eggs of *F. buski* on fields of aquatic plants. This practice provides a major source of inoculum for the intermediate molluscan stages of the life cycle.
3. Infected pigs foraging in fields where such plants are grown polluting the ground with their faeces.

People in endemic areas are periodically re-exposed by consuming raw plant products from infested sites. Eradication of the water caltrop in one endemic area of Thailand temporarily freed the local population from infection (Faust *et al.* 1968).

*The hair samples from modern Thai mammals were donated by the British Museum (Natural History) with the permission of Iain Bishop.



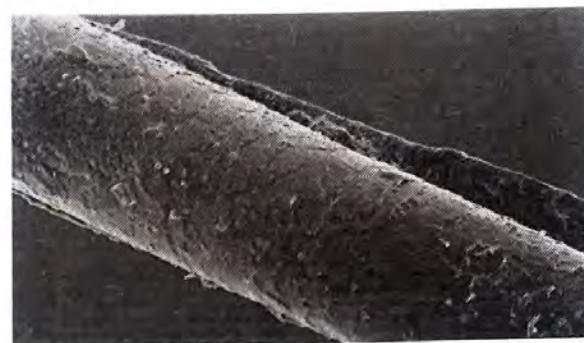
burial 67 no. 1



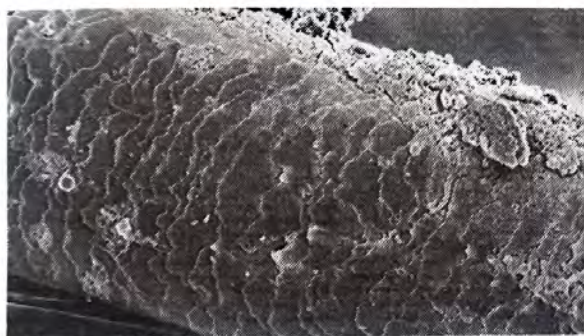
burial 67 no. 2



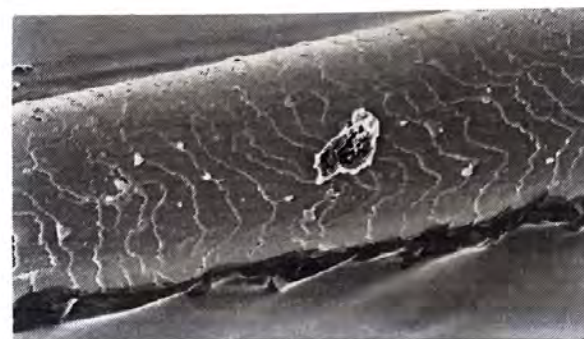
burial 67 no. 3



burial 67 no. 4



burial 67 no. 5



burial 67 no. 6



burial 67 no. 7



burial 67 no. 8

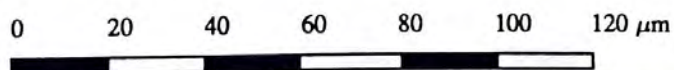
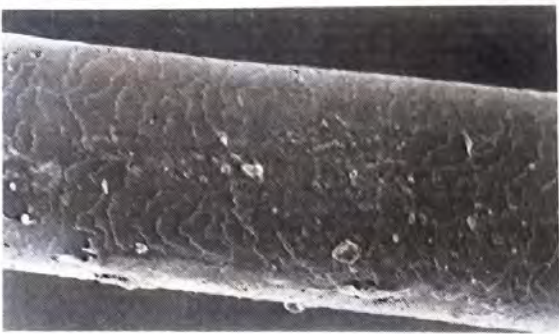
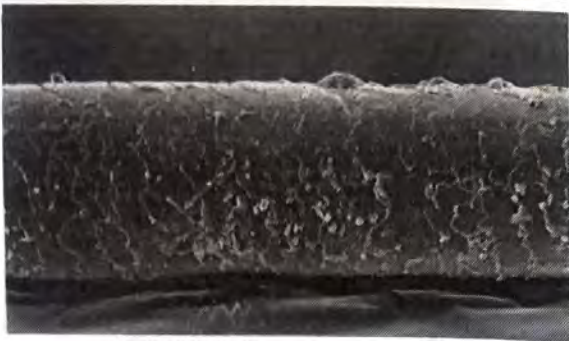


FIG. 48. The hair from Khok Phanom Di burial 67



burial 67 no. 7



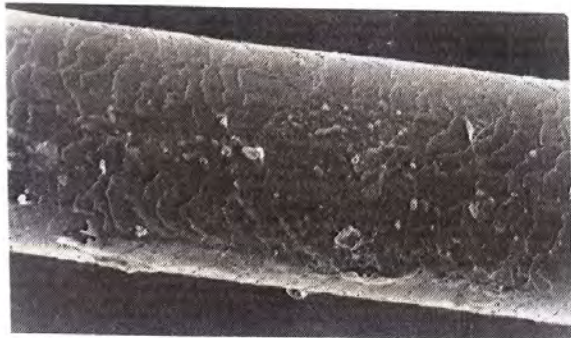
burial 67 no. 8



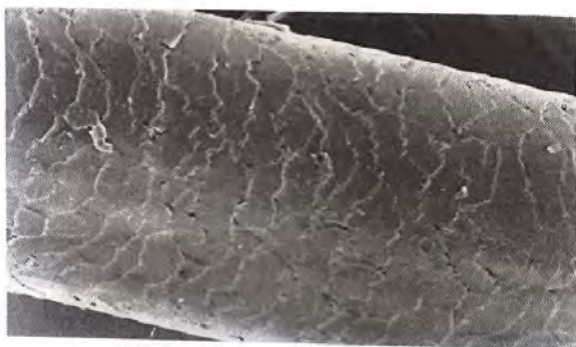
burial 67 no. 9



burial 67 no. 10



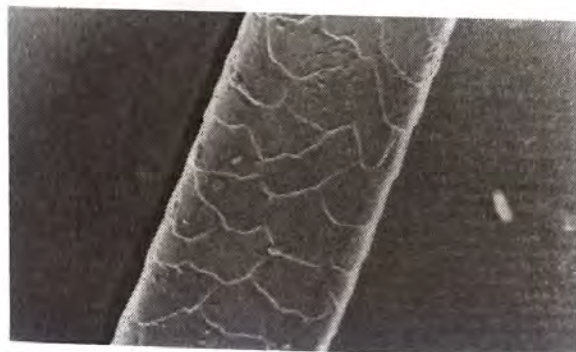
burial 67 no. 11



Homo sapiens



Mus musculus



Rattus

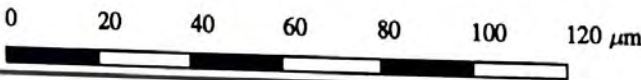


FIG. 49. The hair from burial 67 and that from *Homo sapiens*, *Rattus* and *Mus musculus*

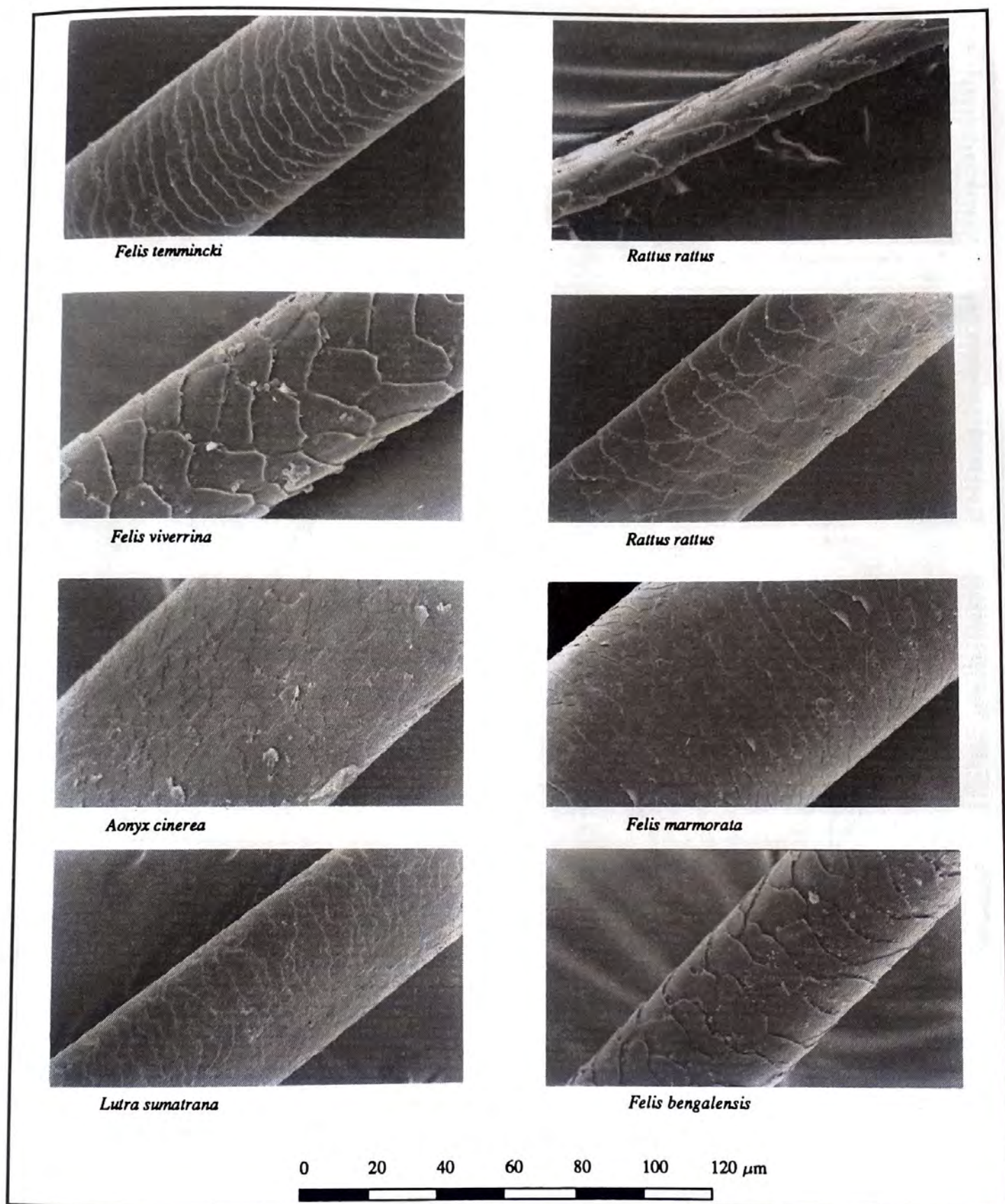
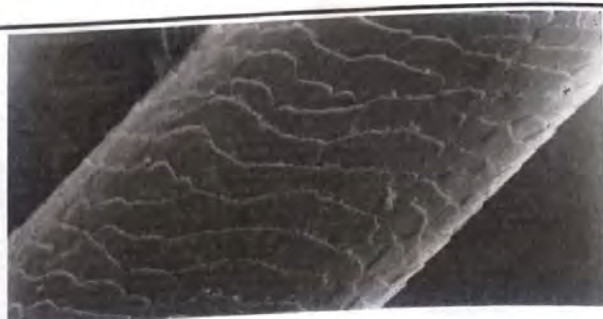
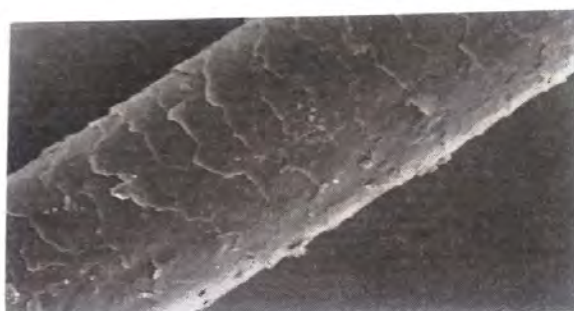
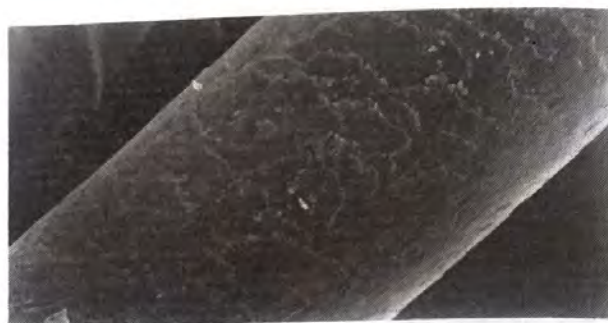
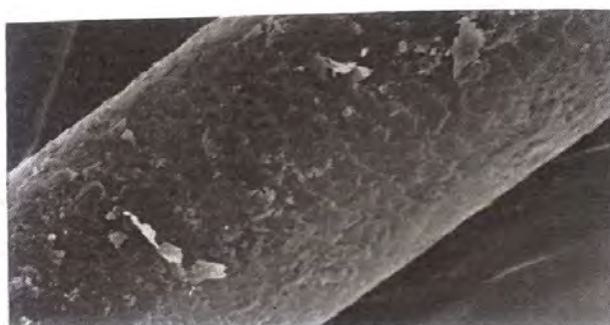


FIG. 50. The hair from Thai mammalian species

*Muntiacus muntjak**Cuon alpinus**Presbytis cristata**Macaca fascicularis**Bandicota indica**Paradoxurus hermaphroditus**Paguma larvata**Panthera tigris*

0 20 40 60 80 100 120 μm

The hair from Thai mammalian species (cont.)

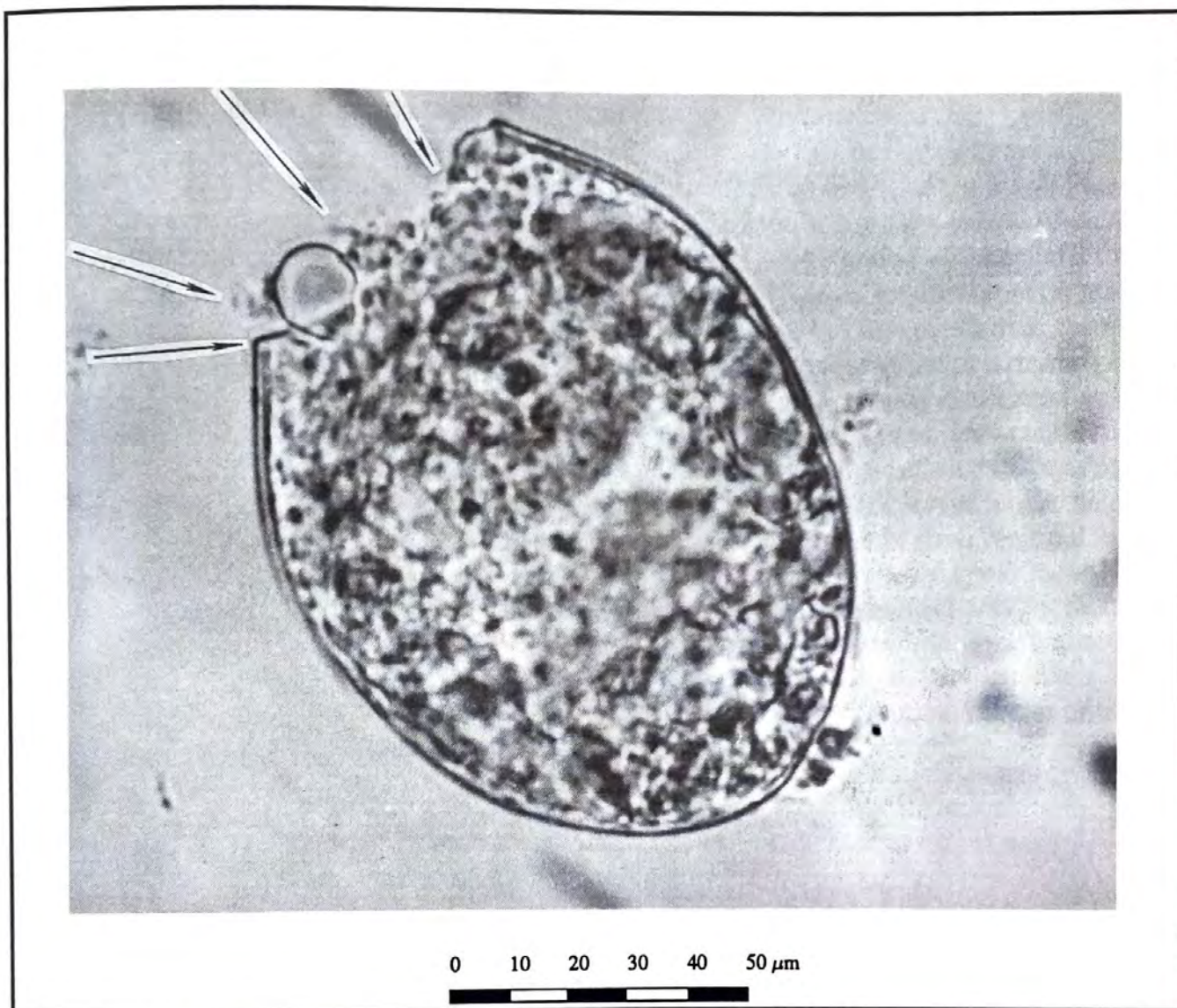


FIG. 51. Helminth egg, possibly of *Fasciolopsis buski*, from the burial 67 coprolite

XVII. THE MOLLUSCAN REMAINS

By G. M. Mason*

INTRODUCTION

The aim of this chapter is to reconstruct the palaeoenvironmental setting of the Khok Phanom Di site on the basis of the molluscan remains. Evidence for changes during the period of occupation will be sought, as will differences from its present-day setting. An attempt will be made to distinguish between the effects of human impact and changes in the physical environment on molluscan species and communities. Matters of food economy, other molluscan usage, relative, absolute and seasonal dating all fall beyond the immediate purview, as does temperature determination based on either oxygen isotopes or contractile shell protein. Since this section is concerned more with palaeoenvironment than with food economy, no measurements are presented. However, it is anticipated that this aspect will be covered in a subsequent contribution to this series. No gross evidence of size changes suggesting over-exploitation of the environment were observed in the field or the laboratory. A subsidiary aim is to determine whether or not exchange in shell material occurred and to detect activities on and off site not otherwise indicated in the archaeological record.

Micro-molluscan species (predominantly land and fresh water/estuarine) will be treated in a later volume due to difficulties of identification, the presence of undescribed taxa, and an almost total lack of ecological data, particularly for the land snails. It is hoped that field studies will resolve some of these problems and also allow collection of reliable habitat information for the large number of macro-species which are poorly known.

THE NATURE OF THE REMAINS

The remains of three classes of molluscs were identified: Gastropoda, Bivalvia and Cephalopoda. No scaphopod, aplacophoran or polyplacophoran elements were detected. The single cephalopod, a nautilus shell, was modified for personal adornment. The other two classes were abundantly represented in both numbers of individuals and species. The gastropods are represented by well over eighty species, only sixty-six of which are considered in this report. The balance, microspecies

*Many people have contributed time and effort to make possible this account. Without the support of the Fine Arts Department and the co-director of the excavation, Dr Rachanie Bannanurag, this research could not have been undertaken. Above all others, I wish to thank Professor Charles Higham for valuable discussions on archaeological matters, constant support and help with the preparation of the original manuscript and his forbearance in allowing resolution of the legion of problems of identification and the literature. For help with identification, my thanks go to Dr Frank Climo (National Museum of New Zealand) and Drs Peter Mordan, John Taylor and Ms Kathie Way, all of the British Museum (Natural History). Professor Bryan Manly (University of Otago) greatly enhanced the value of this report through his statistical analyses which he reports on himself following this consideration. Martin Fisher and Leslie O'Neill (University of Otago) undertook the graphs and drawings of shells respectively. Finally, and most certainly not least, I wish to acknowledge the tireless efforts of the reference and interloan staff of the Otago University Science Library, who handled voluminous and difficult requests with flair, alacrity and unfailing good grace.

less than 5mm in largest dimension, will be considered in a later volume of this report. Apart from some food species, such as *Telescopium* and *Nerita*, most of the gastropods were intact, hard and fresh looking although, with the exception of *Natica tigrina*, they were well bleached. Although there were nearly twelve thousand *N. tigrina*, less than ten calcified opercula were seen and those were from very small individuals which had probably not been eaten. As these opercula, and those of *N. articulata*, are large and robust (and also missing), what may have become of them is a matter for speculation.

No gastropod radulae or statoliths were recovered either from the site at large or from human or probably canine coprolites. Cephalopod statoliths and internal skeletal elements, of conchiolin or carbonate, and beaks, were apparently absent. The bivalve remains, comprising fifty-two species, were single or, in the case of *Anadara granosa*, not infrequently paired, closed valves. No pearls were seen. Many of the fragile species of the families Mytilidae and Tellinidae especially were crushed and are probably largely under-represented.

In general, with the exception of layers 1–3 inclusive and layer 11, all shell material is well preserved in terms of chemical integrity, but in many cases, shattered by burial compaction. Chemical erosion is visible on all taxa at microscopic level and will adversely affect the identification of the micro species. Layers 1–3 and 11 material is very poor and shows the effects of acid conditions and heavy leaching. It is probable that small species have been completely removed from these layers.

DISPERSAL IN SITE

The greatest bulk of the molluscan remains came from concentrated middens some few decimetres thick but in the case of layer 10 lens 2, the shell midden reached a thickness in excess of 2m. For further details, see Higham and Bannanurag (1990), who discuss the stratigraphy and tabulate the faunal remains recovered from shallow pits apparently associated with funebrial ritual. Only small numbers of mainly small to minute species were recovered from non-midden and non-pit contexts.

RECOVERY METHODS

Higham (1990:13–17) discusses the mode of excavation, recovery and restoration of remains from Khok Phanom Di. The salient points are that the site was excavated by conventional means of trowel and brush and the spoils sieved through oscillating screens of 5mm mesh. Recovered material was washed, dried, sorted and labelled with its stratigraphic, feature and space coordinates. Concretionary horizons were broken by mattock and large blocks containing fragile objects were packed for specialized laboratory extraction methods. The molluscs were, with the exception of *A. granosa*, which was counted and discarded with the retention of a 10 per cent sample, sorted into approximate 'species' groups, counted and packed for laboratory study and taxonomic refinement.

Bulk samples of each spit at the rate of approximately 20l per spit per quadrant were taken for the flotation tank recovery of organic remains and sub-millimetre-sized objects (e.g. forams, ostracodes). Samples of 5–10l were also taken from all features. Molluscs larger than about 5mm

recovered by processing these samples are treated in this report, but the balance await a later volume.

Where necessary, further washing and matrix removal was undertaken in the laboratory using dental probes and an ultrasonic cleaning bath.

MINIMUM NUMBERS

Bivalves that were represented by fewer than about thirty valves per feature or spit lot were sorted into right and left halves, the halves matched and the remaining valves counted as individuals. For more numerous bivalves, the larger number of the right or left valves was taken as minimal and, in the case of *A. granosa*, the number of valves was taken and divided by two. The net effect of this treatment may be slightly to under-represent 'true' numbers in a few cases. Most gastropod shells were intact with the exception of the major food species, *Nerita articulata*, *Cerithidea obtusa*, *Telescopium telescopium* and *Ellobium aurisjudae*, which were usually broken to extract the animal. Here, the spire-portion and the body whorl-portions were counted separately and the larger number taken. No statistical treatment was undertaken to maximize the minimum numbers as the small numbers inherent in the data will not materially affect the palaeoenvironmental conclusions and could not justify the many resources involved.

CATALOGUE OF SPECIES

The Indo-West Pacific biogeographical marine province covers over a quarter of the world ocean area and contains a remarkably large and diverse but homogeneous molluscan fauna. The last decade has seen a remarkable increase in the molluscan primary taxonomic literature, new titles appearing at a rate in excess of five thousand a year. The literature is vast and often difficult of access due to obscurity of publication venue, wide range of languages and the fact that much of it was issued in the late eighteenth and early nineteenth centuries. As an example, the modestly sized bivalve family *Arcidae* (bloody cockles) has a bibliography (taxonomic works only) of over 1700 titles ranging in time from Linnaeus (1758) to the present day with most of the major works being 100/170 years old. To ease the way of future workers, each species of shell has been listed with its currently valid name, commonly used synonyms, modern geographic range and, where available, details of its habitat, ecology and biology. Most species are illustrated. The dearth of ecological information can only be remedied by field observation.

All identifications and nomenclatural decisions are the author's, with some confirmatory from the British Museum (N.H.). Most identifications were made from the literature, where possible, against the original description and figure, otherwise monographic treatments at genus or family level were used. An almost total lack of comparative specimens was a major hindrance overcome only in part by a few days' access to two good museum collections in Australia.

Many of the more common Indo-Pacific species may be found described in accessible general works, such as Cernohorsky (1971, 1972 and 1978a), Springsteen and Leobrera (1986), who cover some 1700 species, and Abbott and Dance (1982) who illustrate about 4200 species. Further, more specialized references are given in the catalogue. For fresh water species, Brandt (1974) is indispensable.

NERITIDAE

This ancient family contains marine, brackish, fresh water and partly terrestrialized snails mainly confined to the tropical and sub-tropical areas of the world. There are 38 genus-rank taxa placed in 3 subfamilies. The marine forms range from about 1m below low tide up to the supratidal splash zone and may enter streams, rivers and mangal. Fresh water species may be diadromous at some stage in their life cycle. Herbivores, they graze algae from hard substrates. There appears to be no recent review of the family, but Russell (1941), in a review of the western Atlantic species, covers much of the earlier literature.

Nerita albicilla Linnaeus, 1758

Synonyms: *Nerita ustulata* Sowerby.

Range: Indo-West Pacific oceans, the southern African east coast.

Habitat and ecology: inshore intertidal rocks, frequently in large numbers. It is also found intertidally on boulder shores, some with high wave exposure.

Provenance within site: L10, 2; L7, 1.

Nerita articulata (Gould, 1847) Fig. 52d

Synonyms: *Nerita lineata* Gmelin, 1791; *Nerita balteata* Reeve, 1855; *Nerita birmanica* Troschel, 1877.

Range: Bengal east to Indonesia, New Guinea and north and eastern Australia. Common on all Thai mangrove coasts.

Habitat and ecology: coastal mangal and nypa palm swamps. Berry *et al.* (1973:189) note that *Nerita articulata* (as *N. birmanica*) is the commonest of several neritaceans in the mangrove of West Malaysia, where 'It is found on mud and, more frequently, on trees over wide areas of the mangrove forest near the sea, river, or streams. It does not extend close to the landward limit of the mangrove where prosobranchs tend to become replaced by ellobiid [auriculid] snails and ochidiid slugs.' They also record (*ibid.*:199-200) that the young of the species occur at all times of the year, and that the calcified egg capsules occur on trees, snail shells and patches of firm soil. The animals generally keep above water level by remaining on waterlogged soil or by climbing high in trees. Thus, they would be continuously available as a food source.

Provenance within site: L11, 58; L10, 329; L9, 14; L8, 39; L7, 11; L6, 7; L5, 2; L4, 3.

Neritina violacea (Gmelin, 1791) Fig. 52b

Synonyms: *N. crepidularia*, Lamarck, 1822, *Dostia* Gray, 1842.

Range: South-East Asia and South-West Pacific.

Habitat and ecology: commonly on gravel in areas of reduced salinity, in intertidal areas and often near mangrove.

Provenance within site: L10, 2; L9, 5; L8, 2; L7, 1; L6, 3; L5, 3.

CYCLOPHORIDAE

This large group (64 genus-rank taxa) of operculate land snails is mostly ground dwelling in plant debris and is often abundant amid limestone rocks, in caves and in damp situations. They are distributed through the Old World tropics and subtropics, extending from Africa to Indonesia, South-East Asia, Melanesia, Australia and Japan. There appears to be no recent review of the family, but Tielecké (1940) is useful.

Rhiostoma housei (Haines, 1858) Fig. 52c

Synonyms: *Cylostoma housei* Haines, 1858; *Pterocylos marioni* Ancey, 1898. Solem (1966) suggests that *R. housei* is a geographically variable species and, when better known, may include *R. samuiensis* Tomlin, 1931, *R. jalorensis* Sykes, 1903, *R. smithi* Bartsch, 1932 and *R. tomlini* Salisbury, 1949.

Range: Thailand, Laos, Vietnam, Malaysia.

Habitat and ecology: Recorded as dead shells in steep limestone country and under wet rain-forest in damp conditions (unpublished observation).

Provenance within site: L10, 1.

AMPULLARIIDAE

These tropical, fresh water snails are amphibious, having a vascularized mantle cavity capable of absorbing oxygen from air as well as water. Under unfavourable conditions, some species can aestivate for up to two years. They are generally microphagous vegetarians, scraping up epiphytic algae. Some species may reach large sizes (15cm) (Pain 1972, Alderson 1925). The Thai species have been most recently treated by Keawjam (1986, 1988), thus superceding Brandt's treatment of 1974.

Pila pesmei (Morlet, 1889) Fig. 52d

Synonyms: see Brandt (1974:51). Small specimens are sometimes identified as *Pila gracilis* or *P. globosa*.

Range: Chao Phraya plains to the north and north-east Thailand, into Laos. Also all eastern and south-eastern provinces of Thailand and east into Cambodia.

Habitat and ecology: lentic fresh water and damp terrestrial vegetation.

Note: this identification is based on a small fragment of body whorl attached to a few mm of anterior peristome. It is not known whether this species is eaten as is *P. ampullacea*.

Provenance within site: L10, 1.

VIVIPARIDAE

Members of this family inhabit fresh water and are virtually cosmopolitan, being absent only from South America. Many species have specialized habitat requirements (Brandt 1974, Prasad 1928a).

Filopaludina javanica (Von dem Busch, 1844)

Range: Thailand; south, central, east and south-east regions.

Habitat and ecology: lentic and lotic fresh water.

Provenance within site: L10, 2; L9, 5; L8, 7; L7, 6; L6, 1; L5, 1.

Filopaludina sumatrensis (Dunker, 1852)

Range: Java, Malaya, Indochina, Sumatra and Thailand.

Habitat and ecology: found in both lentic and lotic fresh water.

Provenance within site: L10, 1.

LITTORINIDAE

A world-wide group, well represented in the tropics, which is usually found in colonies in supratidal situations. They are grazers, scraping microalgae and other plants from hard substrates, such as rocks and trees. They are tied to the sea by their reproductive cycle. There are, however, a few fresh water species. Important references are: Rosewater 1970, 1972; Reid 1986, 1989.

Littoraria melanostoma (Gray, 1839) Fig. 52e

Synonyms: this species has usually been placed in the genus *Littorina*, though Brandt (1974:55) put it in *Littorinopsis*. *Littorina melanostoma* var. *articulata* Nevill, 1885 (*non* Philippi, 1846) is a synonym (Reid 1986:174).

Habitat and ecology: Reid (*ibid.*:176) states that this species is found 'on trunks and sometimes leaves in *Avicennia* fringe, 0.3–1.8m above ground, only on the outermost trees in very sheltered situations; most common at back of *Avicennia* zone and in outer parts of *Rhizophora* forest; roots and occasional leaves in *Rhizophora* forest 0.2–0.6m above ground; scarce in *Bruguiera*. Juveniles occur mainly on leaves. Berry and Chew (1973) report juveniles amongst marsh grass [*Fimbristylis* sp.].' Bury and Chew (*ibid.*:333) note that this species breeds all year round, releasing pelagic egg capsules during spring tides. They feed on algae and other micro-organisms.

Range: recorded by Reid (1986:178-9) and Rosewater (1970:433-4) as ranging from South-East India and Sri Lanka to the Bay of Bengal, Burma, Malaysia, Indonesia, Gulf of Siam, Hong Kong and north to Taiwan.

Provenance within site: L10, 2; L9, 4; L8, 1; L7, 1; L6, 3.

Littoraria undulata (Gray, 1839) Fig. 52f

Synonyms: *Littorina tenuis* Philippi, 1846; *L. acuminata* Gould, 1849; *L. conica subintermedia* Nevill, 1885; *L. undulata contracta* Nevill, 1885; *L. u. sulcatula* Nevill, 1885; *Littorina columna* Philippi, 1847; *L. scabra concolor* Weinkauff, 1878 (Rosewater 1970:438).

Range: Indo-West Pacific oceans from Malagasy Republic, South-East Asia, north to Japan, south to northern and eastern Australia and east to Hawaii and Tonga. Rosewater (*ibid.*:483) does not record it from the Gulf of Siam. Brandt (1974:54) records it from mangal in this area but the species in question may be *Littoraria scabra*.

Habitat and ecology: Rosewater (*ibid.*:437) notes this species from intertidal areas on rocky shores, commonly clustered in rock crevices during daylight hours but actively crawling over rocks by night.

Provenance within site: L10, 2; L9, 1; L8, 1; L7, 1; L6, 1.

HYDROBIIDAE

A large and heterogeneous family of some 198 genus-rank taxa divided into 22 subfamilies. Most of these small (generally less than 6mm high) snails live in a great variety of fresh water habitats with a small number being adapted to estuarine conditions and, very rarely, they have become amphibious but not terrestrialized. They are cosmopolitan but have their greatest numbers in the northern hemisphere. Most eat fine particulate matter and micro-organisms. Important references are: Radoman 1973, Taylor 1966, Ponder 1988.

Rehderiella parva (Lea, 1856) Fig. 52g

Synonyms: *Melania crassilabrum* Reeve, 1860; *Pachychilus parvum* Lee, 1856; *Pachydrobia parva* Morlet, 1889.

Range: in Thailand, the lower reaches of the Chao Phraya River, around Bangkok and Thonburi. Also found in Sarawak, Cambodia and the Mekong Delta.

Habitat and ecology: lives in brackish and fresh water under tidal influence (Brandt 1974:71).

Provenance within site: L6, 2.

STENOTHYRIDAE

A group of small (2–3mm high) gastropods inhabiting fresh and brackish waters ranging from Iran, India to South-East Asia and north to China and Japan and south to New Guinea and Australia. They live generally on sandy ground but are also found on decaying wood, on stones and buried in mud. Decaying organic matter and associated micro-organisms are the main food. Many species are very specific in their habitat requirements. References for this family are: Brandt 1974, Hoagland and Davis 1979.

Stenothyra polita (A. Adams, 1851) Fig. 52h

Synonyms: this taxon was originally placed by Adams in *Nematura*. It is also known as *Stenothyra quadrasi* Moellendorff, 1895.

Range: Philippines, Sumatra, Malaysia and Thailand.

Habitat and ecology: common on mudflats and mangrove forests in the Gulf of Siam and also on the Indian Ocean coast of Thailand.

Provenance within site: L9, 1; L8, 4; L6, 1.

IRAVADIIDAE

This family of marine and brackish water snails, found mainly in South and South-East Asia, Indonesia, northern Australia and Japan, contains about 12 genus-rank taxa of which only 2, *Iravadia*

and *Fairbankia*, are recorded from Thailand. The shells of these animals are usually less than 15mm tall. The Thai species inhabit mangrove and nypa palm intertidal and subtidal mudflats of marine and estuarine aspect, where they are microphagous to detritus feeders (Ponder 1984, Brandt 1974).

Fairbankia cochinchinensis Bavay and Dautzenberg, 1910 Fig. 52f

Range: Southern Vietnam, Thailand and Malaysia. In Thailand, it is currently known only from Surat Thani and Samut Prakan provinces (Brandt 1974:138-9).

Habitat and ecology: common in the drainage systems of mudflats, nypa palm and mangrove swamps.

Provenance within site: L10, 3; L9, 20; L8, 36; L7, 3; L6, 9.

ASSIMINEIDAE

There are two subfamilies. The Assimineinae (15 genus-rank taxa) are common in tropical and subtropical regions with a few representatives from temperate areas. They are mainly estuarine and supralittoral, generally in muddy places. The other subfamily, the Omphalotropidinae, are terrestrial, and mainly found in South-East Asia, the Philippines, Melanesia and some Pacific islands further to the east (Abbott 1958, Solem 1959).

Assiminea brevicula (Pfeiffer, 1854) Fig. 52j

Synonyms: *Hydrocena marginata* Morelet, 1865; *Assiminea pinguis* Martens, 1866; *Assiminea miniata* Martens, 1866; *Assiminea rubella* Blandford, 1867.

Range: India, Burma, Thailand, Indonesia, China and Sri Lanka.

Habitat and ecology: widely distributed in mangrove and nypa palm swamps.

Provenance within site: L10, 7; L9, 19; L8, 35; L7, 1; L6, 21; L5, 3.

THIARIDAE

A family of essentially fresh water snails with a few brackish-water representatives. There are about 19 genus-rank taxa distributed through southern Europe, Africa, South and South-East Asia, South America and some Pacific islands. It is noteworthy that reproduction is almost entirely parthenogenic, functional males being found in very few species. The widespread nature of many species, their ability to occupy a great range of habitats and their reproductive mode has led to a large number of species names. Under the genus *Melania* alone, between 1850-70 some 650 epithets were introduced to the literature (Morrison 1954, Solem *et al.* 1982, Ruhoff 1980).

Melanoides tuberculata (O.F. Müller, 1774) Fig. 52k

Synonyms: Brandt (1974:164-5) lists about 35 synonyms for this taxon, generally associated with the genus *Melania* despite the availability of *Melanoides* Olivier, 1804 based on the species as then *Melanoides fasciolata*. The interested reader is referred to his list. The extreme variability of the morphology largely accounts for this rather long synonymy.

Range: from southern Europe through Africa, Asia, to the West Pacific Islands and Australia. Common in all provinces in Thailand.

Habitat and ecology: 'Lakes, ponds, trenches, rivers, brooks and mountain streams. The species mainly found in slightly brackish water and is [locally] abundant in ... tidal areas..' (Brandt 1974:166).

Dudgeon (1989:41) notes that this snail is primarily a deposit feeder, unselectively ingesting fine particles as it crawls and burrows through fine sediments. He has reported (1986) that the species is viviparous and parthenogenic and breeds throughout the year but releases the young from the brood pouch only when conditions are favourable. The adults attain a length of 20–40mm and are thought in general to live for about a year but not infrequently for 18–24 months. This animal can colonize new areas with a suitable habitat with remarkable speed due to its parthenogenic habit.

Provenance within site: L10, 4; L9, 8; L8, 5; L7, 2; L6, 10.

Sermyla riqueti (Grateloup, 1840) Fig. 521

Synonyms: *Melania harpula* Dunker, 1844; *Melania semicostata* Philippi, 1847; *Melania tornatella* Lea, 1850.

Distribution: the coast of the Indian and West Pacific Oceans.

Habitat and ecology: brackish water or estuarine areas under tidal influence. The shape of the shells suggests association with river mudflats rather than streams with sandy bottoms.

Provenance within site: L10, 2; L6, 2.

POTAMIDIDAE

Members of this family are generally restricted to brackish water and are to some extent amphibious, being abundant in mangrove muds and at the mouths of rivers and estuaries. There are about 78 genus-rank taxa placed in eight subfamilies. Predominantly circum-tropical in distribution, a few temperate forms are known. It is thought that they are deposit feeders (Houbrick 1984, Wells 1985).

Cerithidea cingulata (Gmelin, 1791) Fig. 53a

Synonym: *C. fluviatile* (Potiez and Michaud, 1838).

Range: the species ranges into the Indian Ocean from the western Pacific.

Habitat and ecology: Vohra (1970:187) says '*Cerithidea cingulata* ... is one of the most common species on the estuarine shores and mangrove regions of Singapore and West Malaysia'. It is also found in muddy inland creeks and on river banks with overlying mangrove. It tends to avoid clean and well-drained sand but occurs in big aggregations in wet areas especially along furrows, runlets, drainage canals, ditches and channels on the beach. Van Benthem Jutting (1956) reported the occurrence in intertidal regions, brackish water estuaries, mangrove swamps and fish ponds, in India, Ceylon, southern China, Japan, Philippines, Malay archipelago and New Guinea. In Java, it lives and feeds on the upper bottom layer of liquid mud in brackish and supersalted fish ponds with a salinity range of 14–45 per cent [*sic.*, ‰ intended].

At Mata Ikan, East Singapore, ... the snail is found between the levels of mean low water and high water with a maximum density around mean high water of neap tides. Here shells ... were occasionally obtained from the upper beach where organic debris and seepage water accumulated.'

Vohra (*ibid.*) reports that the study of the annual cycle of this snail indicated that after spawning the majority of the larger adult population dies. 'Towards the winter months (December–January) the bimodal distribution of size classes tend to become unimodal as the rapid growth of the young individuals hatched in the summer (June–July) began to close the gap with surviving parent snails. The reproductive activity, however, was spread over a longer period with a possible peak in June–July as indicated by the greater number of juveniles.'

Provenance within site: L10, 7; L9, 3; L8, 1; L6, 4.

Cerithidea obtusa (Lamarck, 1822) Fig. 53b

Synonyms: *C. kieneri* Hombron and Jaquinot, 1854, *C. anticipata* Iredale, 1929.

Range: western Pacific and Indian Ocean.

Habitat and ecology: tropical Pacific species of this family inhabit muddy bays, river estuaries and mangrove swamps, generally in brackish water. Coleman (1981:35) gives mangrove swamps and mudflats and may be seen on mangrove tree roots and trunks. Most of the adults are decollate.

Note: called in Malay '*siput mata meral*' and also '*belitong*' or '*beliton*'. Collected for eating in large quantities from among the buttress roots on the seaward margin of mangal (Purchon and Purchon 1981:309).

Provenance within site: L11, 9; L10, 661; L9, 180; L8, 241; L7, 152; L6, 526; L5, 727; L4, 425; L3, 3.

Telescopium telescopium (Linnaeus, 1758) Fig. 53c

Synonyms: *T. indicator* Mountford 1810, *T. fuscum* Schumacher, 1817.

Range: from Queensland, westward in the Indian and Pacific Oceans.

Habitat and ecology: this gregarious species is found, often in large numbers, in most aspects of mangal but particularly in runnels and shallow pools at low tide. It also occurs on intertidal mudflats where there is sufficient shelter from the sun.

Note: Malay '*siput borongan*'. This species is collected from the landward side of mangroves and marketed as a popular food (Purchon and Purchon 1981:309).

Provenance within site: L11, 38; L10, 416; L9, 365; L8, 159; L7, 117; L6, 39; L5, 7; L4, 1.

Terebralia palustris (Linnaeus, 1767) Fig. 53d

Synonyms: *T. agnatus* Gmelin, 1791; *T. carinatum* Perry, 1811; *T. crassum* Lamarck, 1822.

Range: tropical Pacific.

Habitat and ecology: mangrove swamps.

Provenance within site: L10, 4.

STROMBIDAE

A sand-dwelling shallow-water marine family of about 6 genera and fewer than 100 species. They are generally subtidal to 100m but a few deeper water forms are known. They are herbivorous,

grazing small gracile algae and micro-algae from sand grains. They may be a locally important dietary item (Abbott 1960).

Strombus canarium Linnaeus, 1758 Fig. 53e

Synonyms: if the pale coloration is not due either to diagenesis or taphonomic change, then it would be *S. c. turturella* (Röding 1798), described and illustrated by (Oliver 1975:64-7). This pale form is also *S. isabella* Lamarck, 1822.

Range: it ranges through the southwestern Pacific in shallow water in clean sand (Abbott and Dance 1982:80). Kira (1965:35 pl. 16 figs. 11-12) treats *S. canarium* and *S. turturella* as separate species in the genus *Laevistrombus* of Kira 1955 (type species of this genus is *S. canarium*). He puts the pale form in *L. canarium* and gives its distribution as Formosa and southwards in water of 9-20m.

Habitat and ecology: it is found on mudflats, usually camouflaged by algal growth (Coleman 1981:38).

Note: Malay '*siputgungong*'. Taken from patches of fine algae on sand for consumption (Purchon and Purchon 1981:310).

Provenance within site: L11, 2; L10, 66; L8, 1; L7, 1.

Strombus luhuanus Linnaeus, 1758 Fig. 53f

Synonym: sometimes placed in *Conomurex* as a full genus, e.g. Kira (1965:35 pl. 16 fig. 8).

Range: South-East Japan to Indonesia and eastern Australia and then east to Palmyra and Fiji (Abbott 1960:135; Oliver 1975:82). The closely related *S. decorus* (Röding, 1798) occupies the same environmental niche in the Indian Ocean to the west of the Straits of Malacca.

Habitat and ecology: these epifaunal grazers spend most of their time in aggregations on the surface of coralline sand and clean sandy sediments, but will burrow under the surface to escape predators. When they do so, they leave a shallow depression some 8cm in diameter with a raised rim which, once recognized, makes these animals easy to collect (Savazzi 1988). Berg (1974) notes that as well as a crawling mode of locomotion, these animals can leap rapidly as a response to predators. He observes (*ibid.*:276) that they 'feed on fine macroscopic algae and on the algae and detritus on sand grains. During feeding, sand may be picked up in the proboscis and swallowed, or macroscopic algae may be nibbled off the substratum.' The sexes are separate, the shell of the female being larger than that of the male. They form large colonies to mate and spawn in inshore waters in the zone transitional between reef outcrop and sandy shore in the summer months. Then, they migrate to deeper water Kuwamura *et al.* (1983:433). Abbott (*ibid.*:135) records them from shallow, subtidal water to a depth of 10m usually on coral sand, coral rubble and algal patches, avoiding muddy conditions. Coleman (1981:232) observes that they are to be found in intertidal coral rubble and to a similar depth on sand.

Note: this species is regarded as a desirable culinary item in Japan and elsewhere.

Provenance within site: L10, 17.

CALYPTRAEIDAE (CREPIDULIDAE)

These marine snails usually have a limpet-like shell with an internal shelf. They inhabit tropical and warm temperate seas and are often found in clusters. Food is gained by filter feeding microscopic algae from the water column (Hoagland 1977).

Crepidula walshi (Reeve, 1859) Fig. 53g

Synonyms: *Calyptraea plana* Adams and Reeve, 1850; *Crepidula scabies* Reeve, 1859; *Crypta lamellosa* A. Adams, 1862; *Crepidula orbella* Yokoyama, 1920.

Range: Indo-Pacific, north to Japan and south to Australia.

Habitat and ecology: frequently found commensal with hermit crabs in shallow water. The eggs and the young are brooded. Yipp (1985) suggests that temperature-controlled breeding periods may limit geographic distribution.

Provenance within site: L10, 3.

CYPRAEIDAE

This family, much favoured by shell collectors, has highly polished, generally hemispherical shells which in life are enveloped by the mantle. They are exclusively marine, mainly nocturnal and are found in shallow water throughout the tropics. They are omnivores, eating sponges, algae and small invertebrates. There are about 200 species for which over a thousand names have been proposed (Burgess 1985).

Cypraea errones Linnaeus, 1758 Fig. 54a

Synonyms: *Errones nimiserrans kalaea* Steadman and Cotton, 1943, *Errones vivili* (Steadman and Cotton, 1943; *E. n.* Iredale, 1935; *E. n. proba* Iredale, 1939; *E. n. magerones*, Iredale, 1939; *C. bimaculata* Gray, 1842; *C. coxi* Brazier, 1872.

Range: western Pacific, western Thailand to Andaman Islands. Abundant in the vicinity of Singapore, but not recorded in the Gulf of Siam.

Habitat and ecology: one of the most variable of the cypraeids. Shallow-water dwellers up to about 1m below low tide (Burgess 1985:248). Found on coral reefs and coral sand.

Note: each has been bored twice, one hole at the posterior and the other at the anterior part of the dorsum. On the basis of the erosion of the outermost layer of the shell and purplish coloration, it is highly likely that each was beach-worn before collection. They also have a secondary polish from either much handling or use as a burnisher. Given the pierced holes, it is suggested that they might have been worn as beads.

Provenance within site: L10, 15; L9, 2; L6, 1; L5, 1.

Cypraea helvola Linnaeus, 1758 Fig. 54e

Synonyms: *C. chalconia* Perry, 1811; *C. callista* Shaw, 1909; *C. gareti* Vayssi re, 1910. This species has been placed in *Erosaria*.

Range: from South Africa through the Indian Ocean to Burma, peninsular Thailand and Malaysia (but not in the Gulf of Siam), thence east to Tahiti. A widely spread, common species (Burgess 1985:216).

Habitat and ecology: subtidal, shallow water, usually in coral (Burgess 1985:217; Kira 1965:48).
Provenance within site: L10, 3; L9, 3.

Cypraea cf. *miliaris* Gmelin, 1791 Fig. 54c

Synonyms: *C. lamarckii* var. *enocellata* Gray, 1825; *C. m.* var. *magistra* Melvill, 1888; *C. diversa* Kenyon, 1902; *C. brevis* Smith, 1913; *Erosaria* Troschel, 1863 has been used by many authors at the generic and subgeneric rank for this species as exemplified by Schilder, 1927; 1937 thus: *E. m. differens* and *E. m. effosa* respectively and *E. m. metavona* Iredale, 1935.

Range: from Japan down to the Philippines to Singapore, the Great Barrier Reef and western Burma and western Thailand.

Habitat and ecology: at 5-6m depth in seaweed and at 18-40m on sand, coral and sponge bottom (Burgess 1985:215).

Provenance within site: L10, 3; L8, 1; L7, 1.

Cypraea onyx Linnaeus, 1758 Fig. 54d

Synonyms: these names are often treated as subspecies of *C. onyx*: *succincta* Linnaeus, 1758; *adusta* Lamarck, 1810; *nymphae* Jay, 1850; *melanesiae* Schilder, 1937.

Range: East Africa, western India, Indonesia, Philippines, Micronesia; not at present found in the Gulf of Siam, except for southernmost peninsular Thailand, nor the coasts of Cambodia, nor Vietnam. In Singapore and peninsular Thailand, it is represented by *C. o. melanesiae*.

Habitat and ecology: in Singapore, this species is found in shallow muddy water and about Japan, up to depths of 30m. In the Solomon Islands, it has been collected from 15-20m of silty water not far from mangal shorelines.

Note: this specimen shows holes cut into the anterior and posterior ends of the dorsum, suggesting that it may have been threaded for wearing. It is eaten in Sri Lanka and elsewhere in the Pacific. In Hawaii (Burgess 1985:59) *Cypraea* species are roasted on coals before being eaten.

Provenance within site: L10, 1.

Cypraea sp.

Provenance within site: L6, 1.

NATICIDAE

Natica tigrina (Röding, 1798) A marine family of about 150 species of predatory gastropods that live in sandy mud. Their stout, glossy shells are covered by extensions of the foot. When prey is located, generally infaunal bivalves, a hole is drilled through the shell with the aid of acid secretions and the animal is removed by the highly protrusible proboscis. The family is cosmopolitan in shallow to deep water with some species to be found in the lower littoral (Kabat 1990, Kilburn 1976, Marincovich 1977, Oyama 1969, Shileyko 1977, Golikov and Sirenko 1988).

Natica tigrina (Röding, 1798)

Synonyms: *N. maculosa* Lamarck, 1822, *N. pellistigrina* Kuester, 1850.

Habitat and ecology: found commonly in beds of *Anadara granosa* which it predates along with *Pelecypora trigona* (Broom 1983).

Range: eastern Asia, at 10-30m depth (Abbott and Dance 1982:109).

Provenance within site: L11, 12; L10, 1633; L9, 141; L8, 55; L7, 100; L6, 1057; L5, 173; L4, 48.

Polinices cumingianus (Recluz, 1844) Fig. 54e

Range: type locality in the Sulu Sea, Philippine Islands. Range beyond Philippines unknown.

Habitat and ecology: 'Sandy mud, deep water' (Recluz 1844:210).

Provenance within site: L10, 1.

Polinices didyma (Röding, 1798) Fig. 54f

Synonyms: *P. glaucina* Lamarck, 1822 (*non* Linnaeus, 1798); *P. chemnitzii* and *P. petoveriana* Reclus in Chenu, 1843; *P. bicolor* Philippi; *P. vesicalis* Philippi.

Range: western Pacific and Indian Oceans.

Habitat and ecology: intertidal sandy ground down to about 100m.

Provenance within site: L10, 3.

Polinices tumidus (Swainson, 1840) Fig. 54g

Synonyms: *P. pyriformis* Reclus, 1844; *albula* Reclus, 1851; *ponderosa* and *cygnea* Philippi, 1852; *Mammilla auctt.*

Range: throughout the tropical Pacific Ocean.

Habitat and ecology: common on sand-bars and beaches, where it burrows into the sand. There is then a gap in the distribution, and it becomes common again at depths of 20-80m.

Provenance within site: L10, 6; L9, 2; L8, 2; L7, 1.

MURICIDAE

A large and highly diverse group of carnivorous gastropods split into about 130 genus-rank taxa contained in 8 subfamilies. They are cosmopolitan, living mainly in shallow tropical and subtropical waters. There are a few species, however, habitually found in brackish water of estuaries and mangrove swamps. Like the naticids, they bore into the shells of other invertebrates (gastropods, bivalves, barnacles and sedentary polychaetes) and then eat the animals with their long, flexible probosces. There is little consensus in the literature as to how the family should be divided and as to what should or should not be included. Small, localized populations, large variations of shell sculpture, and small numbers of eggs, from which the young hatch directly, all combine to give a large amount of over-splitting of species in this family.

The literature for this family is extensive, but the following are useful: Emerson and Cernohorsky 1973, Radwin and D'Attilio 1976, E. H. Vokes 1964, 1971, Fair 1976 and Ponder 1972, 1973.

Hemifusus ternatanus (Gmelin, 1791) Fig. 55e

Synonyms: *Hemifusus* is sometimes placed as a subgenus of *Pugilina* Schumacher, 1817.

Range: a not uncommon species, wide ranging in the Indo-Pacific region.

Habitat and ecology: Ozawa (1981:225) records the species from intertidal sandflats where it is a predator on the trochid gastropod *Umbonium moniliferum*. Hamada (1974:75) gives no details of habitat, but notes that juveniles eat the venerid bivalve *Ruditapes*. Morton (1986:107) says that it occurs on the continental shelf of Hong Kong but the depth and substrate are unspecified. Under experimental conditions, he records that it will eat the bivalves *Pinna pectinata*, *Hiatula diplos* and *Sinovacula constricta*, species which are not known from Khok Phanom Di, but it refuses *Tapes philippinarum*, *Anadara granosa*, *Polymesoda erosa* and *Circe scripta*, species which are present. Many authors claim that *Hemifusus* is a scavenging carrion eater, but Morton's work does not support this. On the contrary, it suggests that it is an active predator preferring live, infaunal gaping bivalve prey. There are anecdotal references to *Hemifusus ternatanus* being found on mangrove mudflats.

Note: Hong Kong fishermen, trawling on the continental shelf, catch these animals in considerable numbers for the local fish markets.

Provenance within site: L10, 3.

VOLUTIDAE

A widely-distributed marine family of some 200 species divided among about 70 genus-rank taxa placed in 9, sometimes 10, subfamilies. They are predominantly predators of other molluscs, occasionally scavenging in shallow to intertidal waters over sandy bottom. A few live in deep water. As in the Muricidae, there is much variation in shell shape in some species, and populations can be small and geographically scattered with direct development of the young from a small number of large eggs. This has resulted in up to (and over) 20 names being applied to some species (Weaver and duPont 1970).

Cymbiola nobilis (Lightfoot, 1786)

Synonyms: *Voluta scapha* Gmelin, 1791; *Voluta fasciata* Schubert and Wagner, 1829. The species has been placed by various authors in the following genera: *Voluta*, *Volutella*, *Aulica*, *Volutocorona* and various combinations of these.

Range: from Taiwan to Singapore and thence to the Philippines.

Habitat and ecology: from the lower littoral to about 70m on mud or sandy-mud sediments.

Provenance within site: L10, 2.

Melo sp.

Provenance within site: L10, 1; L9, 2.

Volutid sp.

Provenance within site: L10, 1.

OLIVIDAE

This predominantly tropical group of marine snails have highly-polished cylindrical shells generally 2–5cm in length but may exceptionally reach 10cm. They are essentially sand-dwelling scavengers and carnivores, and are known to eat small bivalves and small invertebrates. There are probably about 150 species (Chavan 1965, Kilburn 1981, Olsson and Dance 1966, Zeigler and Porreca 1969). They are for the most part gregarious. In common with the cypraeids, the shell, completely enveloped by the mantle, is highly polished, brightly coloured and often attractively patterned. Hence its use in many different cultures for personal adornment.

Oliva oliva candida Lamarck, 1811

Synonyms: Zeigler and Porreca (1969:74-5) give *O. ispidula* Röding 1798; *O. hispidula* Blainville, 1828; *O. ispidula* of authors, but not *O. ispidula* L., 1758 as synonyms of *Oliva oliva* and add *O. lacteana* Dautzenberg, 1927, as a synonym of Lamarck's *O. candida*.

Range: widespread in the Indo-Pacific region.

Habitat and ecology: shallow marine waters with a clean, sandy bottom.

Provenance within site: L10, 1.

Oliva sp.

Provenance within site: L10, 1; L8, 1; L7, 2.

CANCELLARIIDAE

This family of about 150 species has about 52 available genus-rank names split into four subfamilies. Most species live in temperate to tropical seas but a few prefer cold, boreal waters. They range from sandy intertidal shores to depths of over 2000m. Petit and Harasewych (1986) suggest that the highly-specialized radula found in this group is used to cut holes in the body sac of small invertebrates to reach internal fluids which are then sucked out (Verhecken 1986a, 1986b, Jung and Petit 1990, Petit 1970, 1974, 1975, 1980, 1984 and 1986, Harasewych and Petit 1984, Petit and Harasewych 1987 and Garrard 1975).

Scalptia cf. *crossei* (Sowerby, 1833) Fig. 55d

Synonyms: *Cancellaria crenifera* Sowerby, 1833; *Trigonaphera* Iredale, 1936, is identical to *Scalptia*.

Range: Indo-West Pacific oceans ranging south to Australia and north to Honshu.

Habitat and ecology: fine sandy bottom at 5–50m depth.

Provenance within site: L10, 5.

CONIDAE

This predominantly tropical marine group typically inhabits coral reefs and shallow waters. There are about 300 species which are usually less than 100mm tall but a few species may exceed 200mm. About 45 genus names are available, but many workers prefer to use only *Conus* until the taxonomy

is better understood. They are active carnivores, with a radula modified into protrusible, poisoned harpoon-like darts with which they catch small fish, worms, molluscs and other invertebrates. The venom is not infrequently fatal to humans (Walls 1978, Ponder 1973, Dautzenberg 1937, Kilburn 1971).

Conus betulinus (Linnaeus, 1758) Fig. 55g

Synonyms: *Cucullus lacteus* Röding, 1798; *Conus coralloides* Perry, 1811; *Conus betulinus immaculata*, Dautzenberg, 1906; *Conus betulinus alternans*, *Conus betulinus tabulata*, *Conus betulinus plurizonata*, *Conus betulinus scripta*, *Conus betulinus paucimaculata*, all of Dautzenberg, 1937.

Range: from East Africa throughout the Indian Ocean up to Japan and south to Queensland, Australia.

Habitat and ecology: an intertidal animal living on sand and sandy mud, also subtidally in shallow water.

Provenance within site: L10, 1; L9, 1; L8, 1; L6, 1; L5, 1.

Conus sp. A

Provenance within site: L10, 2; L8, 1.

Conus sp. B

Provenance within site: L10, 1; L7, 1.

TURRIDAE

A very large family of some 600 genus-rank taxa placed in 15 subfamilies. The shell can often be distinguished by the distinctive 'turrid notch' between the suture and periphery of the outer lip. They are carnivores, inhabiting mainly offshore deeper waters of all seas. All have a poisoned gland linked to barb-shaped teeth (McLean 1971, Powell 1966, Bouchet and Warén 1980, Sysoev and Ivanov 1985).

Turricula javana (Linnaeus, 1767) Fig. 55f

Range: Indo-West Pacific oceans, Japan.

Habitat and ecology: shallow to deep water on mud. An active predator.

Provenance within site: L10, 14.

TEREBRIDAE

A group of about 150 species of mainly tropical, sandy-bottomed gastropods adapted to shallow marine conditions where they feed on polychaetes and hemichordates (Cernohorsky and Bratcher 1976, Miller 1970).

Duplicaria duplicata (Linnaeus, 1758)

Synonyms: *Terebra lamarckii* Kiener, 1838; *Terebra reevei* Deshayes, 1859.

Range: Indo-West Pacific oceans where it is usually uncommon.

Habitat and ecology: intertidal on sandbanks.

Provenance within site: L10, 1.

ARCHITECTONICIDAE

A widely distributed family, most common in warm seas generally at shallow depths, but ranging down to 2000m. They are usually found associated with and feeding on coelenterates (Garrard 1977, Bieler 1988. The latter paper contains important references to his work from 1984-5).

Architectonica perspectiva (Linnaeus, 1758) Fig. 55c

Range: Indo-Pacific Oceans

Habitat and ecology: shallow water on sand.

Provenance within site: L9, 1.

AURICULIDAE

(=Melampidae Stimpson, 1851; = Ellobiidae, H. and A. Adams 1855)

This group of about 30 genus-rank taxa occupies a wide range of terrestrial, intertidal, supratidal and estuarine niches. Of world-wide distribution, these animals appear to be mainly vegetarian, grazing microalgae and consuming fine, organic detritus (Morton 1955a, 1955b).

Auriculastra elongata (Küster, 1844) Fig. 55h

Synonym: formerly placed in the genus *Auricula*.

Range: as for *A. subula*, but it extends to Hawaii, the type locality. In Thailand, it is presently known only from Trat Province.

Habitat and ecology: as for *A. subula*.

Provenance within site: L9, 1.

Auriculastra subula (Quoy and Gaimard, 1832) Fig. 55i

Synonyms: this species has been placed in both *Auricula* and *Marinula*. *Auriculastra dunkeri* and possibly *A. saccata* (both of Pfeiffer) and *semiplicata* A. Adams belong here.

Range: from Mauritius to South and South-East Asia, New Guinea, New Caledonia and eastern Australia.

Habitat and ecology: mangrove swamps, nypa palm forests and well-vegetated mudflats.

Provenance within site: L6, 1.

Cassidula aurisfelis (Bruguière, 1789) Fig. 55j

Synonyms: *Auricula felis* Lamarck, 1819, *A. fusca* Hombron and Jacquinot, 1841.

Range: coasts of India, Burma, Thailand, Malaysia, Indonesia to the Philippines and southern Vietnam.

Habitat and ecology: this animal lives on the mud in mangal and nypa swamps within a few tens of centimetres of the high spring tides so that it probably spends most of its time out of the water. They feed on the organic detritus found on the mud surface and breed all through the year (Berry 1958).

Provenance within site: L11, 3; L10, 125; L9, 112; L8, 44; L7, 28; L6, 191; L5, 113; L4, 110.

Cassidula mustelina (Deshayes, 1830) Fig. 55k

Synonyms: *Auricula mustelina*, *Auricula rhodostoma* Rousseau in Hombron and Jacquinot, 1854.

Range: from Mauritius through South-East Asia to the Philippines, New Guinea, north-east Australia and up to Taiwan.

Habitat and ecology: common in mangrove and nypa palm forests in coastal areas.

Provenance within site: L10, 7; L9, 2; L8, 4; L6, 1; L5, 1; L4, 1.

Ellobium aurisjudae (Linnaeus, 1758) Fig. 56a

Synonyms: *E. labrosum* and *E. subtile* Röding, 1798. *E. judae* Lamarck, 1822.

Range: westward from the Western Pacific.

Habitat and ecology: mangrove swamps

Provenance within site: L11, 111; L10, 412; L9, 47; L8, 6; L7, 6; L6, 4; L5, 4; L4, 4.

Ellobium aurismidae (Linnaeus, 1758) Fig. 56b

Synonyms: *E. midae* and *E. ceramence*, both of Röding, 1798.

Range: ranges westward from the West Pacific.

Habitat and ecology: found near mangrove swamps.

Note: the specimens from the site are atypical of the species at large in their apertural form and may eventually, with better material, be found worthy of subspecific rank.

Provenance within site: L11, 1; L10, 22; L9, 4; L8, 1; L6, 1.

Laemodonta siamensis (Morelet, 1875) Fig. 56c

Synonym: this species has often been placed in *Plecotrema*.

Range: eastern maritime Thailand, Borneo, Sumatra, Sulawesi, southern Korea and the Philippines with a dubious record for Malaysia.

Habitat and ecology: mudflats, nypa palm forests and mangrove swamps.

Provenance within site: L9, 1.

Melampus flavus (Gmelin, 1791) Fig. 56d

Synonyms: *M. monile*, Q and G, 1832 (*non* Lamarck, 1822): *M. taeniolatus* Hombron and Jacquinot, 1854; *M. fortis*, Mousson, 1869.

Range: throughout the tropical Pacific.

Ecology and habitat: landward aspect of mangal.

Provenance within site: L10, 1; L9, 1.

Melampus (Micromelampus) nucleolus (von Martens, 1865) Fig. 56e

Range: New Guinea, Ceram and the Philippines. In Thailand, it is presently known only from Trang Province.

Habitat and ecology: mangrove forest, but exact microhabitat unknown.

Provenance within site: L10, 1; L9, 1; L6, 1.

Melampus (Micromelampus) siamensis (von Martens, 1865) Fig. 56f

Range: Indo-West Pacific oceans. Previously recorded only from Petchburi Province.

Habitat and ecology: mudflats and mangrove forest.

Provenance within site: L10, 3; L8, 1; L6, 1.

ENIDAE (BULIMINIDAE)

This group of land snails, containing about 77 genus-rank taxa, is divided into 4 subfamilies. They are widely distributed in Europe, Africa and Asia.

Enid sp. A Fig. 56j

Provenance within site: L6, 2; L5, 5; L4, 3.

FERUSSACIDAE

A family of land snails of tropical and subtropical distribution, containing about 20 genus-rank taxa. Some genera (e.g. *Cecilioides*) are subterranean or cryptozoic in soil. The shells are generally less than 10mm in spire height, and are glazed, shining and transparent to translucent. This group is especially abundant in the Mediterranean area.

Cecilioides spp. Fig. 56g

Provenance within site: L6, 12; L5, 18; L4, 2.

SUBULINIDAE

A group of land snails with about 74 genus-rank taxa divided into 4 subfamilies. In general, they have high, translucent turreted shells typically small, but may attain 100mm.

Bacillum sp. Fig. 56i

Provenance within site: L6, 6; L5, 22; L4, 25.

ARIOPHANTIDAE

Macrochlamys sp. Fig. 56k

Provenance within site: L6, 4; L5, 11; L4, 34.

NUCULANIDAE

A small group of predominantly offshore deep-water infaunal bivalves. Some of the genera are more or less cosmopolitan, but most species are found in the Indo-Pacific area. A few are subtidal. They seem to be detritivores (Dell 1955, Allen and Hannah 1986).

Nuculana sp. Fig. 57a

Provenance within site: L10, 1.

ARCIDAE

This predominantly marine family of about 25 genus-rank taxa contains 2 subfamilies. There may be about 200 species, but the family is in urgent need of revision. Most members are either infaunal in the lower littoral or sublittoral with a few descending to abyssal depths or byssally attached to hard surfaces in shallow water. One fresh water species is known. They appear to be both deposit and plankton feeders (Reinhart 1935, Sheldon 1917, Lamy 1907).

Anadara granosa (Linnaeus, 1758) Fig. 57b

Range: South-West Pacific, South-East Asia, Australia northwards to Honshu.

Ecology and habitat: this 'cockle' (and the closely-related *Anadara nodosa*, von Martens) has been of economic importance since prehistoric times, and is at present widely cultivated commercially in Thailand (since about 1900), Malaysia and elsewhere in the Indo-Pacific region. This species spawns in July to August and by the age of 6 months usually reaches a size of c.18mm in diameter (c. 50gm), when it can be transplanted for commercial farming. The spat can be collected either in the wild or from seedbeds at a smaller size (0.5gm) and transplanted, but with poorer results. The animals are harvested after 18–24 months, when they have reached about full size of 5–6cm in diameter. The smallest size taken is about 26mm. They are harvested with hand dredges, generally used from small boats.

This species prefers a substrate of fine silt and silty muds which are relatively free of sand. They inhabit areas about mangal coast, especially near river, estuarine and other fresh water outlets where wave action and rapid siltation are at a minimum. The animals are quite active and can recover from modest burial (a few cm of sediment) and can move laterally by means of a muscular foot. They are suspension filter feeders, recovering algae and other phyto- and zooplankton from near the

water/sediment interface. Some detritus is also found in the gut. Despite living near fresh water sources (which provide nutrients for plankton proliferation), salinities of less than 25‰ are fatal. Normal marine salinity is about 35‰ of dissolved solids. The preferred growing area under natural circumstances is 200–500m offshore, situated from mid-tide down to Mid Low Water Spring Tide, the slope being less than 15° from horizontal. Tidal exposure is not usually more than 2–3 hours per cycle. Predators (apart from man) are birds, starfish and, among the molluscs, *Natica tigrina* and *Cymia lacera*, both of which are well represented in the site.

Provenance within site: L11, 19693; L10, 379393; L9, 92848; L8, 65286; L7, 21734; L6, 42446; L5, 15287; L4, 8576.

Anadara gubernaculum (Reeve, 1844) Fig. 57b

Synonyms: *Arca chalcantum* Reeve, 1844; *Arca luzonica* Reeve, 1844.

Range: Gulf of Siam, Philippines, China, Taiwan and north-east Australia.

Habitat and ecology: found in clean sand, generally associated with coral.

Provenance within site: L10, 770.

Anadara nodifera (von Martens, 1860) Fig. 57d

Synonyms: *Arca oblonga* Philippi, 1849.

Range: Taiwan, Japan, Philippines, Malaysia and Burma.

Habitat and ecology: a sublittoral dweller down to about 10m in fine sand or sandy mud, often locally very abundant.

Provenance within site: L10, 44; L8, 2; L7, 1; L6, 3; L5, 1.

Anadara secticostata (Reeve, 1844) Fig. 58a

Synonym: *Arca scapha* Lamarck, 1819 in part; the other part of the Lamarck species being the somewhat similar *Arca antiquata* Linnaeus, 1758.

Range: Indo-West Pacific Oceans.

Habitat and ecology: frequently in clean, shallow water.

Provenance within site: L11, 2; L10, 54; L9, 2; L6, 1.

Anadara uropygimelana (Bory de St.-Vincent, 1824) Fig. 57f

Synonyms: *Arca uropygimelana* Kobelt, 1891; *Arca holoserica* Reeve, 1843; *Arca planicostata* Philippi in Kobelt, 1891; *Anomalocardia holosericea* Reeve of Jousseaume, 1888.

Range: western Pacific, the Red Sea and southern Mozambique, east to the Philippines, Java and New Caledonia.

Habitat and ecology: clean, shallow water in sandy coralline areas.

Provenance within site: L10, 4; L8, 3.

NOETIIDAE

A small family of 7 genera, related to the Arcidae. They are virtually cosmopolitan in shallow seas, where they are free-living filter feeders (Oliver 1987a).

Scelidionarca pectunculiformis (Dunker, 1866) Fig. 57g

Synonyms: *Barbatia pectunculiformis* Dunker 1866; *Noetia pectunculiformis*.

Not *Fossularca pectunculiformis* Lynge, 1909:115; nor *Noetia pectunculiformis* var. *minor* Pallary, 1939:125-6, nor *Striarca afra* (Gmelin, 1790) (Stevenson 1972:200). Range: Indo-West Pacific oceans, Borneo.

Habitat and ecology: Oliver (1987b:286) infers from the shell morphology of this species that it has an infaunal habit. Further information waits upon field observation.

Provenance within site: L10, 7; L9, 4; L8, 5; L7, 8; L6, 6; L5, 4; L4, 2.

MYTILIDAE

A large and diverse family of marine and estuarine mussels with the rare fresh water member. There are about 260 species placed in nearly 70 genus-rank taxa divided currently into 4 or 5 subfamilies. Many of them are inter- and subtidal epibenthic filter feeders forming large colonies. They are generally attached to the substrate by a stout byssus. Others bore into rocks and corals, while some (mainly the Modiolinae) are free-living (Bayne 1976, Lamy 1936, 1937, Soot-Ryen 1955, 1969, Dell 1987).

Mytilid sp. A

The remains are too fragmentary to be identified below family level. There is probably more than one species present.

Provenance within site: L10, 4; L8, 1.

Mytilid sp. B

Provenance within site: L10, 1; L6, 4.

PTERIIDAE

These 'pearl oysters' live mainly in shallow waters in subtropical and tropical seas, generally attached by byssal threads to hard substrates in clean water (Ranson 1961).

Pinctada sp. A

These specimens are too damaged to identify to species level, but show some resemblance to *Pinctada fuscata* (Gould, 1850). This genus commonly inhabits coral rubble in shallow water. It is a byssally-fixed member of the epibenthos.

Provenance within site: L10, 2.

Pinctada sp. B

This appears to be a large *Pinctada* as in the *Pinctada martensi* group. The single specimen has been used as an artefact and has been heavily modified.

Provenance within site: L10, 1.

Pinctada sp. C

This comprises one fragmentary valve somewhat reminiscent of *Pinctada nigra* (Leach).
Provenance within site: L10, 1; L8, 1.

ISOGNOMONIDAE

A small family of 3 genera and about 20 species, many of which are attached by a byssus to the substrate. They are most common in warm, shallow marine waters where they sometimes occur in large numbers (Fischer-Piette 1976).

Isognomon spp. Fig. 58b-c

Note: the material is too fragmentary for identification to species.
Provenance within site: L10, 30; L9, 3; L8, 2; L5, 1.

OSTREIDAE

The true oysters. Many authors have divided this family into two groups: those that incubate their young in the mantle cavity and live in relatively non-turbid water of normal salinity and those non-incubatory oysters that live in low salinity turbid conditions such as in estuaries. An example of the former is *Ostrea*, and of the latter, *Saccostrea* and *Striostrea* (Ranson 1967, Thompson 1954, Harry 1985).

Saccostrea cucullata (Born, 1778)

Synonyms: *S. glomerata* Quoy and Gaimard, 1835, *S. denticulata*, *S. echinata* Quoy and Gaimard, 1835, *S. mordax* (Gould, 1850), *Saxostrea commercialis* (Iredale and Roughley, 1933), *Ostrea cornucopiaeformis* (Saville-Kent, 1893).

Range: this is one of the most widespread of all the oysters, ranging from East Africa and throughout the Indo-Pacific Ocean.

Habitat and ecology: occurs in mangal, attached to roots, branches or anything else which provides a hard surface for attachment. This species is found in a wide range of environments from wave-washed cliffs to the most quiet of backwaters. The low energy environments are marked by rudistiform ecotypes as are the specimens from Khok Phanom Di.

Provenance within site: L11, 7; L10, 37; L9, 5; L8, 1; L6, 4; L5, 5; L4, 4.

SPONDYLIDAE

The thorny oysters. A family of one genus, *Spondylus*, and about 50 species. The group is widely distributed in tropical and subtropical seas. In the adult, the lower (right) valve is cemented firmly to hard substrates. Some species may grow to 40cm in length. Shallow coralline waters are preferred (Dakin 1928, Lamprell 1986, Phillipe 1989a, 1989b, Lamy 1938).

Spondylus sp.

A number of fragmentary valves without hinge lines are probably referable to this family.
Provenance within site: L8, 1; L7, 1.

ANOMIIDAE

The saddle oysters. This group contains 8 genus-rank taxa and very few species. The lower (right) valve generally has a hole or a notch to allow passage of the byssus by which the animal is firmly fastened to the substrate. They are widespread in the world's seas (Yonge 1977, Morton 1976).

Anomia sp.

Provenance within site: L10, 1.

PLACUNIDAE

Window-pane shells. This small family of two genera is very similar to the Anomiidae but in the adult, the byssal notch or foramen is closed and the animals may be either byssally attached or free living. They are generally found in shallow, muddy marine waters (Yonge 1977).

Placuna placenta (Linnaeus, 1758) Fig. 58d

Synonyms: *P. orbicularis* Retzius, 1788; *P. auriculata* Yoldi, 1790.

Range: a widely distributed Indo-West Pacific species ranging from Aden and the Persian Gulf in the west around India and Sri Lanka to Burma and South-East Asia down to Australia and up to China and Japan.

Ecology and habitat: A lagoonal species also found on mud, clay and muddy gravel substrates intertidally to depths of c. 40m.

Provenance within site: L10, 77; L9, 26; L8, 21; L7, 15; L6, 10; L5, 3; L4, 1.

Placuna sella (Gmelin, 1791) Fig. 58e

Range: South-West Pacific, South-East Asia.

Habitat and ecology: subtidal silts.

Provenance within site: L10, 7; L9, 1; L8, 5; L7, 2.

MARGARITIFERIDAE

Margaritanopsis laosensis (Lea, 1863)

Range: Burma, northern Thailand, Laos. Not known from Cambodia. Brandt (1974:261) notes that, despite intense research, his team found only some fossil material in the Pai River valley, Mae Hongson Province.

Habitat and ecology: in fresh water creeks and small rivers.

Provenance within site: L10, 3; L8, 1.

UNIONIDAE

This group of world-wide fresh water mussels of some few hundred species is placed in about 197 genus-rank taxa. Despite a lot of work, the taxonomy of the whole order (Unionoida) is very much in a state of flux but will stabilize as molecular techniques are increasingly applied (Haas 1969, Heard and Gluckert 1970).

Pilsbryconcha exilis exilis (Lea, 1839)

Synonyms: *Anodonta polita* Mousson, 1848; *Monocondylaea compressa* Lea, 1863; *Anodon politus* Sowerby, 1867; *Anodon gracilis* Sowerby, 1867; *Anodon kelletti* Sowerby, 1867; *Anodonta sempervivens* Deshayes, 1876; *Anodonta laminata* Rochebrune, 1881.

Range: Thailand, Laos, Cambodia, southern Vietnam, Malaysia and Indonesia.

Habitat and ecology: still, clear fresh water with rich vegetation.

Provenance within site: L10, 7; L9, 1; L7, 1.

Parasitology: infected with the metacercariae of several species of Echinostomatidae (Brandt 1974:263-4). This is transmissible to humans, where it affects the liver.

Pseudodon inoscularis (Gould, 1844) Fig. 59a

Synonyms: *P. crebristriata* Anthony, 1865.

Range: Salween River and tributaries. In Thailand, known only from the Salween west of Mae Sarieng and the Moei River. Reported from the Pegu and Tenasserim rivers.

Habitat and ecology: rivers, streams and ponds.

Note: Brandt (1974:267-8) has reduced the following species to *Pseudodon inoscularis* thus: *callifer* Martens, 1860; *harmandi* Crosse and Fischer, 1876; *cumingi* Lea, 1850. He notes that the differences may well be due to habitat rather than a demonstration of geographic races.

Pseudodon mouhoti (Lee, 1863).

Habitat and ecology: mountain streams, rivers with sandy ground.

Provenance within site: L10, 8; L9, 6; L8, 4; L7, 5; L6, 1; L5, 1.

Pseudodon spp.

Most of this material is very fragmentary and/or highly modified for use as artefacts. With the possible exception of *P. inoscularis* and *P. mouhoti*, the bulk of the material cannot be identified in detail because of the number of geographic races, which may be little more than ecotypes and the shell-character overlaps of the various *Pseudodon* species. The majority of identifiable shells appear to belong to *P. inoscularis*, predominantly *callifer* with a smaller number of *Pseudodon inoscularis harmandi* and possibly some *P. i. cumingi*. It is almost certain that a small number of *Pseudodon vondembuschianus chaperi* (Morgan, 1885) are present, but no serious attempt has been made to isolate them. Three further species are also present, but cannot be identified consistently from fragmentary remains. These are *Pseudodon inoscularis callifer* (Martens, 1860), which inhabits large rivers, *Pseudodon inoscularis harmandi* Crosse and Fisher, 1876, which is adapted to streams and small rivers in South-East Thailand and Cambodia and *Pseudodon inoscularis cumingi* (Lee, 1850). This species is adapted to streams and rivers, but never in standing water.

Only *Pseudodon mouhoti* has been shown separate from *Pseudodon* species (which includes it in the table).

Provenance within site: L10, 124; L9, 192; L8, 142; L7, 97; L6, 47; L5, 6.

Uniandra contradens rustica (Lee, 1856) Fig. 59b

Synonyms: *Nodularia rustica* Suvatti 1950, *Contradens rusticus* Haas 1952, *Unio thaiensis* Habe 1964.

Range: Cambodia and Thailand: Phetburi River, Chao Phraya basin, Mekong basin and Bang Pakong River.

Habitat and ecology: large rivers and streams.

Provenance within site: L10, 3; L9, 3; L8, 5; L7, 5.

Uniandra contradens tumidula (Lee, 1856)

Synonym: *Unio asperulus* Lee, 1866.

Range: Laos, Cambodia, southern Vietnam and throughout Thailand.

Habitat and ecology: trenches, canals and ponds.

Provenance within site: L9, 2; L8, 5; L7, 3; L6, 1; L5, 1.

LUCINIDAE

A moderately large family comprising some 47 currently recognized genus-rank taxa in 4 sub-families. This family is cosmopolitan, but predominantly tropical and subtropical in shallow (and intertidal) water over soft sediments which are frequently coral mud and sand. It also ranges into deep water. The family is noted for its overwhelming ability to survive in highly marginal, stressful environments with rapid and large temperature and salinity fluctuations, oxygen poor and anoxic water and sediments and high levels of hydrogen sulphide. These infaunal, usually deeply buried animals, appear to be suspension rather than deposit feeders with some degree of omnivory. They have many unusual food-collecting mechanisms, one of which in particular allows them to consume large organic particles. They are thus peculiarly well fitted, almost to the total exclusion of other bivalve groups, to occupy the angiosperm seagrass biotope. They also have a mutualistic feeding association with bacteria.

'Lucina' philippinarum Reeve, 1850

Range: 'Bay of Manila and Singapore' (Reeve 1850).

Habitat and ecology: 'in sandy mud at the roots of mango-trees' (Reeve 1850).

Provenance within site: L10, 1.

CHAMIDAE

A small family of sedentary marine bivalves commonly called 'jewel boxes'. The flat left valve is cemented to hard substrates, generally in shallow to intertidal clean waters, especially in coral reef areas. They are known to have been eaten in the Hawaiian Islands in prehistoric times (Kay 1979, Nicol 1952a, 1952b, Bernard 1976, Lamprell in press).

Chama reflexa Reeve, 1846

Range: Indo-West Pacific oceans.

Habitat and ecology: commonly found on rocks and pebbles between tide marks.

Provenance within site: L10, 1.

CARDIIDAE

The heart cockles. The 200 species comprising this family are placed in 43 genus-rank taxa divided into 5 subfamilies. They are mainly marine, but a few are found in brackish water. Most are shallow, infaunal filter feeders moving about actively just below the sediment surface and when disturbed are capable of jumping and swimming to escape predators. The family is virtually cosmopolitan and many of its species are palatable to and easily taken by humans. They occur abundantly in sand and mudflats (Kafanov 1978, Kafanov and Popov 1977, Keen 1980).

Acrosterigma (Regozara) flavum (Linnaeus, 1758)

Synonyms: The generic placing of the species has no consensus. Abbott and Dance (1982:328) place it in *Trachycardium*, while Cotton (1961:241) placed it in *Vasticardium* and remarked that *Regozara* of Iredale 1936 is based on Iredale's *Regozara olivifer*, which is a neonym for *Cardium flavum* Linnaeus, 1758. However, Keen (1969:587) places *Vasticardium* as the subgenus of *Acrosterigma*.

Range: Indo West-Pacific, ranging from Australia to Japan.

Habitat and ecology: not uncommon in clean sandy bottom in offshore waters at depths of 10-15m, not infrequently found on sandy beaches.

Provenance within site: L10, 1.

Note: this specimen has been moderately beach-rolled, and has not been collected live.

TRIDACNIDAE

Despite the fact that there are only seven living species in this family, their large size (*Tridacna gigas* is the largest known living bivalve) and their peculiar anatomy and nutritional mechanisms has occasioned an extensive literature. The best entry to this area is through Morton (1983:139-224), Rosewater (1965, 1982), and Yonge (1980). These authors provide good reviews and bibliographies of the taxonomy, nomenclature, biology and ecology of these animals. The shell from members of this family has been widely used by many peoples, including those of Khok Phanom Di, for the manufacture of hand tools and other items. Seventeen fragments of tridacnid shell were recognized, representing at least three species.

Tridacna derasa (Röding, 1798)

Range: at present only at the outer end of the Gulf of Siam, also in the western Indian Ocean and western Pacific.

Habitat and ecology: because of its size, which is over 50cm in length, this taxon can live in a variety of areas ranging from the outer barrier reef (intertidally to depths of 0.5m below C.D.), to

large sandflats with few coral patches, to lagoonal coral heads, but usually in lagoons associated with acropora coral rubble at depths ranging from 0–20m.

Provenance within site: L9, 1.

Tridacna maxima (Röding, 1798)

Synonym: *Tridacna elongata* Lamarck, 1819.

Range: Gulf of Siam, Indo-West Pacific oceans to central Pacific.

Habitat and ecology: this species commonly grows to a length of 35cm and typically lies free on the surface of coral reefs or coral sand or partly embedded in coral. It may byssally attach to coral reef platforms, especially those of barrier and fringe reefs and is somewhat rare in sheltered bays.

Provenance within site: L4, 1.

Tridacna squamosa Lamarck, 1819

Synonyms: *Tridacna imbricata* (Röding, 1798).

Range: Africa, Indo-West Pacific oceans, South-West Pacific.

Habitat and ecology: this species grows to about 40cm in length and settles in more sheltered coral reef areas, where it attaches to living corals, often in shallow lagoons or calm water, but also known from fringe and barrier reefs. Usually associated with acropora coral.

Provenance within site: L10, 5; L9, 1; L7, 1.

Tridacna spp.

All the recognizable tridacnid material is either in the form of tools or variously worked and/or eroded fragments, a number of which cannot be ascribed at any species. It is thought probable that, while *Tridacna gigas* is known from the Gulf of Siam, the fragments could be accommodated by any of the three other species mentioned.

Provenance within site: L10, 1; L7, 2; L6, 2; L5, 1; L4, 2.

MESODESMATIDAE

A small group of about 40 species. They are marine or estuarine, actively burrowing in sediments in shallow water. Their siphons are used for filter feeding (Beu 1971, Lamy 1914).

Atactodea striata (Gmelin, 1791) Fig. 57e

Range: Indo-West Pacific oceans and Indonesia.

Habitat and ecology: sheltered beaches with wide sandflats and a shallow slope. These beaches receive little wave action and are usually composed of fine, well sorted sand.

Provenance within site: L10, 5; L9, 1; L6, 1.

Coecella horsfieldi

According to Beu (1971), this genus has been spelled *Caecella* due to a misreading of the original description of the genus by Gray 1853.

Synonyms: *Caecella oblonga*, *C. transversalis* and *C. zelandica* all of Deshayes, 1854.

Range: Indo-West Pacific oceans, West Pacific, South-East Asia.

Ecology and habitat: this animal lives in sublittoral sandflats and in sandbars near river mouths where there may be both scouring and, occasionally, reduced salinity.

Provenance within site: L10, 4.

Donacilla nitida (Deshayes, 1854) Fig. 59d

Range: Australia and South-East Asia.

Habitat and ecology: this species lives on sandy beaches, where it is buried at shallow depths above and below low tide mark.

Provenance within site: L10, 32; L9, 19; L8, 29; L7, 28; L6, 46; L5, 2; L4, 2.

TELLINIDAE

This is a rather large family of about 94 genus-rank taxa, generally split into 2 subfamilies, the Tellininae and the Macominae, with a third, Strigillinae, adopted by some authors. Tellinids are strictly marine and range all oceans and seas from the poles to the equator, and range from high-water neap tides to depths in excess of 1000m. Predominantly infaunal shallow water deposit feeders (with a few suspension mixed-mode feeders), the tellinines and strigillines are tropical and subtropical, while the macomines are cold temperate to polar. The containing substrate may range from fine muds to coarse gravels.

Important taxonomic and ecological works for the Indo-West Pacific members of this group are: Afshar (1969) (importantly, in conjunction with Boss 1971); Boss (1966, 1969 and 1971); Dall (1900), who gives a good bibliography of the literature from Linnaeus to 1900; Lamy (1920); Salisbury (1934) and Yonge (1949), preferably to be read with Pohlo (1969).

Apolymetis spectabilis (Hanley, 1844)

Range: Philippines, Australia, Japan.

Habitat and ecology: unknown.

Provenance within site: L10, 2.

Tellina (Serratina) capsoides Lamarck, 1818 Fig. 59e

Synonyms: *Tellina pristis* Lamarck, 1818; *Tellina lima* Philippi, 1847; *Tellina concentrica* Gould, 1850; *Tellina diaphina* Deshayes, 1854; *Tellina denticulata* Deshayes, 1854; *Tellina (areopagia [sic]) siamensis* von Martens, 1860; *Tellina negrosiensis* Burton, 1878; *Tellina (Tellinella) thymares* Melville, 1896; *Tellina (Merisca) pristiformis* Pilsbry, 1901; *Pristis audouini* Lamy, 1918; *Tellina (Pristis) pristis major* Lamy, 1918.

Range: east coast of Africa to Suez, across the Indian Ocean to South-East Asia and thence north to Japan, south to Australia and east to Fiji.

Habitat and ecology: shallow water off mangal coast, in soft sediments of sand to mud grade, frequently intertidal and sometimes in estuaries.

Provenance within site: L10, 1; L7, 1.

Tellina (Tellinides) opalina Gmelin, 1791 Fig. 60a

Synonyms: *Tellinides rosea* Crouch, 1827 (*non* Gmelin 1791, *nec* Spengler 1798); *Tellina planissima* Anton, 1839.

Range: there appear to be two populations, one in the western Indian Ocean, and the other centred on South-East Asia but extending east to Fiji.

Habitat and ecology: the scanty information available suggests an estuarine or near a river mouth setting.

Provenance within site: L.10, 1.

Tellinid sp.

This material is too fragmentary to identify below subfamily level. It is probably tellinine.

Provenance within site: L10, 5.

PSAMMOBIIDAE

This group of shallow-water marine infaunal deposit feeders contains about 100 species ranged in about 30 genus-rank taxa. Their bright, radial colour banding in red, orange and purple gives rise to the popular name of sunset shells. A small group (the Novaculinae) in South and South-East Asia is found in fresh and brackish water (Coan 1973, Ghosh 1920).

Asaphis violascens (Forskäl, 1775) Fig. 60b

Synonym: *A. dichotoma* (Anton, 1839).

Range: tropical Indo-West Pacific oceans.

Habitat and ecology: in muddy or gravelly substrates at low tide, and especially sandy beaches at the same level.

Provenance within site: L10, 125; L9, 1; L8, 2; L6, 2.

CORBICULIDAE

This family of fresh to brackish water bivalves is found mainly in tropical and subtropical areas. Many of the larger species are taken for food (Prashad 1924, 1928b).

Polymesoda (Geloïna) erosa (Solander, 1786) Fig. 60c

Most modern authors would agree that there are only three species of *Polymesoda (Geloïna)*. These are: *P. (G.) erosa*, *P. (G.) expansa* (Mousson, 1849) and *P. (G.) bengalensis* (Lamarck, 1818). These appear to be the earliest valid names for these taxa. Specimens from this site are all attributed to *P. (G.) erosa*, but it is probable that there are some *P. (G.) expansa* which could not be distinguished statistically on measurements of over 100 valves. Brandt (1974) also lists three species with a dubious fourth species. They are: *P. (G.) coaxans* (Gmelin, 1791), (= *P. (G.) erosa*),

P. (G.) proxima (Prime, 1864) (= *P. (G.) expansa*), and *P. (G.) bengalensis* (Lamarck, 1818) and *P. (G.) galathea* (Mörch, 1850). Brandt considers that this last species is probably a slightly elongate form of *P. (G.) bengalensis*, with which the present author concurs. For further information on the synonymy of these three species, see Brandt (1974:309 ff) and Morton (1983:309).

Habitat and ecology: both *P. (G.) erosa* and *P. (G.) expansa* are largely sympatric with a widely overlapping geographical distribution in the Indo-Pacific. Typically, these species occur together in pools or runnels on the landward side of coastal mangal where the soil pH may drop to less than 5.4 and where the shells are rarely covered by the tides and considerable periods of emersion are the rule. This is one of the few molluscan genera which appears to be confined to mangal both in the New and the Old Worlds.

Note: Whilst it seems likely that the *Polymesoda* shells have been brought into the site for food, there is also a possibility that some of the shells, on close scrutiny, exhibit signs of industrial use as is recorded by Glover (1986:151 ff) for various prehistoric peoples in South-East Asia and Australia.

Provenance within site: L11, 48; L10, 652; L9, 149; L8, 85; L7, 96; L6, 336; L5, 81; L4, 48; L3, 2.

VENERIDAE

This large, diverse and possibly polyphyletic family is currently split into twelve subfamilies with about 150 genus-rank taxa. There are probably in excess of 500 species all of which are marine in shallow to deep water worldwide. Most are infaunal, shallow-burrowing suspension filter feeders (Palmer 1927, Fischer-Piette and Delmas 1967, Fischer-Piette and Metivier 1971, Frizzell 1936, Nielsen 1964, Fischer-Piette and Vukadinovic 1977).

Anomalocardia squamosa (Linnaeus, 1758) Fig. 61a

Synonyms: *Venus squamosa* Linnaeus, 1758, *Cryptogramma squamosa*; *Anomalocardia* (*Anomalodiscus*) *squamosa*.

Range: Gulf of Siam, Singapore, Mergui Island, thence westwards variously to the Gulf of Manar, to the north up to Japan and southwards to Australia (Sydney).

Habitat and ecology: a strand species known from mangal coasts, found predominantly intertidally in fine sand.

Provenance within site: L10, 9; L8, 1; L7, 2.

Bassina (*Callanaitis*) cf. *parva* Marwick, 1927 Fig. 60d

Range: this subgenus ranges from eastern Australia and New Zealand to the Philippines, Indonesia, South-East Asia and southern Japan.

Habitat and ecology: sandy mudbanks.

Note: Kotaka (1977:128) remarks that the type material for a closely-related species (*B. (C.) hayasakai*) was recorded from a shell mound near Miaoli, Taiwan, which suggests that there is one prehistoric community which may have had culinary, decorative or industrial uses for this species.

Provenance within site: L10, 9; L9, 1; L8, 1; L7, 1.

Circe scripta (Linnaeus, 1758) Fig. 61b

Range: Indo-West Pacific oceans up to Japan.

Habitat and ecology: from the lower intertidal zone to depths of 7–10m on clean sand where it may be locally abundant.

Provenance within site: L10, 2.

Dosinia juvenilis (Gmelin, 1791)

Synonym: *Dosinia juvenis* (Dillwyn, 1817). This species is close to *Dosinia histrio* (Gmelin, 1791) and it is possible that it appears in the literature under this name.

Range: South-West Pacific, Philippines to Japan.

Habitat and ecology: subtidal shallow water, probably in fine sand.

Provenance within site: L10, 13.

Dosinia trailli (A. Adams, 1855) Fig. 61c

Range: unknown.

Habitat and ecology: probably sublittoral in sands and muddy sands.

Provenance within site: L10, 9.

Marcia hiantina (Lamarck, 1818) Fig. 61d

Synonyms: *Venus virginia* L., 1767 (*partim*); *Venus callipyga* (non Born), *remularis*, *vermiculosa*, *flammiculata*, all of Lamarck, 1818; *Tapes luzonica* Sowerby, 1852; *Tapes radiata* Deshayes, 1853.

Authors have combined the above species names (with appropriate changes of gender) with the following genus-rank names: *Venus*, *Tapes*, *Hemitapes*, *Paphia* and *Katelsysia*.

Range: Indo-West Pacific oceans, South-East Asia (including the Gulf of Siam), north to Japan and south to Australia.

Habitat and ecology: mudflats and channels in mangal.

Provenance within site: L11, 1; L10, 274; L9, 5; L8, 2; L7, 10; L6, 5.

Meretrix lusoria (Röding, 1798) Fig. 62a

Synonyms: *M. cytherea* Lamarck, 1805 (*non* Fabricius, 1794); *M. nympha* Mörch, 1853 (*non* Fitzinger, 1826). Frequently confused with *Meretrix meretrix* (Linnaeus, 1758), which is mainly confined to parts of the Philippine Islands.

Range: South-East and East Asia up to and including Japan, Korea and China.

Habitat and ecology: found in vast numbers in sandy ground from just below low tide down to about 20m.

Note: this species is of commercial importance as a food source in most of the areas in which it occurs.

Provenance within site: L11, 1607; L10, 19949; L9, 3357; L8, 1299; L7, 555; L6, 27; L5, 11; L4, 3.

EXCAVATION OF KHOK PHANOM DI

Paphia undulata (Born, 1778) Fig. 62b

Synonym: *P. scordalus* Iredale, 1962; *Tapes rimosa* Sowerby, 1852. This species has also been placed in the subgenera *Paratapes* and *Neotapes*, both in *Paphia*.

Habitat and ecology: may form large colonies in muddy, sheltered intertidal substrate to a depth of 20m. Commonly eaten.

Range: widespread and common throughout the Indo-West Pacific oceans.

Provenance within site: L11, 3; L10, 82; L9, 2.

Pelecyora trigona (Reeve, 1850) Fig. 62c

Synonyms: this species has been placed in the genera *Artemis*, *Cytheraea* and *Dosinia*.

Range: Indo-West Pacific oceans.

Habitat and ecology: an infaunal, suspension feeding animal living in intertidal mudflats often with *Anadara granosa* which it may locally outnumber 3:2 (Broom 1982:139).

Provenance within site: L11, 5; L10, 118; L9, 34; L8, 13; L7, 4; L6, 16; L5, 1.

Ruditapes philippinarum (Adams and Reeve, 1850) Fig. 62d

Synonyms: *Tapes denticulata* Sowerby, 1852, *T. japonica* Desh., 1853, *T. semidecussata* Reeve, 1864.

Range: Sakhalin Island, south to Japan, China, Korea, Taiwan and South-East Asia, but despite its name, not the Philippines, the true type locality being southern Korea (Kuroda *et al.* 1971:426).

Habitat and ecology: this species inhabits sandy and gravelly mud in the intertidal zone, in sheltered areas and to a depth of 20m. In Japan, this edible bivalve is of considerable economic importance.

Provenance within site: L10, 4.

CORBULIDAE

A small family of about 100 species placed in 17 genus-rank taxa. They are mainly marine and estuarine and are rare in fresh water. Living infaunally, they are siphonate filter-feeding shallow burrowers, some of which may attach to the substrate with byssal threads. Sediment surfaces are also browsed for diatoms, bacteria and organic debris (Lamy 1941, Yonge 1946, H. E. Vokes 1945).

Corbula erythron Lamarck, 1818

Synonym: *Corbula pallida* Hinds, 1843.

Range: east and north-east of Asia up to Japan and spasmodically in the central West Pacific area.

Habitat and ecology: subtidal, somewhat offshore to 20m depth in sandy bottom and sometimes gravel and shell debris.

Provenance within site: L10, 1.

TEREDINIDAE

Members of this family, the shipworms, are notorious for their wood-boring habits. The pelagic larvae settle on wood surfaces, then eat their way through the object to form tunnels metres long, lined with a calcareous glaze. The shells which surround the anterior end of these animals are highly variable and generally of little diagnostic value even at the generic level. However, the pallets, a pair of variously ornamented rods of calcium carbonate, are usually specific at the generic and species levels. The family contains about 70 species placed in 15 genera. They are cosmopolitan (Nair and Saraswathy 1971, Turner 1966).

Teredinid sp.

This family is represented by a single, somewhat eroded and undiagnosable valve from 10:17. It is possible that it was washed or carried into the site inside a piece of wood which was subsequently burnt or rotted away.

NAUTILIDAE

Nautilus pompilius (Linnaeus, 1758)

Synonyms: Saunders and Ward (1987:36 table 1) holds there to be five valid species of modern *Nautilus* with a questionable sixth (*N. repertus* Iredale, 1944). He regards the following names as synonymous with *N. pompilius*: *moretoni* Willey, 1896; *marginalis* Willey, 1896; *perforatus* Willey, 1896; *pompilia* Schimansky, 1948; *cordatus* Lister, 1685; *rumphii* Schimansky, 1948; *ambiguus* Sowerby, 1849; *alumnus* Iredale, 1944.

Range: there is one specimen from Khok Phanom Di (B72). As the shell contains gas-tight chambers, it floats to the surface of the sea where it may be dispersed thousands of kilometres by wind and currents from its living locality. The presence of three polychaete worm tubes on the septum bounding the posterior aspect of the body chamber and a further one on the umbilical callus indicates a lapse of some time between death and recovery from the sea. This animal is known to live in the Philippines, Fiji, Andaman Islands, the New Hebrides and is widespread in the Papua-New Guinea area and the Great Barrier Reef. It is thought from the distribution of dead shells that it will be found living at localities yet to be discovered (Saunders and Landman 1987:41). Drift shells of *N. pompilius* have been recorded from the western coast of Thailand (House 1987:55, map fig. 1), but none from the Gulf of Siam. Gorshkov (1974:206 map) shows that during August, the surface currents in the Gulf of Siam move west from the western Philippines along the west side of the Gulf, east across the head of the Gulf and down the eastern side. This suggests that at this time of the year, numbers of *Nautilus* may have been transported into the Gulf and stranded on its shores.

Habitat and ecology: this animal lives in clean tropical waters off steep, deep fore-reefs and is a carnivorous, opportunistic feeder living off carrion, crustaceans, fish and coleoid cephalopods. During the day, it lives at depths of up to 500m (the shells implode at c. 800m), presumably to avoid teleost and elasmobranch predators, and each evening rises to shallow depths (sometimes much less than 100m) to feed before returning to the depths in the early morning. This diurnal manoeuvre is readily possible with low energy expenditure by altering the buoyancy of the chambered shell

(Saunders and Ward 1987). They are thought to live for at least four years. For many centuries, these animals have been caught with baited lines and traps in various parts of the Philippines.

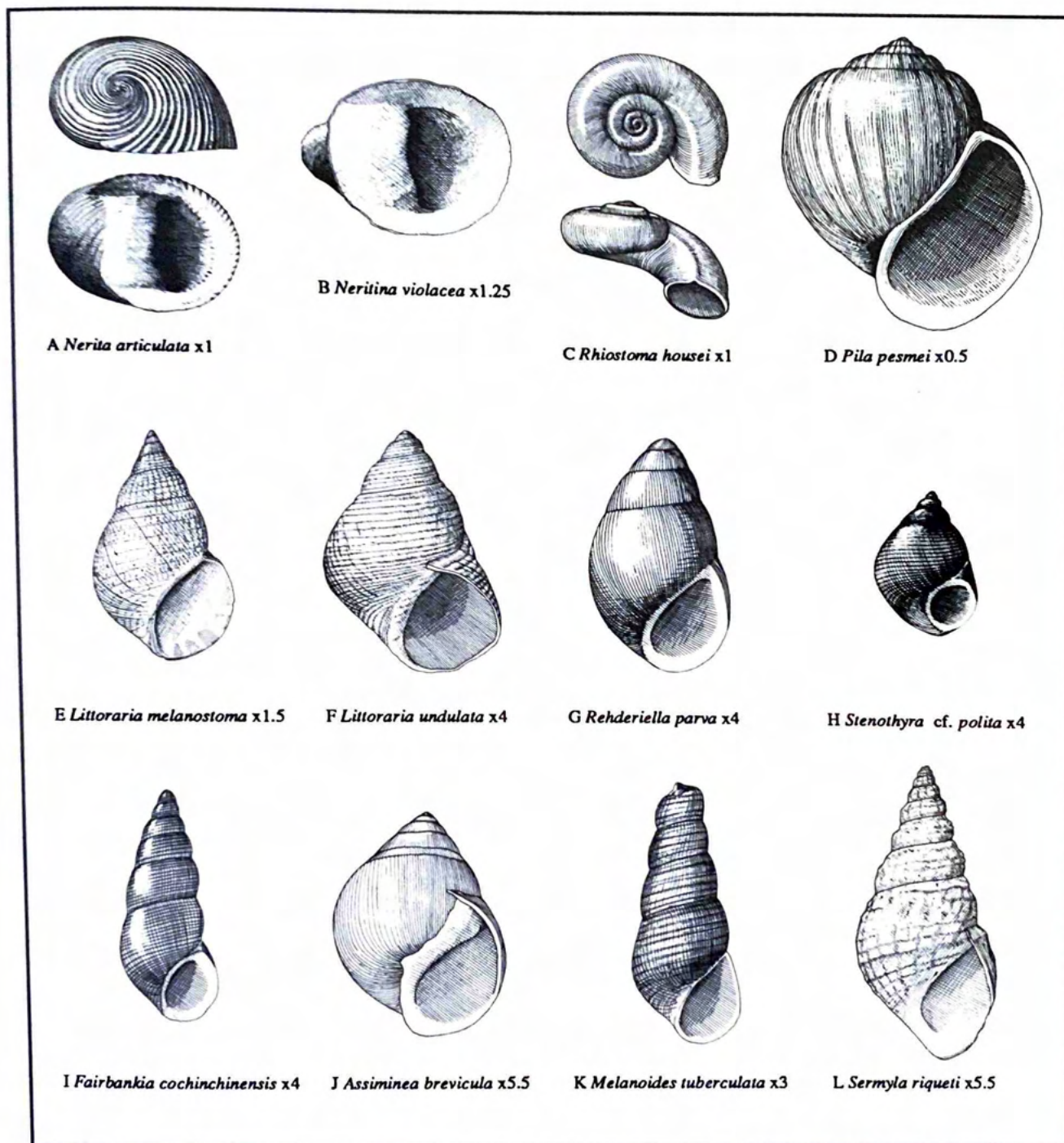


FIG. 52. Shells of the families Neritidae, Ampullariidae, Littorinidae, Hydrobiidae, Stenothyridae, Irvadiidae, Assimineidae and Thiariidae

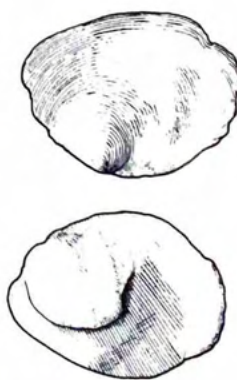
A *Cerithidea cingulata* x2B *Cerithidea obtusa* x1C *Telescopium telescopium* x0.8D *Terebralia palustris* x0.8E *Strombus canarium* x1F *Strombus luhuanus* x1G *Crepidula walshi* x1.5H *Natica tigrina* x1

FIG. 53. Shells of the families Potamidae, Strombidae and Naticidae

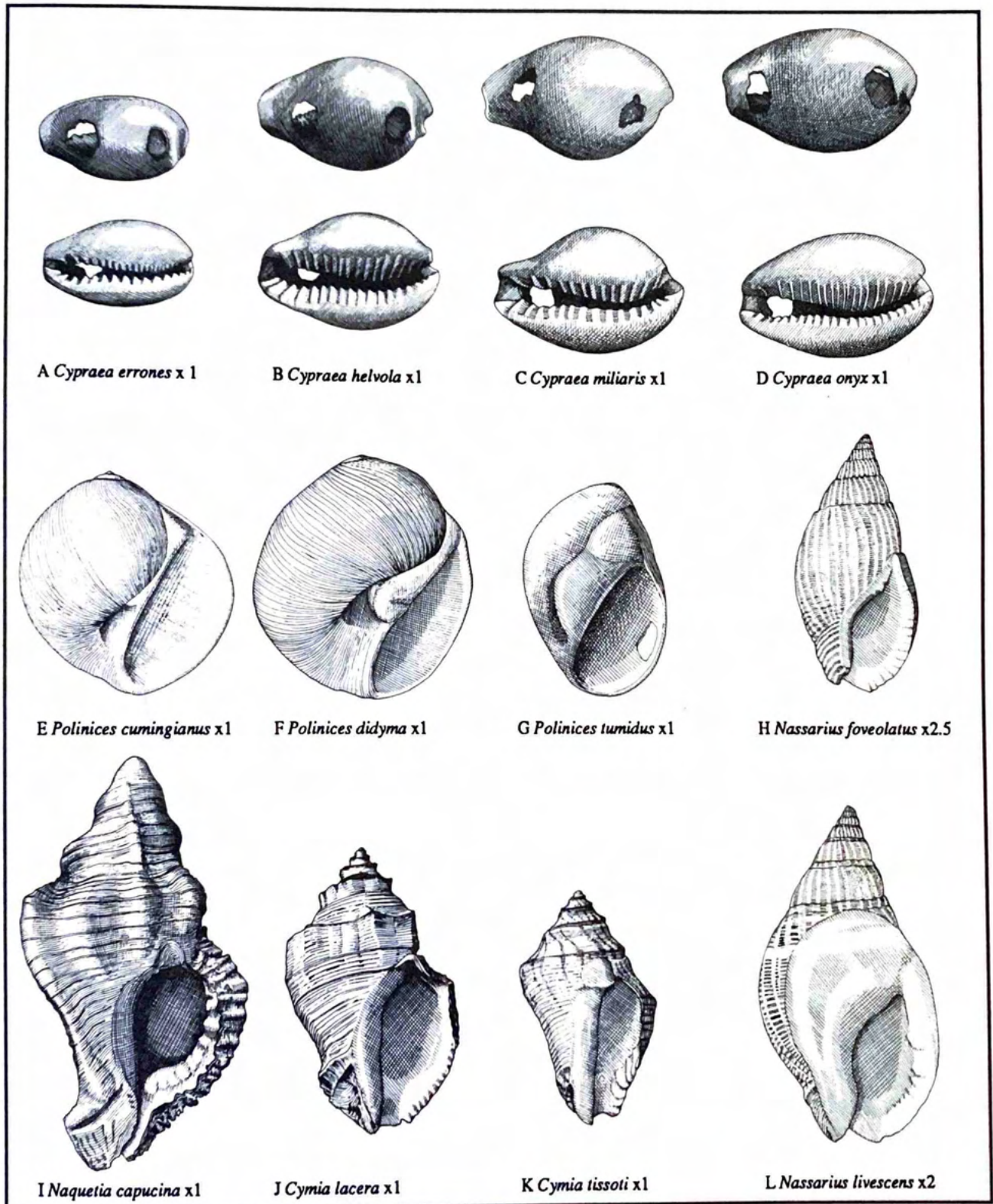


FIG. 54. Shells of the families Naticidae, Cypraeidae, Muricidae, Thaididae and Nassariidae

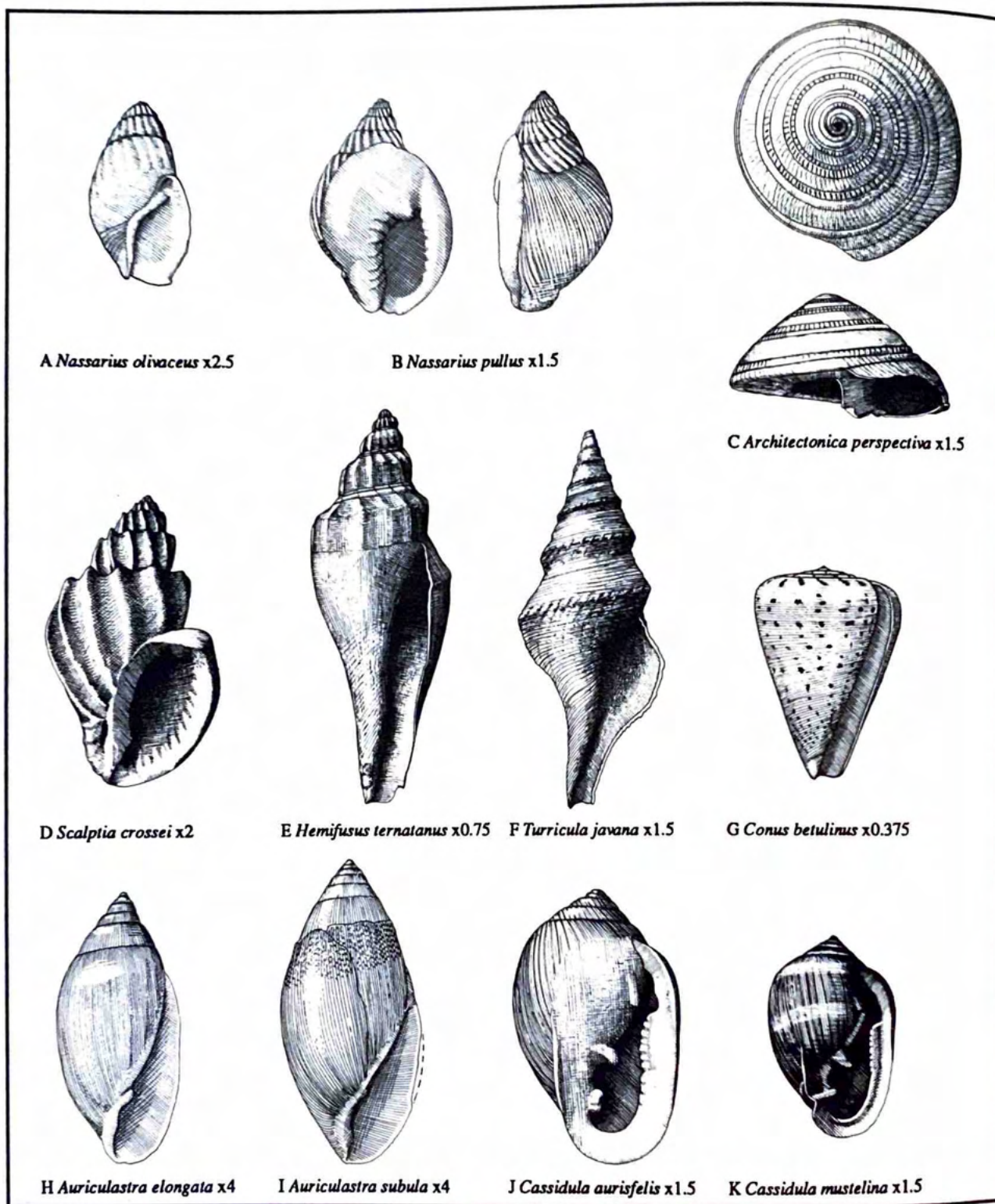


FIG. 55. Shells of the families Nassariidae, Melongenidae, Conidae, Turridae, Terebridae and Auriculidae

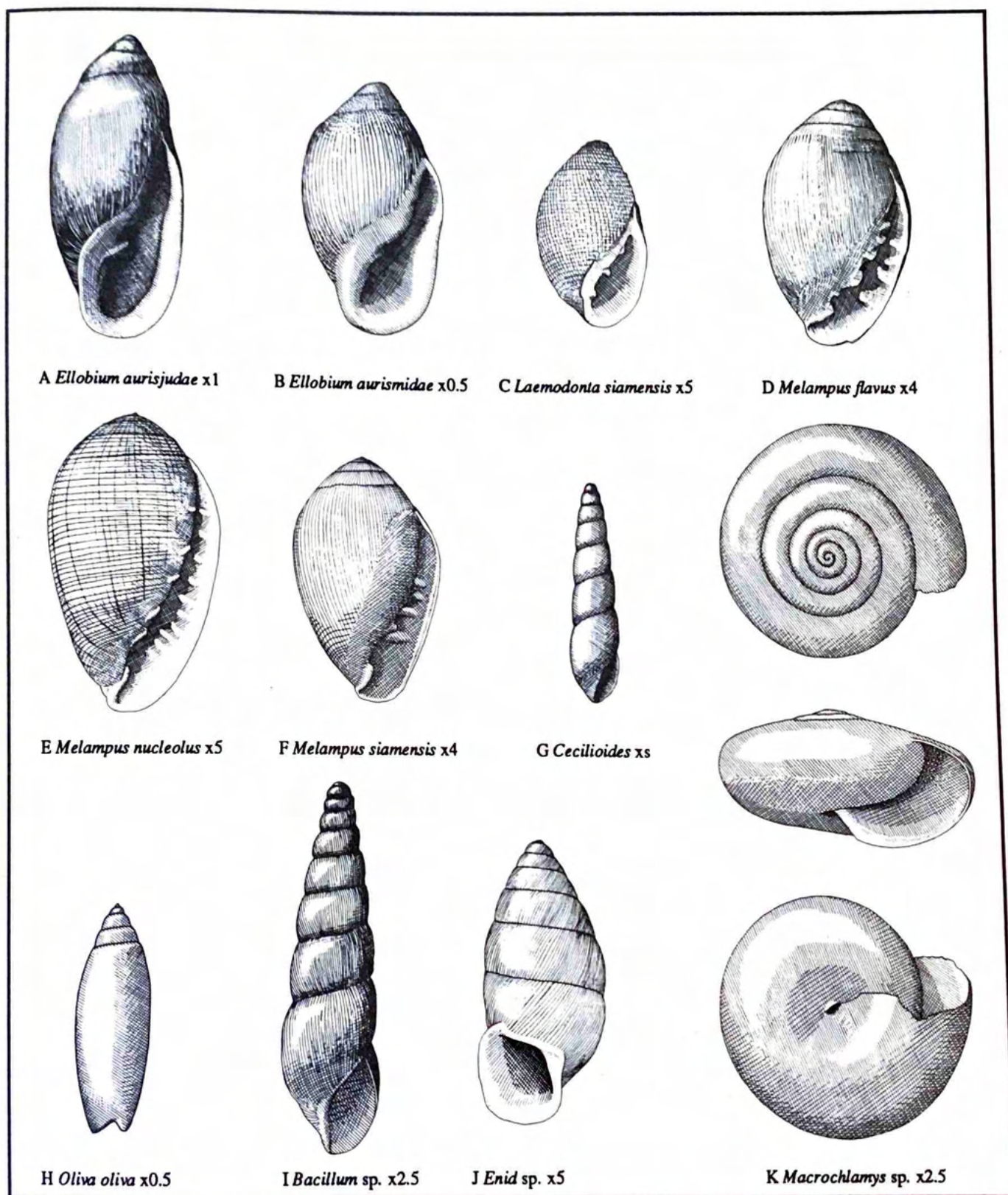


FIG. 56. Shells of the families Auriculidae, Enidae, Olividae, Ferussacidae, Ariophantidae and Subulinidae

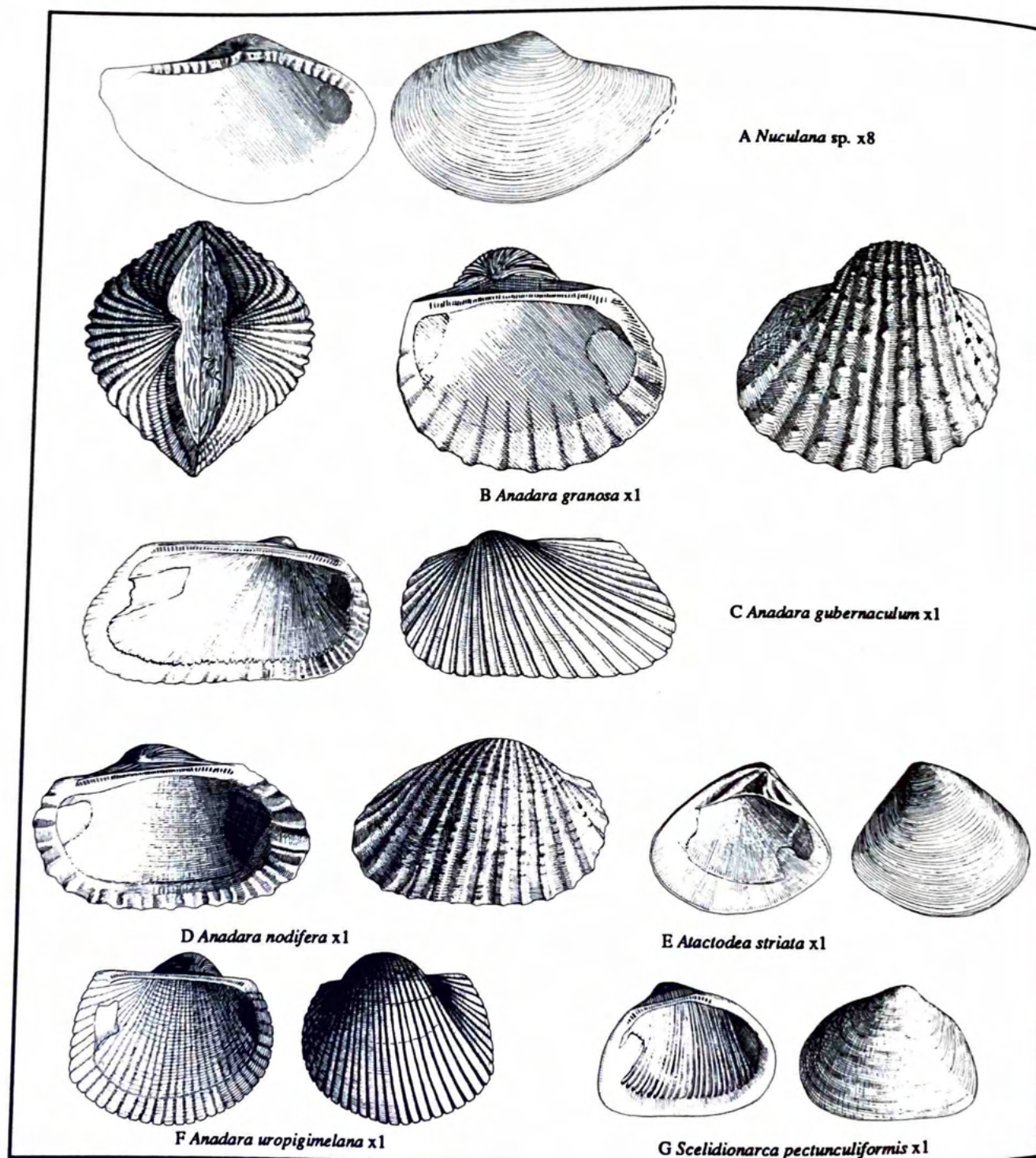


FIG. 57. Shells of the families Nuculanidae, Arcidae, Noetiidae and Mesodesmatidae

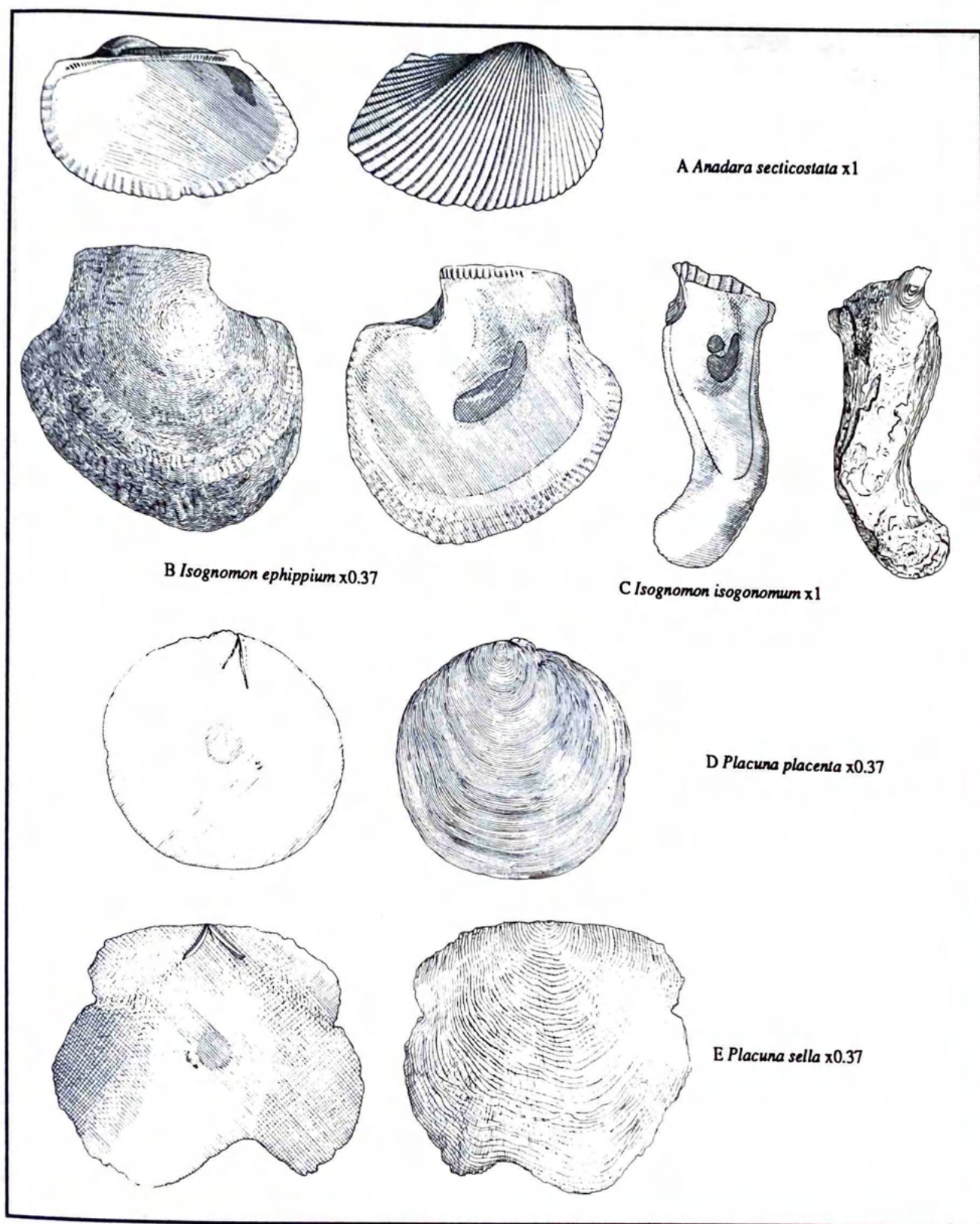


FIG. 58. Shells of the families Arcidae, Isognomonidae and Placunidae

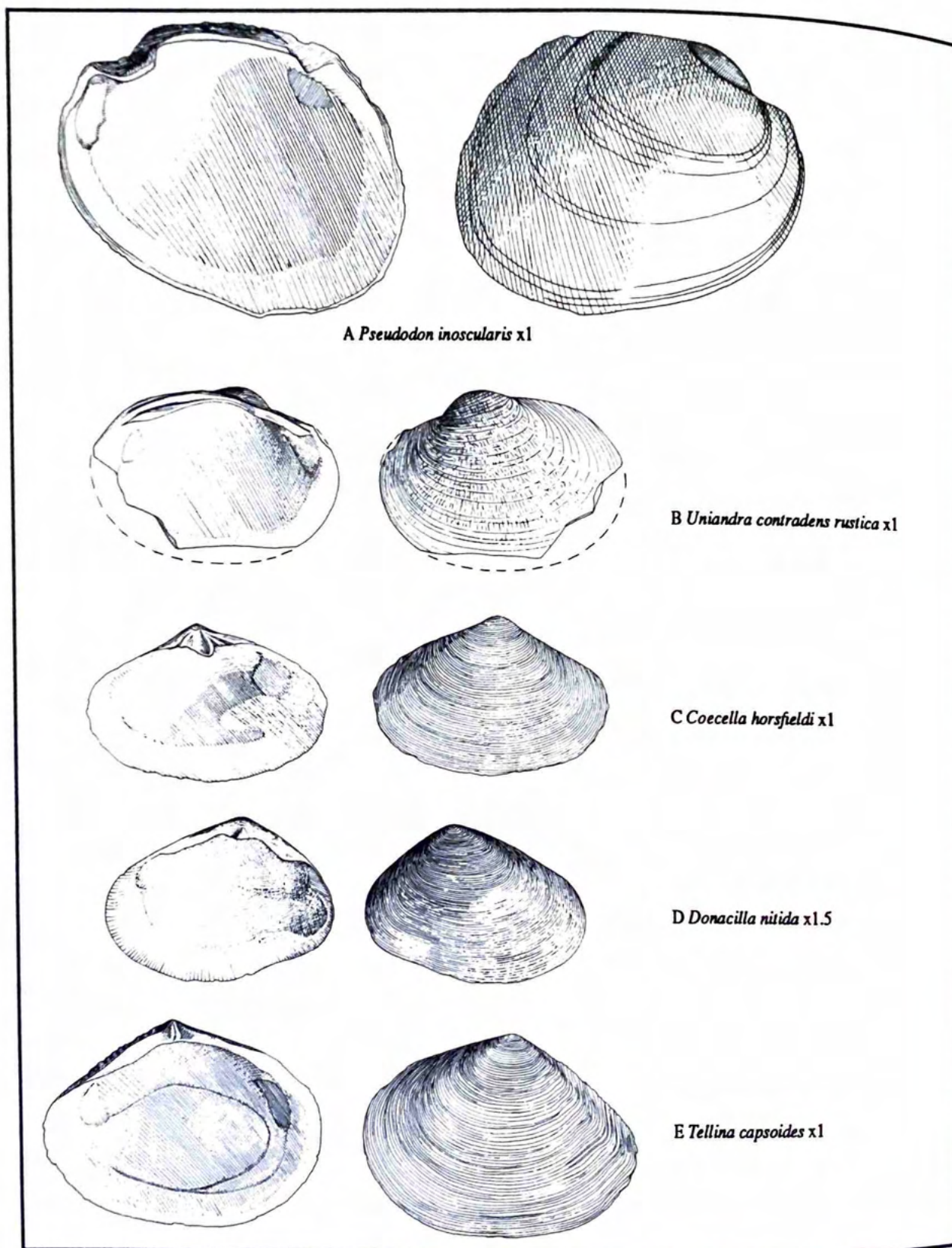


FIG. 59. Shells of the families Unionidae, Mesodesmatidae and Tellinidae

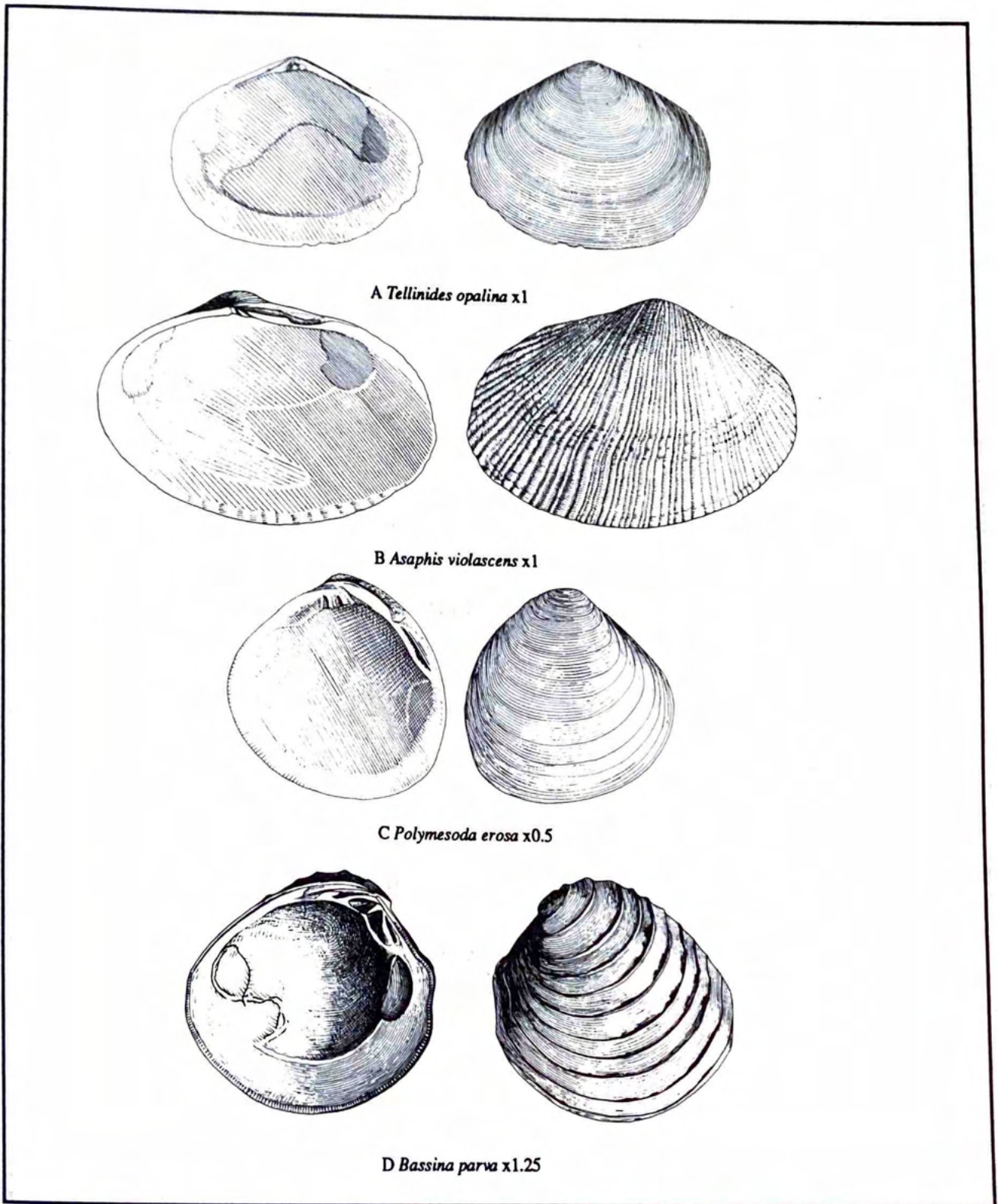
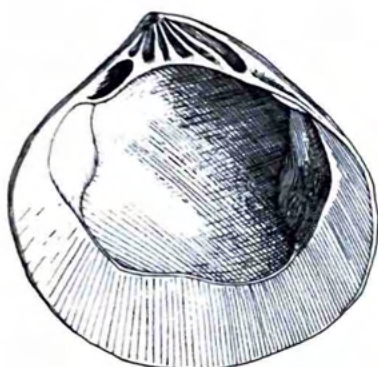


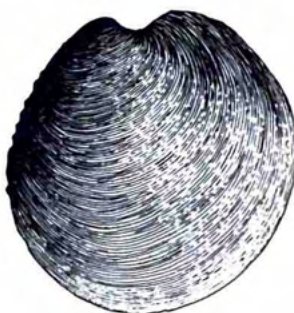
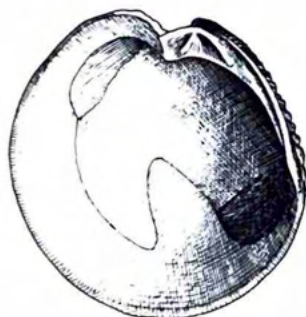
FIG. 60. Shells of the families Tellinidae, Psammobiidae, Corbiculidae and Veneridae



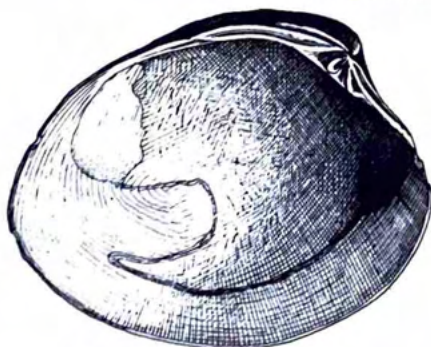
A *Anomalocardia squamosa* x1.5



B *Circe scripta* x1

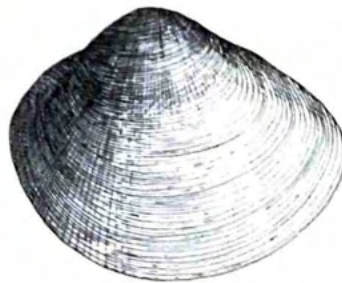
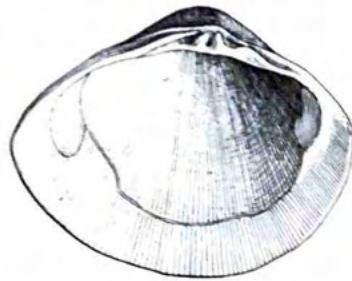


C *Dosinia trailli* x1.25

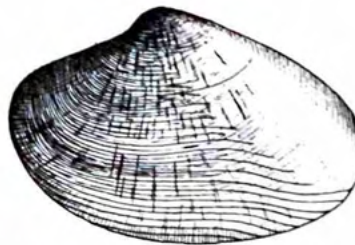
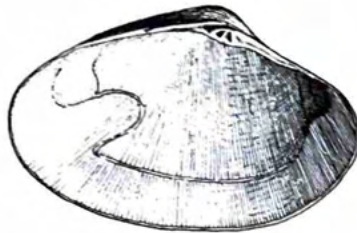


D *Marcia hiantina* x1

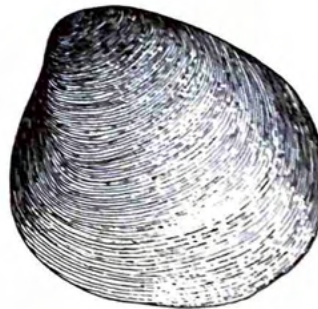
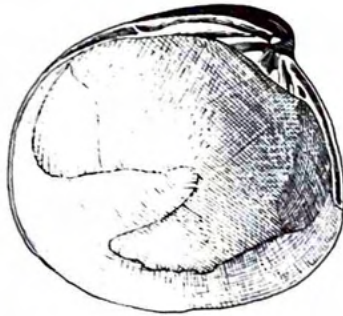
FIG. 61. Shells of the family Veneridae



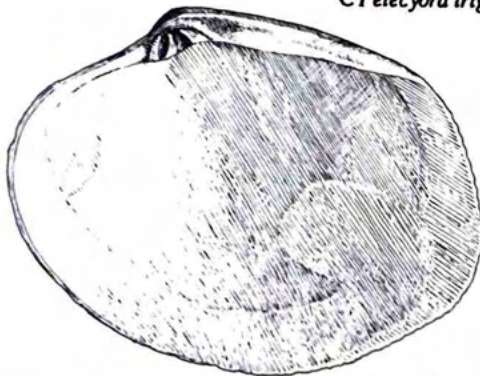
A *Meretrix lusoria* x1



B *Paphia undulata* x1



C *Pelecycora trigona* x1



D *Ruditapes philippinarum* x1.5

FIG. 62. Shells of the family Veneridae

TABLE 52: *The distribution of shell species in the site*[illegible]

THE MOLLUSCAN REMAINS

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The distribution of shell species in the site (cont.)

Species	112	111	1025	1024	1023	1022	1021	1019	1018	1017	1016	1015	1014	1013	1012	1011	1010	1009	1008	1007	1006	1005	1004	1003	1002	1001	997	996	995	994	993	992	991	897	896	895	894	893	892	891	796	795	794	793	792	791	698	697	696	695	694	693	692	691	595	594	593	592	591	495	494	493	492	491	394	393	392	391	299	298	297	296	295	294	293	292	291	290	289	288	287	286	285	284	283	282	281	280	279	278	277	276	275	274	273	272	271	270	269	268	267	266	265	264	263	262	261	260	259	258	257	256	255	254	253	252	251	250	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222	221	220	219	218	217	216	215	214	213	212	211	210	209	208	207	206	205	204	203	202	201	200	199	198	197	196	195	194	193	192	191	190	189	188	187	186	185	184	183	182	181	180	179	178	177	176	175	174	173	172	171	170	169	168	167	166	165	164	163	162	161	160	159	158	157	156	155	154	153	152	151	150	149	148	147	146	145	144	143	142	141	140	139	138	137	136	135	134	133	132	131	130	129	128	127	126	125	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	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	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112																																																																																																																																																																																																																																																																													
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XVIII. THE MOLLUSCAN REMAINS: CONCLUSIONS

By G. M. Mason

SOURCES OF THE REMAINS

The molluscan species list, examined in terms of how various species arrived in the site, shows that 72 per cent (89 species) fall easily into the categories of foodstuff, tool material and ornaments, being 44, 18 and 10 per cent respectively. Two further groups, autochthonous and miscellaneous, make the balance of 5 and 23 per cent respectively. The food group is dominated by five species of gastropod (*Nerita articulata*, *Cerithidea obtusa*, *Telescopium telescopium*, *Natica tigrina* and *Ellobium aurisjudae*) and three species of bivalve (*Anadara granosa*, *Polymesoda erosa* and *Meretrix lusoria*) which collectively account for 99.4 per cent of all individuals in the site. Presence in the food category is largely based on the writer's knowledge of molluscan species commonly available in present-day Thai markets and those of modern Malaysia as instanced by Purchon and Purchon (1981). An apparent lacuna in the archaeological literature precludes knowledge of prehistoric mainland South-East Asian shellfish food preferences. However, it is thought that, in the view of the geographically widespread and multicultural consumption of all the fourteen food species most common in the site, all would have been eaten at Khok Phanom Di. For *Cassidula aurisfelis*, which occurs regularly from the base to near the top of the site, there is no record of its being eaten nor do the remains show any damage suggesting that the animals were extracted and consumed. It is thus placed in the autochthonous group along with the closely related *C. mustelina* and four pulmonid taxa (an enid, *Cecilioides* sp., *Bacillum* sp. and *Macrochlamys* sp.). The abrupt appearance near the base of layer 6 of the four fully terrestrial genus-rank taxa can be explained most parsimoniously by assuming some rapid change in the environmental setting which allowed their influx to the site. A less economical hypothesis is that there was either a rapid change in the usage of the site or in diagenetic conditions affecting the mineralization and preservation of small and minute shell species. For the former alternative, there is no conclusive archaeological evidence and for the latter, the upper layers of the site are heavily leached and conditions of preservation are poor in comparison to lower layers.

The species falling into the categories of tools or ornament/ritual are largely self-evident from the morphology, modifications or archaeological context (e.g. grave goods or in the shallow pits plausibly connected with funebral ritual). Among the edged tools, the fresh water mussels in the genus *Pseudodon* are especially prominent along with a lesser number of blood cockles (*Anadara* spp.) and *Isognomon* spp. It seems probable that some, at least, of the sporadic tridacna fragments are swarf from adze manufacture, so well documented from western Oceania where stone was also at a premium. Among the ornamental species are the ubiquitously used tropical species of the genera *Cypraea*, *Nassarius*, *Oliva*, *Polinices* and *Conus*. With the exception of the *Nassarius* species,

all are variously punched, drilled or otherwise modified for stringing or suspension. *Nassarius* spp. and *Scalptia crosseii* are all fresh, live-collected shells but without any obvious modification. However, they seem only to occur in a mortuary context.

With twenty-nine species (23 per cent), the miscellaneous group is the second largest, and includes anything which cannot confidently be attributed to one or more of the preceding categories. The ten bivalves in this group are all marine and, without exception, would have been living with food species. It is tempting to suppose that they were accidentally imported with *Anadara granosa*, *Meretrix lusoria* and *Saccostrea*, with which they are found living. Of the few marine gastropods in this group, only the slipper limpet (*Crepidula walshi*) can certainly be accounted for: their introduction was accidental inside dead *Cymia* spp. which are known to be an edible species. That there may be a non-culinary use for *Cymia* is suggested by two facts, the first being that a number were obviously brought onto the site long after the animal's death, as shown by calcareous invertebrate overgrowths and massive destruction of the shell fabric by boring organisms. The second observation, made whilst the author was engaged in archaeozoological fieldwork in North-East Thailand, was that *Cymia* shells were used in some religious or other ceremony the details of which could not be elicited from the local people. The other marine species, *Duplicaria duplicata* and *Architectonica perspectiva*, may not have been devoid of aesthetic appeal or may have held some other virtue for the site's inhabitants, if one must speculate.

The balance of these miscellaneous species all derive from a mangal-estuarine or fresh water environment and all are, without exception, small to minute (2–12mm) in size. They comprise seventeen species, all of which may be found in mangal, with many extending into estuarine and fresh water. Assuming a constant rate of influx into the site, there are about four individuals per decade being brought in. The most parsimonious hypothesis to account for their presence is that they were commonly occurring in the immediate surroundings of the site and that they were carried in accidentally by people, and perhaps by domestic animals.

Water plants, such as lotus (*Nymphaea lotus*), watercress (*Neptunia oleracea*), water caltrops (*Trapa bicornis*) and water morning glory (*Ipomoea aquatica*) are an important part of the modern Thai diet and there is no reason to think that these, and others, were not used in the past. These plants would have been an effective vehicle to transport the bulk of the fresh water snails, at least, onto the site.

PARASITOLOGY

As molluscs, particularly fresh water species, are very commonly intermediate vectors for trematode and other parasites adversely affecting human and animal health, the Khok Phanom Di species list was scrutinized to reveal five species, all fresh water, of parasitological importance (Table 53).

Information for this section is largely derived from Brandt (1974) and the comprehensive recent report by the Tropmed Technical Group (1986), with supplementary detail from papers in Sucharit (1986).

If eaten raw, or improperly cooked, *Pila pesmei* may transmit one or both *Angiostrongylus cantonensis* and *Echinostoma ilocanum* to human and other vertebrate subjects. The former is known to cause eosinophilic meningoencephalitis, a condition frequently fatal to humans. *E. ilocanum*

TABLE 53: *Molluscan species of parasitological importance*

Species	Species
<i>Pila pesmei</i>	<i>Filopaludina sumatrensis</i>
<i>Sermyla riqueti</i>	<i>Melanoides tuberculata</i>
<i>Segmentina</i> cf. <i>trochoideus</i>	Family Planorbidae

canum generally does not have fatal consequences to human hosts, but frequently causes diarrhoea which may become chronic and precipitate the usual effects of malnutrition and dehydration. Pilid species are not infrequently eaten raw in Thailand today despite well known warning from health authorities. consumption of *Filopaludina sumatrensis* is widespread in Thailand and elsewhere, often in the raw state. Thus the chances of infection with one or more of the four *Echinostoma* spp. intestinal flukes borne by this gastropod are considerably enhanced. More than fifteen parasite species are known to infect *Sermyla riqueti* and *Melanoides tuberculata*. It is unclear which if any of them are transmitted to humans, and, if so what the medical consequences are. *Segmentina* cf. *trochoideus* is known to act as host to *Fasciolopsis buski*, a giant intestinal fluke reaching 75mm in length.

There appear to be no mollusc species present which are known vectors to the schistosomiasis group of parasitic diseases. However, it is possible that the main vectors are large gastropods with an extremely thin, fragile shell which has escaped preservation in the site, such as *Lymnaea* spp.

HABITAT ANALYSIS

Table 54 presents the molluscan species grouped into five broad habitats: marine, mangal, estuarine, fresh water and land. These are subdivided into eighteen generalized biotopes. The information in the literature is highly uneven in reliability; it is not infrequently contradictory, or is so vague as to be inutile. Of particular service in compiling the table were Way and Purchon (1981), Morton and Morton (1983) and Frith *et al.* 1976.

Mudflats: normal salinity. Broom (1982) has given an account of a mudflat community dominated by *Anadara granosa* at Kuala Selangor (3° 20' N, 101° 14' E) on the south bank of the mouth of the Sungai Buloh River. Of the sixteen genera identified as mudflat dwellers at Khok Phanom Di, eight occur at Broom's location. These are *Stenothyra*, *Cerithidea*, *Natica*, *Cymia*, *Nassarius*, *Anadara*, *Tellina* and *Pelecypora*. In this intertidal to subtidal community, *Anadara granosa* is the most abundant species, followed by *Pelecypora trigona*. The micro-grazing gastropod *Cerithidea obtusa* also occurs in large numbers. Molluscan predators are represented by *Natica tigrina* and *Cymia lacera*, while scavengers are well represented in *Nassarius pullus*, *Nassarius olivaceus* and three other *Nassarius* species closely related to those found at Khok Phanom Di. There seems little doubt that, allowing for the small difference in latitude manifesting in closely-related species such as *Stenothyra polita* and *Stenothyra glabrata*, *Tellina capsoides*, *T. opalina* with *T. lux* and *T. pudica* and the Nassariids, that there was at Khok Phanom Di a typical *Anadara granosa* community

exposed to some degree of estuarine influence. Of the remaining thirteen mudflat species, three (*Cymbiola nobilis*, *Paphia undulata* and *Strombus luhuanus*) probably belong to slightly deeper water and the remaining ten species (*Cerithidea obtusa*, *Telescopium telescopium*, *Crepidula walshi*, *Cypraea miliaris*, *C. onyx*, *Anadara nodosa*, *Scelidionarca pectunculiformis*, *Placuna placenta*, and *Placuna sella*) are nearer the shore with their main stronghold at the seaward side of the mangal. This last group will be considered with the mangal species.

Muddy sand: of the fourteen species recorded in Table 54, only three (*Polinices cumingianus*, *Nassarius livescens* and *Bassina parva*) are not known either from a mud or clean sand substrate. Little can be gleaned from the literature on the muddy sand setting.

Clean sand: the major community on sheltered sandflats containing small to moderate amounts of silt is dominated by the infaunal bivalve *Meretrix lusoria* with smaller numbers of *Atactodea striata*, *Anomalocardia squamosa*, *Circe scripta*, *Dosinia juvenilis*, *Dosinia trailli*, *Marcia hiantina* and *Ruditapes philippinarum*. These bivalves are predated upon by the naticid gastropods *Natica tigrina*, *Polinices didyma* and *Polinices tumidus*. Other carnivorous gastropods include *Nassarius pullus*, *Hemifusus ternatanus*, *Conus betulinus*, *Turricula javana*, with prey comprising other molluscs, polychaete worms and assorted invertebrates. Other molluscs found on a sandy eulittoral and sublittoral environment are *Asaphis violascens* and the herbivorous gastropods *Strombus canarium* and *Strombus luhuanus*.

It is possible that an *Enhalus*-dominated seagrass community was present at low water extreme tides and was represented by some of the above species, but distinctive species such as lucinid bivalves would be needed to settle the issue.

Coral association: modern associations of hermatypic corals are known from the head of the Gulf of Siam at Kho Si Chang and a brief review of their macrobenthic animals is given in Tsuchiya *et al.* (1986a, 1986b). The only mollusc they mention that may have been recovered from Khok Phanom Di is *Arca ventricosa*, which may be *Anadara uropigimelana* of this account. Tsuchiya and Lirdwitayapaisit (1986), dealing with the same islands, mentioned some ten molluscs only one of which, *Atactodea striata* (in sand), is recorded at Khok Phanom Di. Morton (1983), in his substantial review of coral-associated bivalves, notes that burrowing species include *Anadara uropigimelana* and *Anadara secticostata*. The three species of *Tridacna* (*T. derasa*, *T. squamosa* and *T. maxima*) are likely to be directly associated with coral. In biogenic sands are to be found *Asaphis violascens* and *Circe scripta* and the grazers *Strombus canarium*, *Cypraea errones* and *C. helvola*. Predators include *Cypraea onyx*, *Nassarius livescens*, *Hemifusus ternatanus*, *Oliva oliva*, *Conus betulinus* and *Architectonica perspectiva*. A shallow off-shore area with some hard ground to allow the establishment of corals, or perhaps just a sandbank, and low suspended sediment and turbidity to allow photosynthesis in the symbionts of both corals and tridacnids seems very likely somewhere upcurrent from the site.

The presence of intertidal and subtidal rocky shore cannot be established as virtually all the species placed in this group can be found in other environments. The present-day topography does not in any way suggest the presence of rocky islands or a prominent rocky coast in prehistoric times. The nearest high point is Khao Kirirom, about 6km to the south-east. It is adjacent on its western margin with brackish-water sediments, and was probably some distance from the sea during the

occupation of Khok Phanom Di.

Mangal mudflats: this community is predominantly ecotonal in the sense that it is an area where the lower shore molluscs overlap with those more typical of the mangal plant formation. In the former group may be placed the bivalves *Anadara granosa*, *Placuna placenta*, *P. sella*, *Tellina capsoides*, *Tellinides opalina* and *Marcia hiantina* with carnivorous or scavenging gastropods embracing *Nassarius foveolatus*, *N. livescens* and *N. pullus*. Species more typical of mangal include *Stenothyra polita*, *Cerithidea cingulata*, *C. obtusa*, *Telescopium telescopium*, *Terebralia palustris*, *Cypraea miliaris* and *Scelidionarca pectunculiformis*.

Seaward mangal: this three-dimensional habitat may be divided into mud substrate, tree-trunks and logs submerged by the tides and mangal trunks and canopy above tidal influence. Each has its own distinctive group of inhabitants. Infaunal mud-dwelling bivalves may include the uncommon *Anadara granosa* and *Marcia hiantina* and sometimes abundant *Placuna placenta* and *P. sella*. Oyster clumps (*Saccostrea cucullata*) may also occur set in the mud along with its chief predator *Cymia lacera*. *Stenothyra polita* with *Assiminea brevicula*, *Cerithidea cingulata*, *C. obtusa*, *Telescopium telescopium*, *Terebralia palustris* and *Cypraea miliaris* form a group of gastropods grazing microalgae and other small organisms from the mud surface and may often be found concentrated in large numbers in rills and channels in the mangal and on the adjacent mudflats.

In many ways, the intertidal trunks act like a sheltered rocky shore to bear large numbers of sessile organisms that need a hard substrate such as *Isognomon* spp., *Chama reflexa*, *Saccostrea cucullata* (and perhaps nestling *Scelidionarca pectunculiformis* ?), *Spondylus* sp. and *Anomia*. Some of the byssally attached pteriids may be found in this niche. Browsing gastropods climbing over this dense epifauna include *Nerita articulata*, *Cerithidea cingulata* and *C. obtusa* and *Terebralia palustris*. The predators include *Naquetia capucina* (eating polychaete worms), *Cymia tissoti*, which drills and eats barnacles and the various *Nassarius* species.

The subaerial faunule includes the pulmonates *Cassidula aurisfelis* and *C. mustelina* and *Littoraria undulata*, which is largely confined to the mangal edge. *Littoraria melanostoma* is more wide ranging in the mangal. *Nerita articulata* is as nearly widespread, grazing upon microalgae from hard surfaces and even the surface of firm mud.

Central mangal: as the maritime influence falls, and the regime of brackish and fresh water tightens its grip along with increased areas of supratidal ground bearing the fern *Acrostichum aureum* with its associated plant species, the auriculid pulmonates *Auriculastra elongata*, *A. subula*, *Cassidula aurisfelis*, *C. mustelina*, *Ellobium aurisjudae*, *E. aurismidae* and *Laemodonta siamensis* come to dominance. Co-dominant in the subaerial realm is *Nerita articulata* and the aquatic gastropods comprising *Neritina violacea*, *Stenothyra polita*, *Fairbankia cochinchinensis*, *Assiminea brevicula* and the predatory *Nassarius olivaceus*. *Littoraria melanostoma* is a typical canopy species. To landward, the mangal may pass into salt meadows or the dry-footed *Barringtonia* forest association. *Polymesoda erosa*, a member of the essentially fresh water family Corbiculidae is one of the few molluscs dependant on the mangal association for its existence. It is highly adapted to survive long periods of emersion and the wide range of salinities that occur at the landward edge of the mangal. Here again, the auriculids are the dominant gastropods many of the smaller species extending into the rushes and grasses of the saltmarshes where present. Aquatic species include

Neritina violacea and *Fairbankia cochinchinensis*, with *Littorina melanostoma* found in trees and shrubs that may extend into the salt marshes. The presence of salt meadows, while deemed highly probable, can be safely established only with a better knowledge of the detailed ecology of the small auriculids such as *Laemodonta* and *Melampus*.

Estuarine species: this group of animals is characterized by a tolerance of large and rapid fluctuations of salinity and includes both typically marine species that are euryhaline and fresh water species that tolerate some degree of salinity. The only species present at Khok Phanom Di that may be restricted to estuarine conditions is *Rehderiella parva*, *Stenothyra polita* and *Sermyla riqueti*, although all may possibly be found in the estuarine aspect of the mangal association, as is *Neritina violacea*. An essentially fresh water species ranging into brackish waters is *Melanoides tuberculata*. The only bivalve which seems to be peculiarly estuarine is *Coecella horsfeldi* which is found in intertidal sandbars in estuaries and estuarine mangrove. Marine species tolerating a river-mouth setting include *Cerithidea cingulata*, *C. obtusa*, *Cymia tissoti* and *Nassarius olivaceus*, all mainly in the associated mangal and mangal mudflats along with the bivalves *Placuna placenta*, *P. sella*, the two tellinids and the venerids *Marcia hiantina* and *Pelecypora trigona*. It can thus be seen that evidence for a substantial nearby estuary is strong.

Fresh water environment: among the purely lentic species is the amphibious snail *Pila pesmei* and the two fresh water mussels *Pilsbryconcha exilis* and *Uniandra contradens rustica*. With the exception of the naiad *Uniandra contradens tumidula* confined to lotic waters, the balance of the fresh water faunule may inhabit either running or standing water. However, it is obvious from the numbers of fresh water mussels alone that appreciable bodies of freshwater were of easy access of Khok Phanom Di.

Land molluscs: little can be gleaned from the almost non-existent literature on Thai terrestrial molluscs on the five non-auriculid (ellobiid) land species. *Fairbankia cochinchinensis* and *Assiminea brevicula* are essentially estuarine/mangrove species that may be found in damp or wet places and should not be considered to be typical terrestrial species. The habitat requirements for *Rhiostoma housei*, the enid sp., *Cecilioides* sp., *Bacillum* sp. and *Macrochlamys* sp. are unknown, but it is suspected that if *Macrochlamys* is typical of the family (Ariophantidae), it may well be a burrower, eating soil invertebrates. Further information will have to await field observation.

TABLE 54: *The preferred habitats of shell species in the site*

Species	Marine						Mangal				Estuary					FW		Land		
	M	MS	S	FA	C	H	MF	SE	C	LE	G	M	S	H	CH	LE	LO	G	N	B
<i>Nerita albicilla</i>	-	-	*	-	-	*	-	-	*	-	-	-	-	-	-	-	-	-	-	-
<i>Nerita articulata</i>	-	-	-	-	-	-	-	*	*	*	-	-	-	*	-	-	*	-	-	-
<i>Neritina violacea</i>	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	*	-	-
<i>Rhiostoma housei</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
<i>Pila pesmei</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	-
<i>Filopaludina javanica</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	-
<i>Filopaludina sumatrensis</i>	-	-	-	-	-	-	-	*	*	*	-	-	-	-	-	-	-	-	-	-
<i>Littoraria melanostoma</i>	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Littoraria undulata</i>	-	-	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-
<i>Rehderiella parva</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Stenothyra</i> cf. <i>polita</i>	*	-	-	-	-	-	*	*	*	*	-	*	-	-	*	-	-	-	*	-
<i>Fairbankia cochinchinensis</i>	-	-	-	-	-	-	-	*	*	*	-	-	-	-	-	-	-	-	*	-
<i>Assiminea brevicula</i>	-	-	-	-	-	-	-	*	-	-	-	*	-	-	-	*	*	-	-	-
<i>Melanoides tuberculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-
<i>Sermyla riqueti</i>	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-
<i>Cerithidea cingulata</i>	*	-	-	-	-	-	*	*	-	-	*	-	-	-	-	-	-	-	-	-
<i>Cerithidea obtusa</i>	*	-	-	-	-	-	*	*	-	-	*	-	-	-	-	-	-	-	-	-
<i>Telescopium telescopium</i>	*	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Terebralia palustris</i>	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Strombus canarium</i>	-	-	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Strombus luhuanus</i>	-	-	*	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Crepidula walshi</i>	*	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cypraea errones</i>	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cypraea helvola</i>	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cypraea miliaris</i>	*	-	*	-	*	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cypraea onyx</i>	*	*	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Natica tigrina</i>	*	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Polinices cumingianus</i>	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Polinices didyma</i>	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Polinices tumidus</i>	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Naquetia capucina</i>	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cymia lacera</i>	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cymia tissoti</i>	-	-	-	-	-	-	-	*	-	-	-	-	-	*	-	-	-	-	-	-
<i>Nassarius foveolatus</i>	*	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Nassarius livescens</i>	-	*	-	*	*	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Nassarius olivaceus</i>	*	-	-	-	-	-	*	*	*	-	-	-	-	-	*	-	-	-	-	-
<i>Nassarius pullus</i>	*	*	*	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hemifusus ternatarus</i>	-	-	*	-	*	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cymbiola nobilis</i>	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Oliva oliva</i>	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Scalptia crosseii</i>	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Conus betulinus</i>	-	-	*	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Abbreviations: FW, fresh water; *, habitat; +, likely habitat; Marine habitat M, mud, silt; MS, muddy sand, sandy mud; S, sand; FA, fine algae patches; C, coral patches or reefs; H, hard ground of rocks or boulders; Mangal MF marine mud flat adjacent to mangal just beyond closed canopy; SE, seaward edge of mangal canopy; C, mangal midway between sea and dry land; LE, landward edge of mangal association; Estuary G, general estuarine setting; M, mud; S, sand; H, hard bottom/tree-trunks; CH, channels; Fresh water S, still; R, running; Land G, general, terrestrial; N, nypa, damp or dry land; B, *Barringtonia* association, dry land

The preferred habitats of shell species in the site (cont.)

Species	Marine						Mangal				Estuary					FW		Land		
	M	MS	S	FA	C	H	MF	SE	C	LE	G	M	S	H	CH	LE	LO	G	N	B
<i>Turricula javana</i>	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Duplicaria duplicata</i>	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Architectonica perspectiva</i>	-	-	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Auriculastra elongata</i>	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	*	-
<i>Auriculastra subula</i>	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	*	-
<i>Cassidula aurisfelis</i>	-	-	-	-	-	-	-	*	*	*	-	-	-	-	-	-	-	-	*	*
<i>Cassidula mustelina</i>	-	-	-	-	-	-	-	*	*	*	-	-	-	-	-	-	-	-	*	*
<i>Ellobium aurisjudae</i>	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-
<i>Ellobium aurismidae</i>	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-
<i>Laemodonta siamensis</i>	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	*	-
<i>Melampus flavus</i>	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
<i>Melampus nucleolus</i>	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-
<i>Melampus siamensis</i>	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-
<i>Enid</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
<i>Cecilioides</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
<i>Bacillum</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
<i>Macrochlamys</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
<i>Nuculana</i> sp.	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
<i>Anadara granosa</i>	*	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Anadara septicostata</i>	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
<i>Anadara nodifera</i>	*	*	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Scelidionarca pectunculiformis</i>	*	-	-	-	-	-	*	*	-	-	-	+	-	-	-	-	-	-	-	-
<i>Mytilid</i> sp. A	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
<i>Mytilid</i> sp. B	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pinctada</i> sp. A	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pinctada</i> sp. B	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pinctada</i> sp. C	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Isognomon</i> spp.	-	-	-	-	-	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Saccostrea cucullata</i>	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Spondylus</i> sp.	-	-	-	-	*	*	-	+	-	-	-	-	-	-	-	-	-	-	-	-
<i>Anomia</i> sp.	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Placuna placenta</i>	*	-	-	-	-	-	*	*	-	-	-	*	-	-	-	-	-	-	-	-
<i>Placuna sella</i>	*	-	-	-	-	-	*	*	-	-	-	*	-	-	-	-	-	-	-	-
<i>Margaritanopsis laosensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-
<i>Pilsbryconcha exilis exilis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
<i>Pseudodon mouhoti</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	-
<i>Pseudodon</i> spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	-
<i>Uniandra contradens rustica</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
<i>Uniandra contradens tumidula</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
' <i>Lucina</i> ' <i>philippinarum</i>	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	*	-	-	-
<i>Chama reflexa</i>	-	-	-	-	-	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-
<i>Acrosterigma flavum</i>	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Tridacna derasa</i>	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Abbreviations: FW, fresh water; *, habitat; +, likely habitat; Marine habitat M, mud, silt; MS, muddy sand, sandy mud; S, sand; FA, fine algae patches; C, coral patches or reefs; H, hard ground of rocks or boulders; Mangal MF marine mud flat adjacent to mangal just beyond closed canopy; SE, seaward edge of mangal canopy; C, mangal midway between sea and dry land; LE, landward edge of mangal association; Estuary G, general estuarine setting; M, mud; S, sand; H, hard bottom/tree trunks; CH, channels; Fresh water S, still; R, running; Land G, general, terrestrial; N, nypa, damp or dry land; B, *Barringtonia* association, dry land

The preferred habitats of shell species in the site (cont.)

Species	Marine						Mangal				Estuary					FW		Land		
	M	MS	S	FA	C	H	MF	SE	C	LE	G	M	S	H	CH	LE	LO	G	N	B
<i>Tridacna maxima</i>	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Tridacna squamosa</i>	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Tridacna</i> spp.	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Atactodea striata</i>	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Coecella horsfieldi</i>	-	-	*	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-
<i>Donacilla nitida</i>	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Tellina capsoidea</i>	*	*	*	-	-	-	*	-	-	-	-	*	-	-	-	-	-	-	-	-
<i>Tellinides opalina</i>	*	*	*	-	-	-	*	-	-	-	-	*	-	-	-	-	-	-	-	-
<i>Asaphis violascens</i>	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Polymesoda erosa</i>	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-
<i>Anomalocardia squamosa</i>	-	*	*	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
<i>Bassina parva</i>	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Circe scripta</i>	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Dosinia juvenilis</i>	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Dosinia trailli</i>	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Marcia hiantina</i>	-	*	*	-	-	-	*	*	-	-	-	*	*	-	-	-	-	-	-	-
<i>Meretrix lusoria</i>	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Paphia undulata</i>	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pelecypora trigona</i>	*	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-
<i>Ruditapes philippinarum</i>	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Corbula erythron</i>	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Teredinid</i> sp.	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-

Abbreviations: FW, fresh water; *, habitat; +, likely habitat; Marine habitat M, mud, silt; MS, muddy sand, sandy mud; S, sand; FA, fine algae patches; C, coral patches or reefs; H, hard ground of rocks or boulders; Mangal MF marine mud flat adjacent to mangal just beyond closed canopy; SE, seaward edge of mangal canopy; C, mangal midway between sea and dry land; LE, landward edge of mangal association; Estuary G, general estuarine setting; M, mud; S, sand; H, hard bottom/tree trunks; CH, channels; Fresh water S, still; R, running; Land G, general, terrestrial; N, nypa, damp or dry land; B, *Barringtonia* association, dry land

KHOK PHANOM DI AND SEA LEVELS

Khok Phanom Di is set on the eastern side of the Bangkok plain, which has very low relief and a gradient of 1:10,000 or less, rising from sea-level to a height of 2–3m. It is obvious that this low-lying deltaic region at the head of the Gulf of Siam would have been greatly influenced by Holocene sea-level changes; a change of just 50cm being potentially capable of producing large revisions of terrestrial fresh water regime and landward or seaward migration of the strandline of many kilometres. These formerly mangal-bound coasts would have been affected differently with respect to a falling or rising mean sea-level: a rising sea would rapidly destroy mangal by coastal revision following Bruun's Rule and the killing of salt-intolerant plant species. A falling sea tends to aid the development of mangal by providing less salt-stress and increased ground for colonizing. An additional effect is to liberate land-locked sediment by increasing drainage rate by virtue of the lower base level.

The molluscs indicate quite clearly that, at first settlement, the site was set in closed canopy mangal, probably within the range of spring high tides. As there is little or no evidence for flooding in the site, it must be assumed that it was higher than the surrounding land surface. 'The position of a coastline in time and space is determined by (1) the vertical displacement and/or tilting of the depositional surface, (2) the rate of sediment accumulation or erosion across that surface, and (3) variation of sea-level' – (Collier *et al.* 1990:117).

Let us now briefly consider the factors influencing relative sea-level change. A gravitationally isotropic globe can be idealized in the figure of the rotational spheroid. This ideal smooth figure is highly deformed to become the gravitational equipotential surface known as the Geoid. This latter figure, in the oceanic parts of the earth's surface, has a relief of more than $\pm 120\text{m}$ with respect to the rotation of the ellipsoid. The Geoid is further deformed by tidal and atmospheric phenomena. The shape of the Geoid changes continuously through time at a rate determined by the imposed forces and the visco-elastic properties and structure of planetary materials. The main event (by an order of magnitude) in the Holocene was the transference of some $3 \times 10^{19}\text{kg}$ of mass from the north polar region to the world ocean (Kaula 1980). The two major effects of this mass transfer were rapid and large positive and negative RSL change in the northern polar and subpolar regions caused by glacio-isostatic relaxation and a rapid, global absolute rise in sea-level, variously offset by a hydro-isostatic depression of the ocean basins. The prediction of how these massive and geologically rapid events were manifested in terms of the local sea-level curve is complicated by a number of problems, not least of which are the rate of melting of polar ice and the rate of adjustment of the Geoid. It is now abundantly clear that a global sea-level curve is a chimaera, and that even for a small region such as the North Sea, there is a multiplicity of divergent sea-level curves for the Holocene alone (Shennan 1989). In short, the post Pleistocene release of meltwater has not resulted in a globally even upward radial shift of sea-level through the Holocene following a smooth 'Shepard' Curve, but follows a much more complex pattern determined by Geoid deformation complicated by local or regional seismotectonic events and a plethora of factors discussed by Higgins (1965).

There are no absolutely stable land areas in the world (Inqua Neotectonics Commission 1980). Global models of RSL variation, based on simple glacial loading/unloading principles, have been worked by among others Clark (1980) and Peltier (1988), but Mörner (1980) points out that the Geoid is also subject to changing rotational and external gravitational potentials which are also linked to geomagnetic variations. This implies that the deep sea core oxygen isotope record will not be an accurate history of glacial volume (Mörner 1980:691 fig. 4). It is clearly premature to rely on theoretical models of palaeogeoid behaviour for local RSL curves at low latitudes, though they may apply some broad constraints.

That seismotectonic activity is continuing along the Burma subduction zone where the Indian plate is plunging beneath the South-East Asian microcontinents is shown by Guzman-Speziale *et al.* (1987) and further south subduction with large-scale transcurrent faulting continues under the Andaman Sea and Sumatra (Verma *et al.* 1979). The opening of the Gulf of Siam is one of the largest changes in the geography of South-East Asia since late Cretaceous times and is thought by Bunopas and Vella (1983) to have reached a climax in early Quaternary time. Inspection of Somboon's (1988) isopach map for the Holocene Bangkok clay on the Thai central plain strongly suggests that quite rapid tectonic changes are occurring. The eastern part of the plain bordering the Bang Pakong River in the vicinity of Khok Phanom Di shows strong anomalies suggesting that active faulting is taking place. Somboon (*ibid.*) presents convincing evidence for a Holocene

marine transgression of the lower Bangkok Plain reaching a maximum some 5000–6000 BP before gradually retreating to the present position. He depicts a strand bordered by a brackish swamp, saltmarsh and mangal.

THE ENVIRONMENT OF KHOK PHANOM DI

In an attempt to separate, as it were, the cultural signal from the environmental input, Fig. 63 shows the number of shell species per spit. Superposed on the time axis are the mortuary phases, gaps in the sequence of interments and all the shell middens and pit features containing significant amounts of shell. It can be seen that there is a general correspondence between the level of burial activity, the number of species present and the volume of shell midden. The number of individuals per species per spit shown in Table 52 reveals virtually no systematic trend with time. For this reason, it was decided to use only presence/absence data and avoid, thereby, a number of problems connected with the fact that the eight most abundant species represent over 99 per cent of individuals in the site. Fig. 63 shows that, early in the history of the site, up to forty-three species occurred in a spit, and that there was a gradual reduction with time so that, at the base of layer 3, only two species were found.

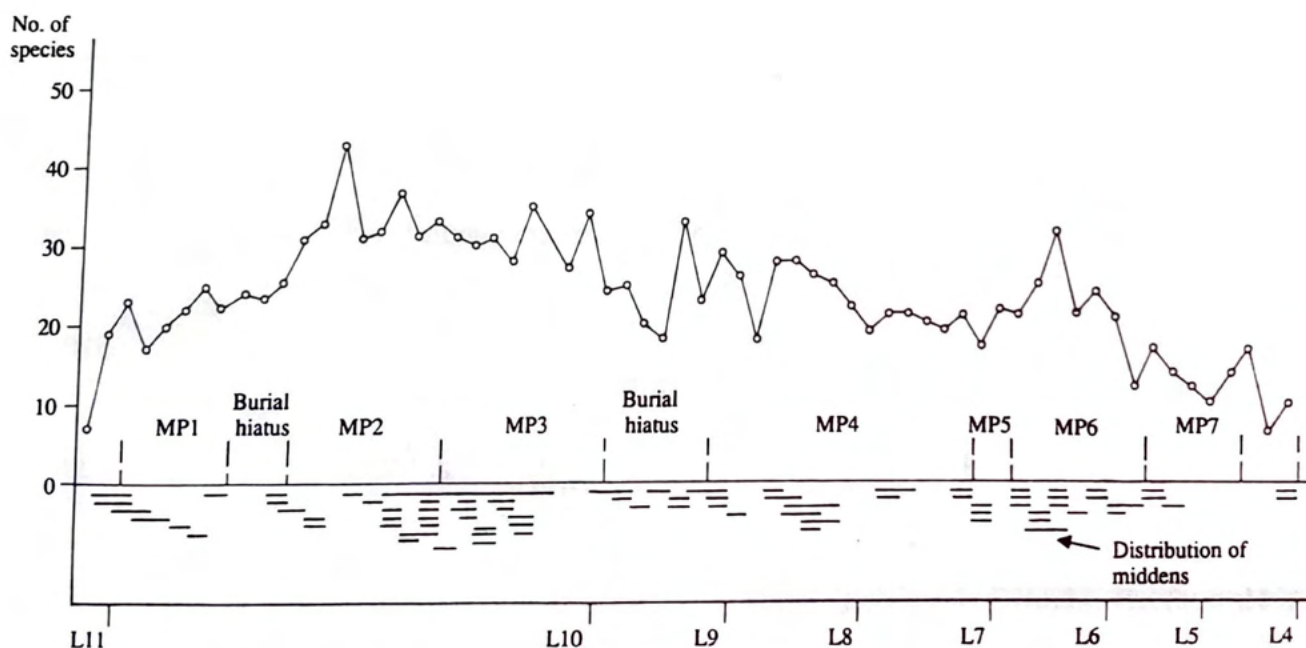


FIG. 63. The distribution of the number of mollusc species found in each layer and spit

In order to interpret the data in environmental terms, species have been assigned to one of the following broad habitats. The assignment where a species could be found in one or more of these habitats has been described above by Manly. Fig. 64 shows the varying dominance of each of the

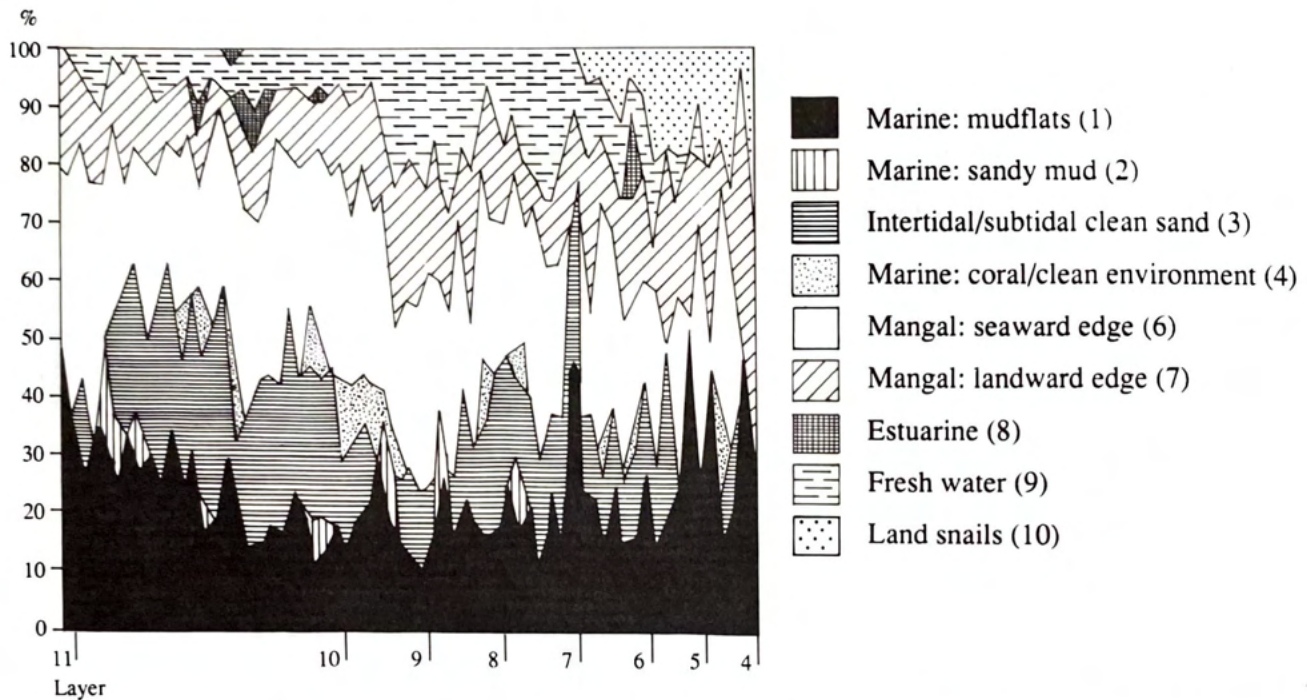


FIG. 64. The percentage frequency by layer of shell species assigned to each of the ten major habitats identified for Khok Phanom Di

ten habitats, represented by the percentage frequency of species assigned to each. Fig. 65 shows the reconstruction of the habitat in the vicinity of the site during layers 11 and 4 respectively.

- Habitat 1 represents marine subtidal and intertidal mud (Fig. 66). The number of species in question quickly rose to a maximum in layer 10:12–15 then remained more or less constant until the beginning of layer 3.
- Habitat 2 is muddy marine sand, subtidal to intertidal (Fig. 67). Representation of this habitat was patchy from the beginning of the site to layer 7:6, when it substantially disappeared.
- Habitat 3 is clean subtidal and intertidal sand possibly associated with coralline growth. It will be recalled that some remains of coral were found in the site (Fig. 68). It was weakly present in layer 11 and during layers ascribed to MP1, flourished in MP2–3, shows a gap for the layer 9 burial hiatus and continued at a much reduced level in layers 9–4.
- Habitat 4 represents a clean water shallow to intertidal coralline association. The distribution of species here follows quite closely those of habitat 3 but is somewhat patchy at all times (Fig. 69).

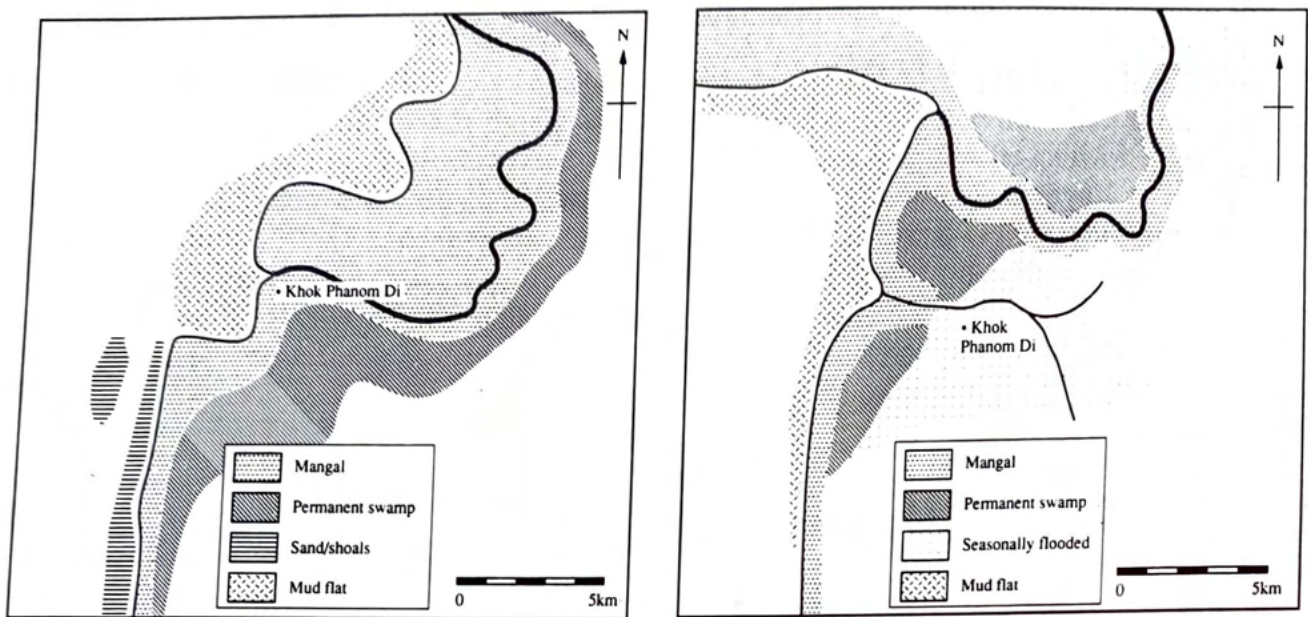


FIG. 65. The reconstruction of the environment of Khok Phanom Di during layer 11 (left) and layer 4

- Habitat 5 represents clean water rocky ground, subtidal to intertidal. The species occurring in this habitat could equally well have been placed either in seaward mangal or the clean coralline association. However, Manly's results show some reason to suppose that this habitat was present in its own right. The indications are weak at all times (Fig. 70).
- Habitat 6 describes the marine aspect of the mangal and will be substantially intertidal with a small supralittoral element. There was an initial peak in layer 11, then a fall off of species numbers in the layer 10 burial hiatus. Numbers then reached a maximum in upper layer 10 slightly after the habitat 1 maximum, and declined thereafter gradually to the top of layer 4 (Fig. 71).
- Habitat 7 represents the landward aspect of the mangal and may also include proximity to the fresh water aspect of the estuarine environment. There were consistent small numbers of species from the beginning to the end of the site but with a short-lived increase at lower layer 9 near the hiatus in the burial sequence (Fig. 72).
- Habitat 8 represents estuarine species which may or may not have been associated with mangal. They are few in number and show small fluctuations from the beginning to the end of the site. Possible reasons for these changes are obscure, but may relate to fortuitous preservation in the site (Fig. 73).
- Habitat 9 includes fresh water species, stream, lake and river. There are consistent low numbers of species from the start of the site through to layer 9:4. There was then a marked and sustained increase in species numbers to the start of layer 7. Thereafter, there was a gradual decrease in numbers to layer 3, where there was a total absence (Fig. 74).
- Habitat 10 represents pulmonate land snails. With the exception of a single shell in 10:11 (*Rhiostoma housei*), which may have been imported from higher, limestone hilly areas, there

are no land snails until their abrupt entrance at layer 6:6 with four species all apparently living on the site (Fig. 75).

The species count graphs show a series of maxima. Sandy coast and marine species reached a maximum in lower and mid layer 10, followed by a maximum in the seaward mangal species in middle to late layer 10 and lower layer 9. This was accompanied by a weak burst of estuarine species in upper layer 10 to be followed by a dramatic rise in fresh water species from upper layer 9 to upper layer 7, with a dip at about layer 8:1 obviously due to a lack of midden deposits in this context. This was followed by the sudden appearance of land snails, apparently living on site, and a rapid reduction in all mollusc remains. This succession of habitat florescences seems totally to lack any perceptible cultural cause and is most plausibly interpreted as being a real environmental signal.

It is therefore concluded that the simplest picture consistent with this evidence is that the earliest inhabitants of Khok Phanom Di settled on a slightly elevated river levee close to an open coast bearing patches of clean, sandy and coralline sediment.* There was also a substantial estuary not far from the site. With the passage of time, the diminution of seaward mangal species and those from clean water habitats suggests a prograding, muddy coastline and increasingly fresh water environment.

In identifying the timing of the major environmental change indicated by the intrusion of land snails, the increase and subsequent decrease in fresh water species and the associated change in the landward mangal species, some provision must be made for the elapsed time between such a change and its reflection in the distribution of molluscan species. There are strong indications that the inhabitants of the site encountered the advent of non-estuarine, even non-riverine, conditions certainly by the beginning of layer 6. Such a change could have taken the form of the cutting off of a loop of the ancestral Bang Pakong River, or even the relocation of the river bed following a major flood. It is argued that, in terms of the elapsed time, this change could have occurred somewhere in lower layer 8 and upper layer 7. Under such conditions, access to riverine and coastal resources would have required more physical effort and time. There is a tendency for shell bead numbers to coincide with the availability of a clean sandy to coralline environment. The changes described above are represented in figure 65. Consideration of the micro-molluscs, now in progress, might modify some of these conclusions.

*The analysis of the sediments directly underlying layer 11 will be published in a later volume of this report. L. Aitken has informed the author that the grain size analysis of this material is consistent with a river levee.

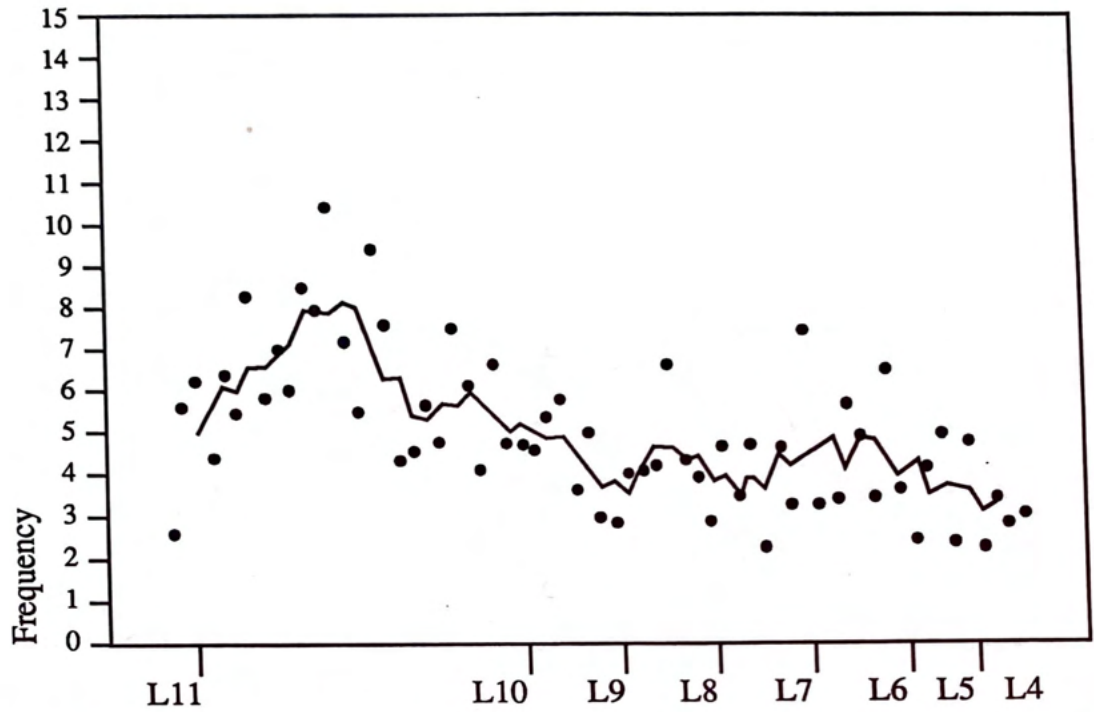


FIG. 66. The distribution of species assigned to habitat 1: subtidal to intertidal marine muds

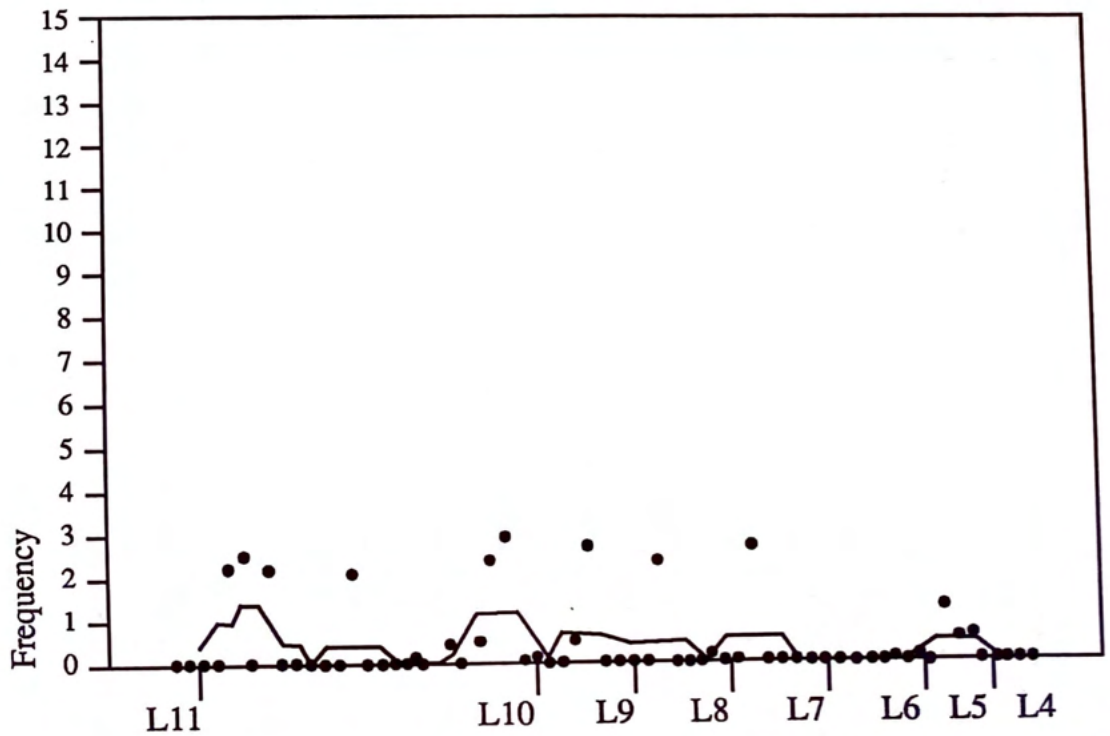


FIG. 67. The distribution of species assigned to habitat 2: subtidal and intertidal marine sandy muds

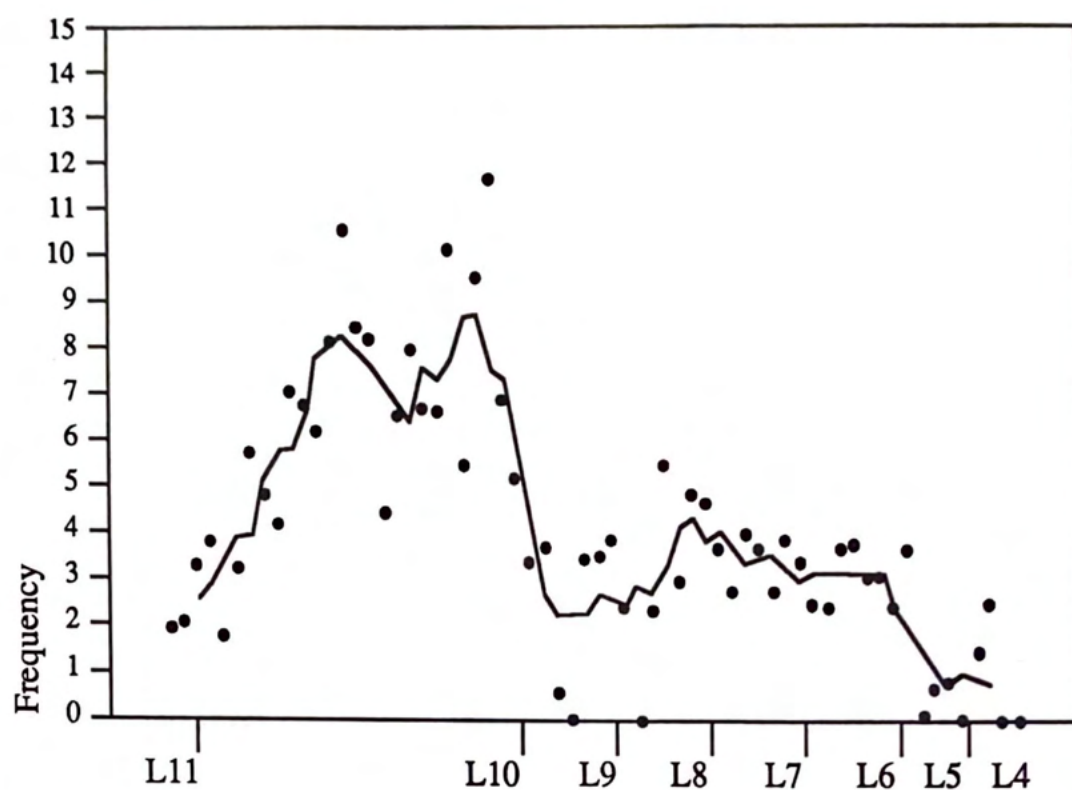


FIG. 68. The distribution of species assigned to habitat 3: clean subtidal and intertidal marine sand

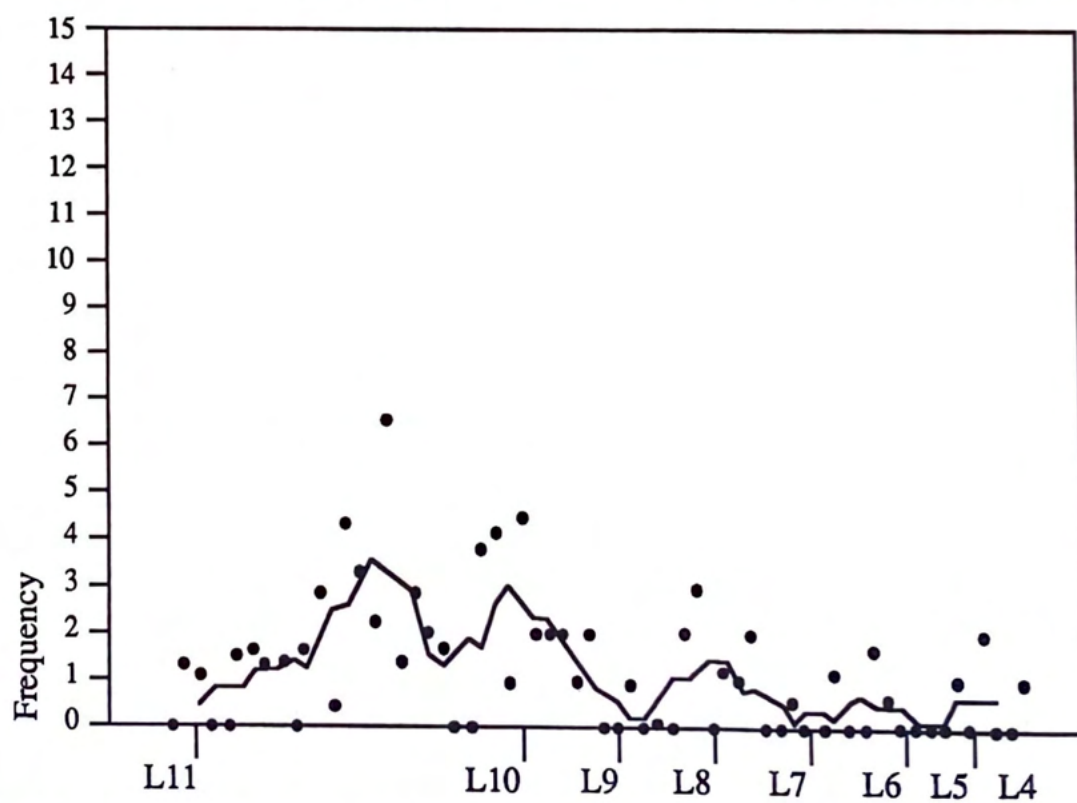


FIG. 69. The distribution of species assigned to habitat 4: clean coralline subtidal and intertidal conditions

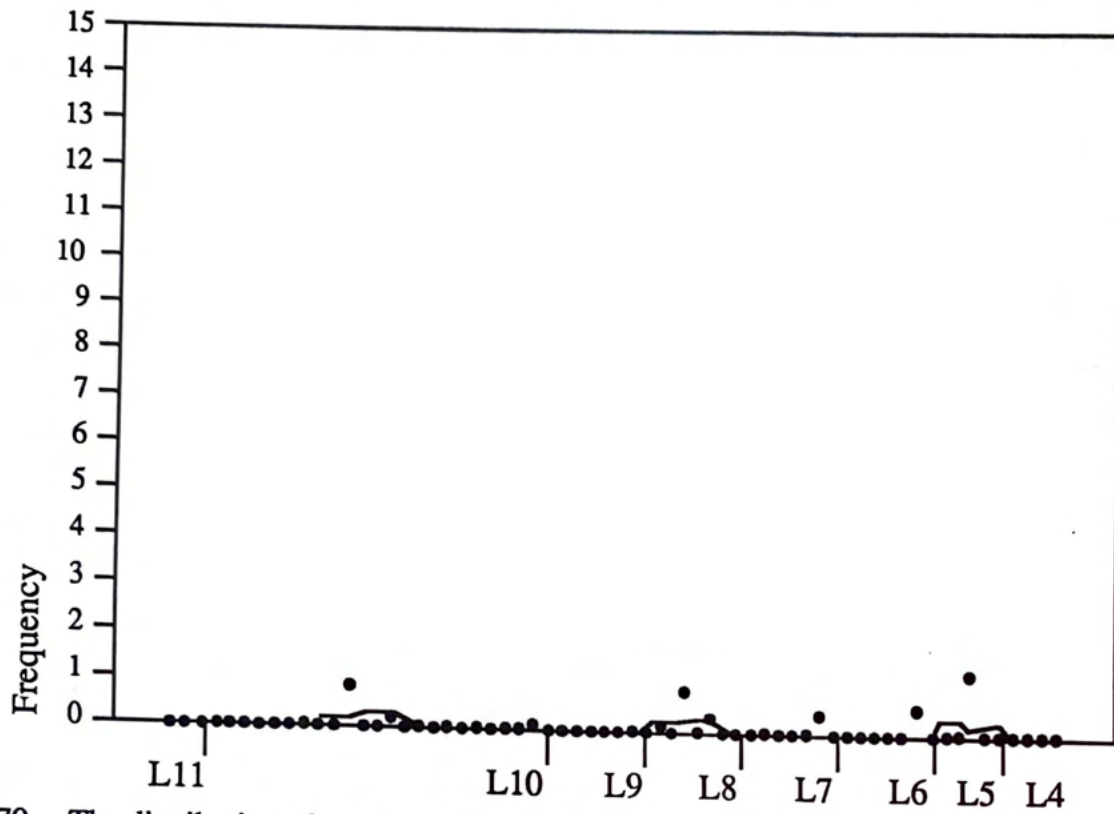


FIG. 70. The distribution of species assigned to habitat 5: clean rocky subtidal and intertidal conditions

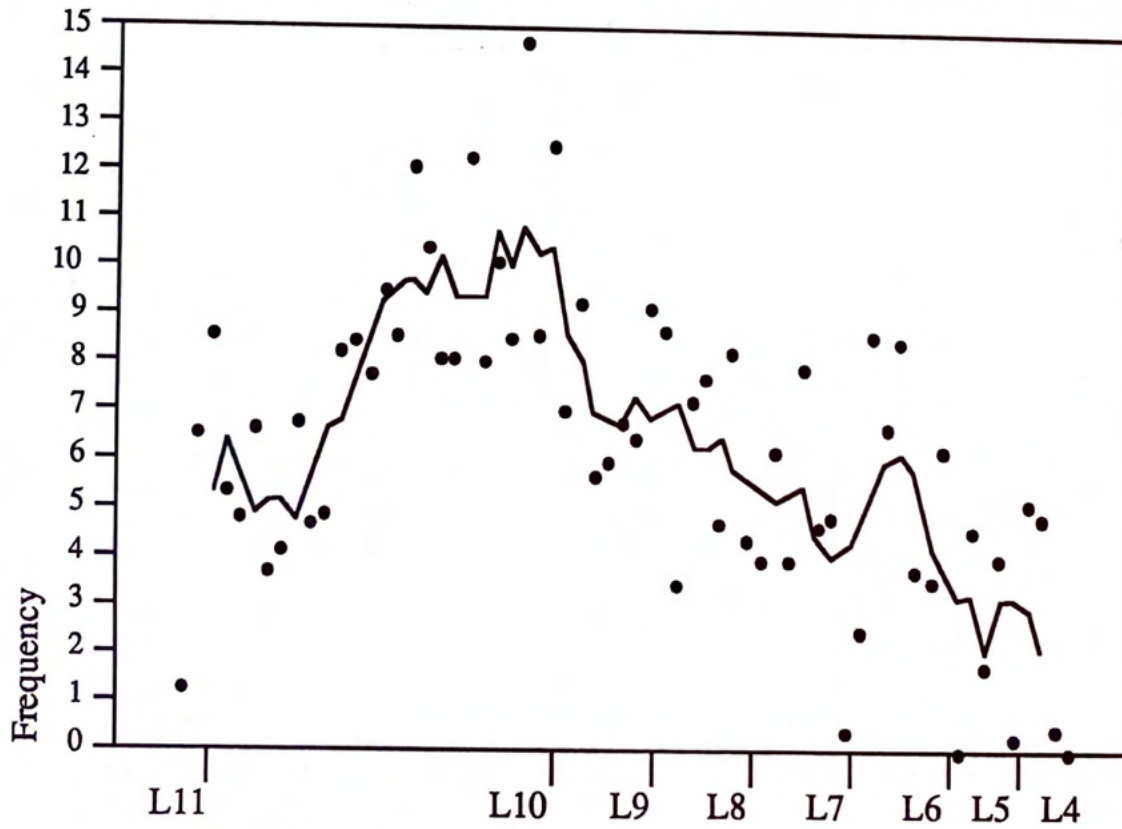


FIG. 71. The distribution of species assigned to habitat 6: seaward facing mangal

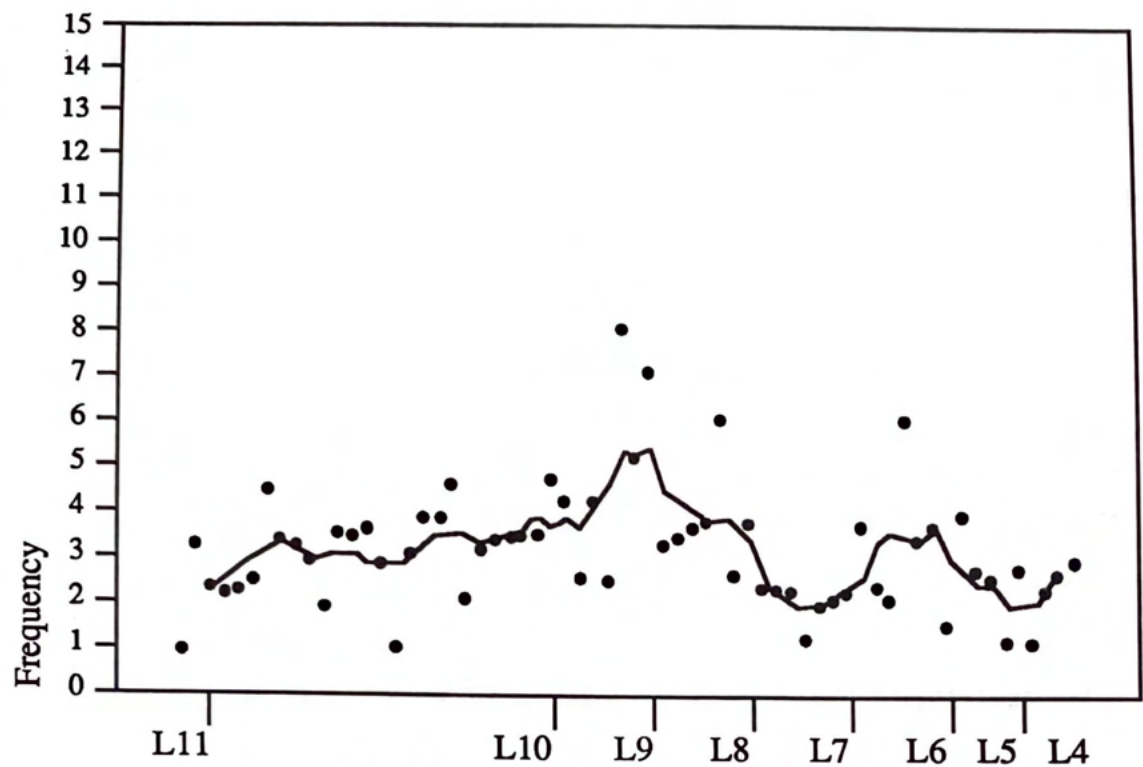


FIG. 72. The distribution of species assigned to habitat 7: landward mangal

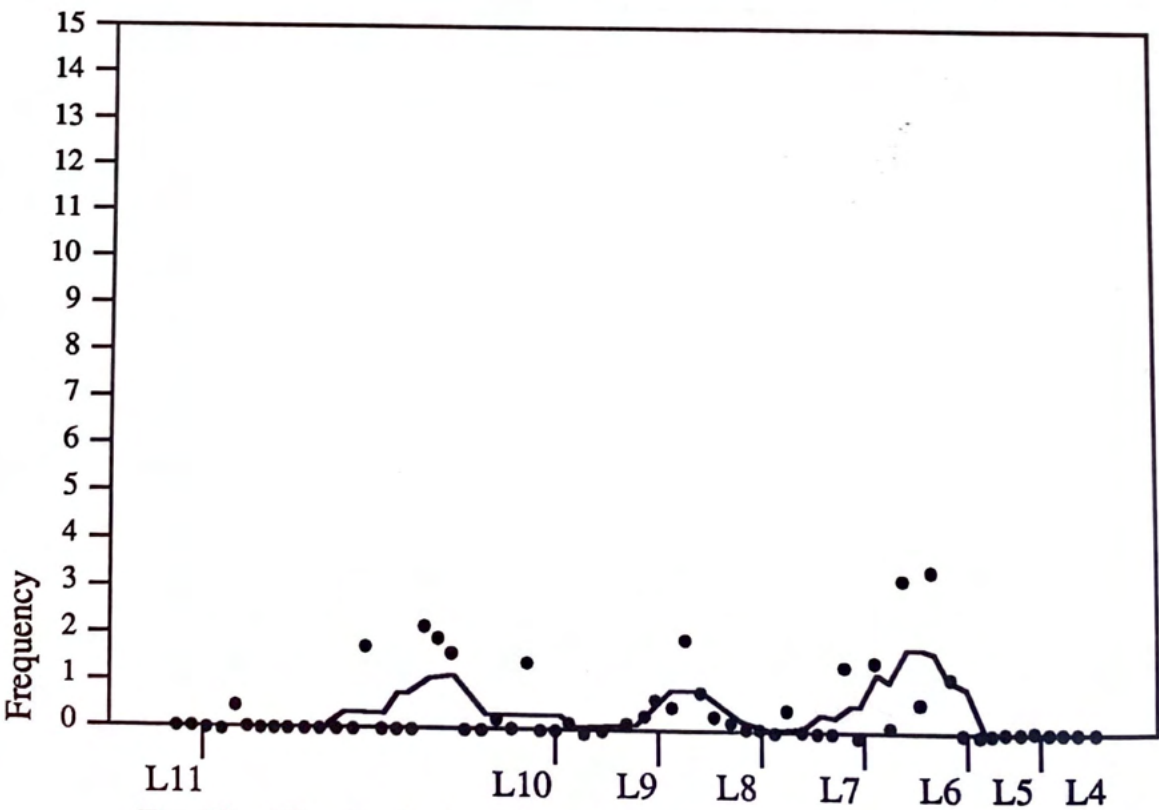


FIG. 73. The distribution of species assigned to habitat 8: estuarine

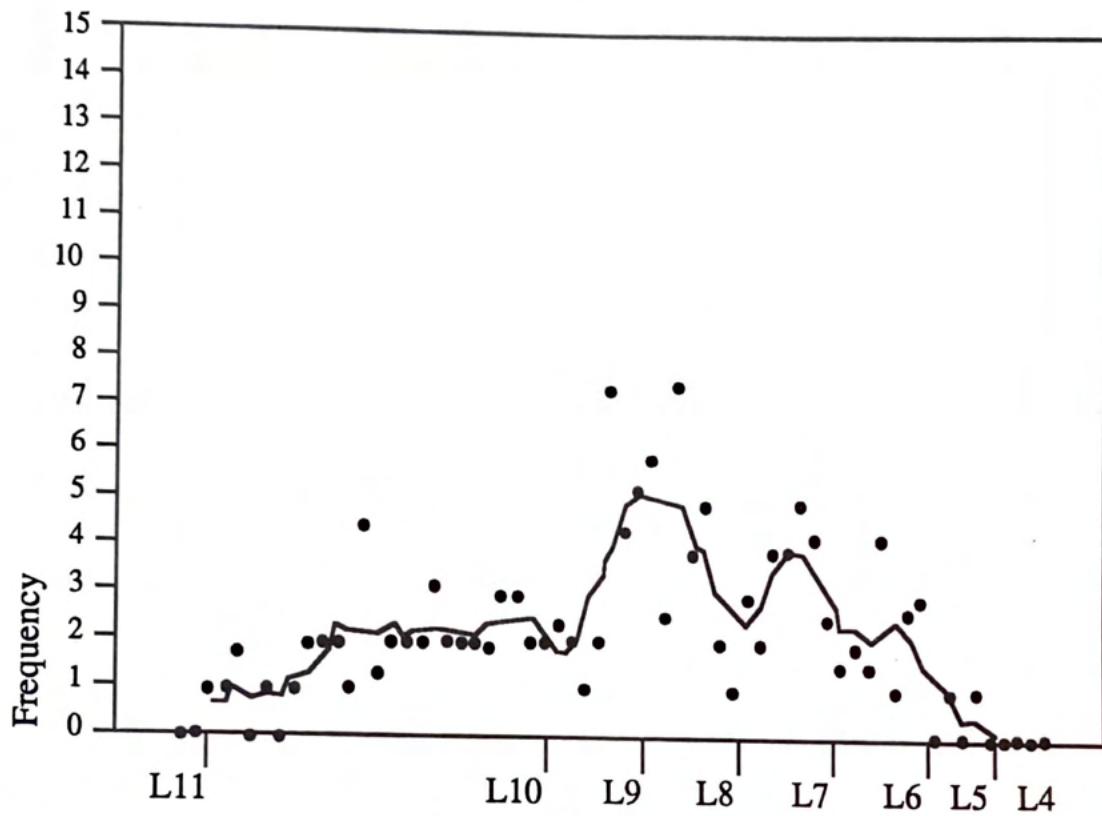


FIG. 74. The distribution of species assigned to habitat 9: fresh water river, stream and lake

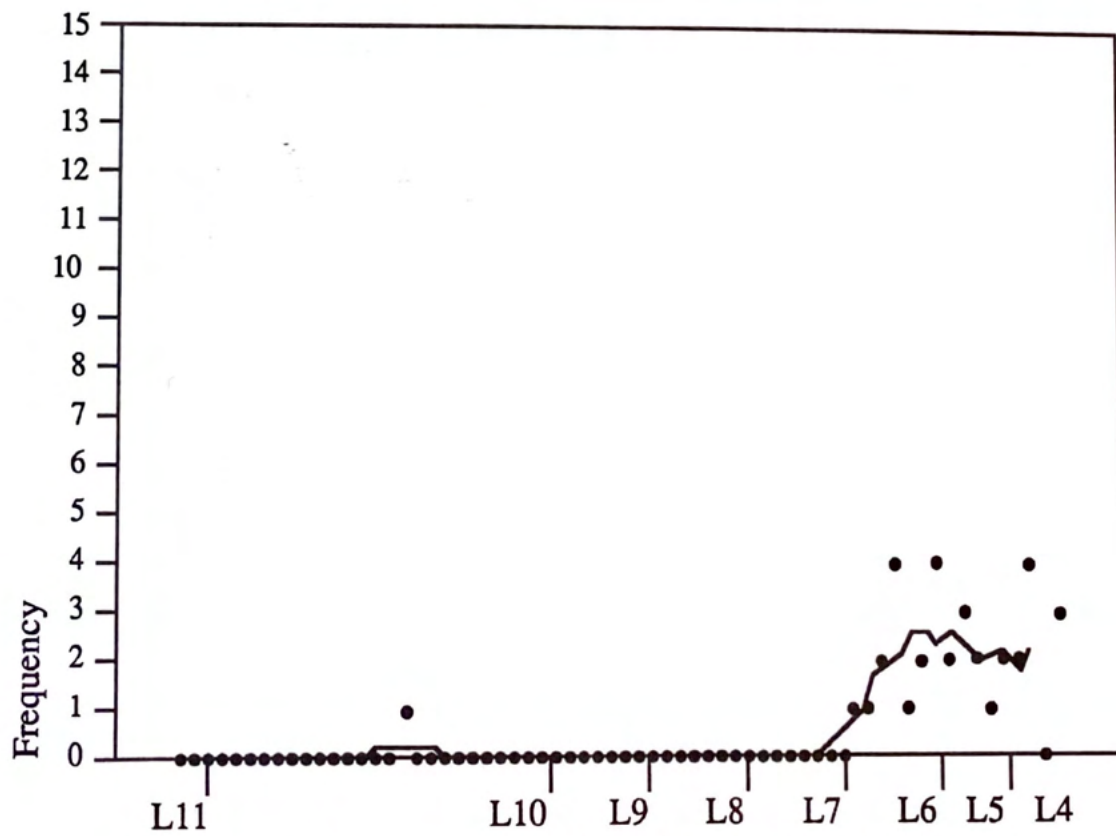


FIG. 75. The distribution of species assigned to habitat 10: dry land

XIX. THE STATISTICAL ANALYSIS OF SHELL SPECIES COUNTS

By Bryan F. J. Manly

INTRODUCTION

THIS chapter describes the methods of statistical analysis that have been used on the shell counts for 119 species obtained from the cultural sequence at Khok Phanom Di. This comprises eleven layers which, with their component spits, involve sixty-four successive contexts. The original data for species counts are shown in Table 52, while Table 55 shows species presences (1) and absences (0). Further data consist of information on the habitats that can be used by each of the species, as shown in Table 56.

The statistical analyses were designed to answer first the following questions concerning patterns in species occurrences over time:

- (a) Are there time trends in the total number of species present?
- (b) Are there changes with time in the species occurrences in the sense that as the stratigraphic units become further apart in time they tend to differ more and more in terms of species compositions?
- (c) Are species compositions more similar for spits within layers than for spits in general?
- (d) What are the time trends, if any, in the occurrences of shells from different habitats?

Following the analyses on time trends, consideration was given to the relationships between species in terms of the following questions:

- (e) How do the species relate in terms of similar distributions of occurrences over time?
- (f) Do species similarities in terms of habitat use correlate with similarities in times of occurrence?

One of the problems with a set of data such as that shown in Table 52 is the very large difference between the counts for the few very common species and for the large number of species seen occasionally. This tends to mean that all statistical analyses are dominated by the data for the common species which are present in all or nearly all contexts. However, the occurrences of the uncommon species may provide particularly valuable information about trends.

The usual way to reduce the influence of large counts in a situation like this involves transforming the data. For example, the count X can be replaced by $\log(X+1)$, or by that count as a proportion of the total count for the species in all spits. Alternatively, if there are large numbers of species, an analysis can simply be based on presences and absences of species.

In the present case some initial calculations based on counts as a proportion of species total counts was not found to illuminate time trends, whereas clear results were obtained using presence-absence data. For this reason all the results that will now be described were based only on the presence-absence data that are shown in Table 55.

CHANGES WITH TIME IN SPECIES OCCURRENCES

Figure 63 shows the total numbers of species present in the 64 spits. The patterns of changes shown would appear to be real since highly significant results are obtained from serial correlation, Von-Neumann ratio, runs above and below the median, and regression tests for randomness of the series (Manly 1991, ch. 9). Hence there is clear evidence that total numbers of species occurrences changed in a non-random manner, and question (a) must have an affirmative answer.

To answer question (b), it is possible to set up an array with 64 rows and 64 columns in which the element in row i and column j , a_{ij} , say, is the number of spits that separate spit i and spit j . For example, $a_{12} = 1$ since spits 1 and 2 are adjacent, and $a_{15} = 4$ since spits 1 and 5 differ by 4. The array will be symmetric with $a_{ij} = a_{ji}$ since the difference between spits i and j is the same as the difference between spits j and i . Diagonal values a_{ii} can be set equal to zero since spits are not different from themselves.

A second 64 by 64 array can also be set up with the element b_{ij} in the i th row and j th column being some measure of the extent to which species occurrences differ between spit i and spit j . There are many possible measures that can be used for this purpose. Here the number of differences in species occurrences will be used. That is to say, b_{ij} will be the total number of species that either occur in spit i but not in spit j or occur in spit j but not in spit i . With this definition, $b_{ij} = b_{ji}$, and $b_{ii} = 0$, for all i and j from 1 to 64.

Having set up the two arrays, question (b) can be rephrased to ask whether there is a significant level of positive correlation between the a_{ij} and b_{ij} values. This can then be established using Mantel's (1967) matrix randomization test that is described for example by Manly (1991, ch. 7). (More standard tests for significant correlation are not valid because of the nature of the data, with the values within each of the two arrays not being statistically independent of each other.)

It is found that the usual Pearson correlation coefficient between the corresponding elements in the two arrays is $r_{ab} = 0.257$, where this is significantly large at about the 0.01 per cent level on a two-sided test. There is therefore very strong evidence that species occurrences in spits tend to get more and more different as the spits get further apart in time. Furthermore, the regression equation relating the b_{ij} distances to the a_{ij} distances is found to be

$$b_{ij} = 18.72 + 0.11a_{ij}$$

which indicates that on average there is an increase of 0.11 in the number of species differences between spits for every spit that separates them.

Question (c) can be answered using another Mantel randomization test. This requires a third 64 by 64 array to be set up, such that c_{ij} , the value in the i th row and j th column, is zero for two spits within the same layer, but is otherwise equal to the number of layers that separate the spits. For example, if spit i is in layer 10 and spit j is in layer 8, then $c_{ij} = 2$. Having set up this array,

question (b) can be restated to ask whether there is a significant positive correlation between the species differences b_{ij} and the corresponding layer differences c_{ij} .

It is found that the correlation between the species and layer differences is $r_{cb} = 0.270$, which is significantly large at about the 0.01 per cent level according to a Mantel test. Hence there is very strong evidence that spits within layers are relatively similar in terms of species occurrences, and that the differences between spits tend to be greatest for the layers that are furthest apart. The fitted regression equation

$$b_{ij} = 18.96 + 0.89c_{ij}$$

shows that on average species differences increase by 0.89 for each level of difference between two spits.

EXAMINATION OF CHANGES WITH TIME IN SPECIES NUMBERS FROM DIFFERENT HABITATS

Attention is now turned to question (d) concerning the nature of any time trends in the numbers of shells collected from species using different habitats. The data on this question are provided in Table 56, which shows the 119 species with an indication of which of ten types of habitat these species can inhabit, and Table 55, which shows the species presences and absences in different spits. These data provide a method for assessing trends in the availability of different habitats at different times in the past on the assumption that an increase in the amount of habitat of a particular type would have led to an increase in the number of species that use this habitat.

It is straightforward to allocate species that are only found in one habitat to that habitat. However, what should be done for species that are found in two or more habitats is not so clear. The principle that was used in this study was that if a species X can occur in h habitats, which are represented by $n_1, n_2, \dots, n_h$ other species, respectively, then it is appropriate to allocate the occurrence of species X to the h habitats as n_1/n_T to habitat 1, n_2/n_T to habitat 2, and so on. The total 'occurrence' of species X in the h habitats then adds to 1, which maintains the correct total number of species.

To implement this principle an iterative process was used, as follows:

- (i) For each of the 64 spits all of the species that were present were assigned to habitats by allocating species that only occur in one habitat to that habitat, allocating species that can occur in two habitats 1/2 to each of these habitats, allocating species that can occur in three habitats 1/3 to each of these habitats, etc. This resulted in an iteration 0 allocation, with the correct total number of species occurrences in each spit and the correct total number of occurrences for each species.
- (ii) Starting again with species 1 in spit 1 and continuing through to species 119 in spit 64, each occurrence of a species that can use more than one habitat was reallocated to those habitats, but in proportion to the numbers of allocations found in iteration 0 rather than equally. This resulted in an iteration 1 allocation.
- (iii) The allocation process described in (ii) was repeated until an allocation produced a negligible change in moving from one cycle to the next. This required about ten iterations.

Of course, there is no reason why this allocation process should produce species numbers in different spits that are proportional to the absolute amounts of different habitats present when spits were laid down since some types of habitat may be inherently able to support more species than others. However, it can be hoped that the numbers allocated to a habitat in different spits are approximately proportional to the relative amounts of the habitat in those spits. Thus the species allocations should track trends in habitat availabilities to some extent at least.

Figures 66–75 show the final allocations that were achieved after the iterative process was completed. Moving averages of the numbers in five successive spits are also shown in order to make the trends clearer.

RELATIONSHIPS BETWEEN SPECIES

Question (e) asks how the 119 species relate in terms of their patterns of presences and absences in the 64 spits. One method of answering this is based on an approach to data analysis that has been discussed by Hubert and Schultz (1976) under the title 'quadratic assignment'. In general this type of data analysis involves finding an ordering of a number of items so as to maximize the correlation between two criteria of differences between those items. In the present case, this can be considered as the problem of listing the 119 species in such a way that the distance apart of two species on the list is correlated as highly as possible with the number of differences between the occurrences of those species.

An algorithm for producing a listing of this type is as follows:

- (i) Start with the 119 species listed in any arbitrary order. Calculate the elements in a 119 by 119 array such that the element A_{ij} in the i th row and j th column is the distance apart of species i and species j on the list. For example, for the first and third elements in the list $A_{13} = A_{31} = 2$. Calculate also a 119 by 119 array such that the element B_{ij} in the i th row and j th column is the number of spits where either species i is present but not species j , or species j is present but not species i . Find the ordinary Pearson correlation r_{AB} between the corresponding elements in the two arrays, where this is a measure of the extent to which the closeness of two species on the list matches the similarity between their times of occurrence.
- (ii) See whether swapping the first species with any of the other species increases r_{AB} and, if so, make the swap. Then, keeping the first species fixed, try swapping the second species with each of the other species. Continue in this way, swapping each species with any species further down the list if this increases r_{AB} , until the last species in the list is reached.
- (iii) Compare the correlation before starting step (ii) with the correlation at the end of that step. If there is no difference then accept the listing of the species as it stands. Otherwise, if step (ii) led to an increase in the correlation then start step (ii) again. When this algorithm is applied with the data shown in Table 55 it changes an initial negative correlation between distances on the list and presence-absence differences for species into the value $r_{AB} = +0.54$. The reordered list of species that gives this correlation is shown in Table 57. Clearly, species with similar patterns of occurrences now tend to be close in the list, which starts with species seen in every spit and ends with those seen mainly in the later spits.

Multidimensional scaling was also used to produce a 'map' of the relationships between species as described by Manly (1986, ch. 6). Basically, the purpose of this type of analysis is to produce the spatial configuration of n objects that matches as closely as possible the differences between those objects that are contained in a given n by n array. In the present case the objects are the 119 species and the difference between species i and species j can be taken as the number of spits where i is absent and j is present or j is absent and i is present, i.e., B_{ij} as defined above.

Multidimensional scaling can be used to produce a one-dimensional 'map' (with the n objects assigned to positions along a line), a two-dimensional 'map' (with objects having horizontal and vertical coordinates), a three-dimensional map (with objects having three coordinates), and so on. Good one- or two-dimensional solutions are obviously desirable since they are easiest to show on paper.

The computer program ALSCAL-4 (Young and Lewyckyj 1979) was used to analyse the data. A two-dimensional solution with a 'stress 1' fit of 0.108 was found to be about as good as a three-dimensional solution with a 'stress 1' fit of 0.087. The output from the program for the two-dimensional solution was the values for two coordinates for each of the 119 species. Plotting the species against these coordinates gives Fig. 76, which shows that the species can be represented approximately as points on the circumference of an ellipse. The concentration of points on the left-hand side corresponds to the large number of species that occur in only a few spits, whereas the species on the right-hand side occur all or most of the time. Consequently, the horizontal dimension corresponds to 'abundance'. The species at the top of the figure are those that tend to occur in the early spits, while those at the bottom tend to occur later. Hence the vertical dimension corresponds to 'earliness'.

THE CORRELATION BETWEEN SPECIES OCCURRENCES AND HABITAT USE

The final question (f) listed in the introduction to this chapter concerns whether species that are similar in terms of habitats where they can occur, as listed in Table 56, also tend to be similar in terms of the spits in which they occur. A Mantel randomization test was used to examine this question. The difference in habitat between species i and species j was measured by the difference between Schoener's (1968) niche overlap and unity:

$$H_{ij} = 0.5 \sum_{h=1}^{12} |p_{ih} - p_{jh}|$$

where p_{ih} is the proportional use of habitat h by species i , assuming that if a species can use m habitats then these habitats are used $1/m$ of the time each. This is clearly not a reasonable assumption but serves as a first approximation. Twelve habitats were used in the calculation of these distances since two of the 119 species being considered do not use any of the ten habitats listed in Table 56. One of these species was allocated habitat 11 and the other habitat 12. Values of H_{ij} vary from 0 (use of the same habitats) to 1 (no common habitats used). The difference in species times of occurrence was measured by an equation similar to H_{ij} but with

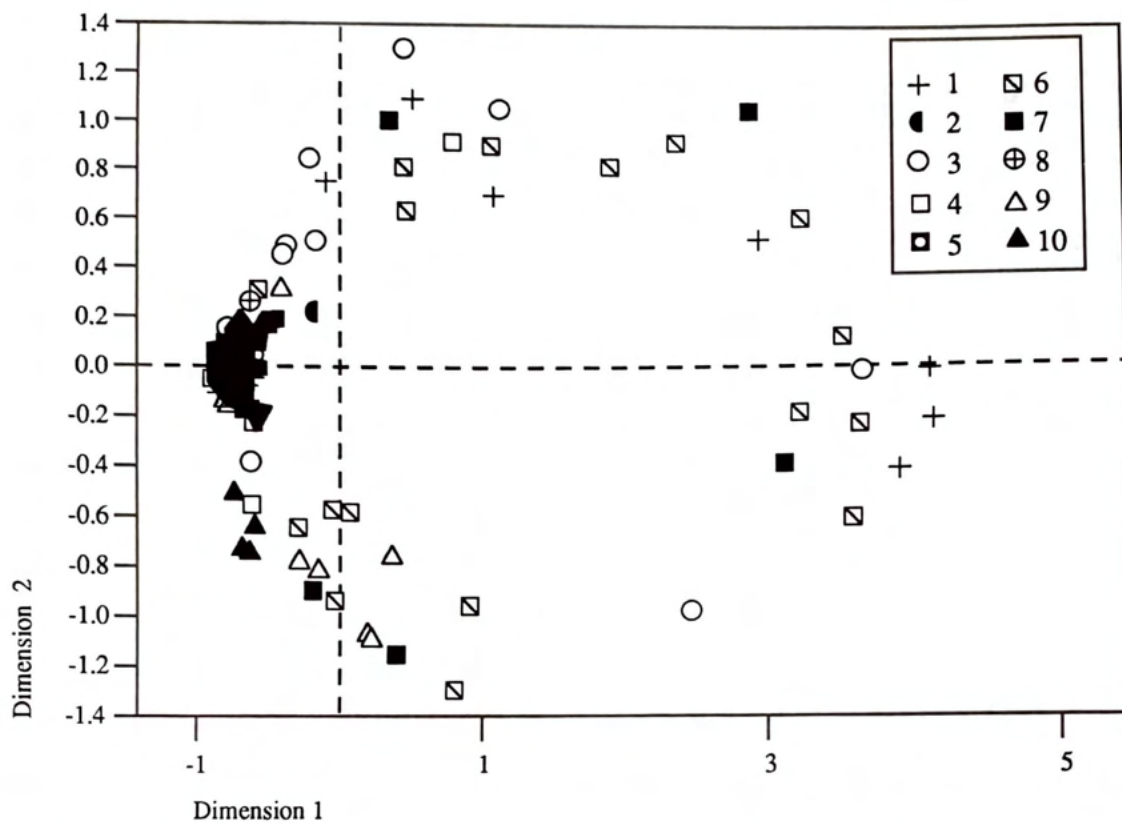


FIG. 76. The relationship between the species obtained from multidimensional scaling in two dimensions, set against their preferred habitats. 1: marine mudflats, 2: marine, sandy mud, 3: intertidal/subtidal clean sand, 4: coral/clear marine water, 5: marine, hard substrate, 6: mangal, seaward edge, 7: mangal, landward edge, 8: estuarine, 9: freshwater, 10: land snails

the twelve habitats replaced by the sixty-four spits, and p_{ih} redefined to be $1/m$ if species i is seen in spit h , or otherwise 0, where m is the total number of occurrences of species i . This produced an array O_{ij} of occurrences differences that range from 0 for two species seen in exactly the same spits to 1 for species only seen in different spits.

A regression of the O_{ij} values on the H_{ij} values gives the fitted equation

$$O_{ij} = 0.876 + 0.042H_{ij}$$

which suggests that species that use completely different habitats ($H_{ij} = 1$) have on average an occurrence difference measure that is 0.042 higher than species that use the same habitats ($H_{ij} = 0$). The Pearson correlation between H_{ij} and O_{ij} values is 0.074, which shows that the relationship between these two distances is not strong. However, a Mantel randomization test shows that the relationship is significant at the 0.1 per cent level so it does appear to be real.

TABLE 55: The distribution of shell species by presence or absence from Khok Phanom Di

Species	L11	L10	L9	L8	L7	L6	L5	L4
<i>Nerita albicilla</i>	0	0	0	0	0	0	0	0
<i>Naquetia capucina</i>	0	1	1	0	0	0	0	0
<i>Hemifusus ternatanus</i>	0	0	0	0	0	0	0	0
<i>Turricula javana</i>	0	0	0	0	0	0	0	0
<i>Scelidionarca p.</i>	0	0	1	0	0	0	0	0
<i>Mytilid sp. A</i>	0	0	0	0	0	0	0	0
<i>Mytilid sp. B</i>	0	0	0	0	0	0	0	0
<i>Pinctada sp. A</i>	0	0	0	0	0	0	0	0
<i>Pinctada sp. B</i>	0	0	0	0	0	0	0	0
<i>Pinctada sp. C</i>	0	0	0	0	0	0	0	0
<i>'Lucina' philippinarum</i>	0	0	0	0	0	0	0	0
<i>Chama reflexa</i>	0	0	0	0	0	0	0	0
<i>Atactodea striata</i>	0	0	0	0	0	0	0	0
<i>Apolymetis spectabilis</i>	0	0	0	0	0	0	0	0
<i>Tellina capsoides</i>	0	0	0	0	0	0	0	0
<i>Tellina opalina</i>	0	0	0	0	0	0	0	0
<i>Tellinid sp. A</i>	0	0	0	0	0	0	0	0
<i>Anomalocardia squamosa</i>	0	0	0	0	0	0	0	0
<i>Bassina parva</i>	0	0	0	0	0	0	0	0
<i>Circe scripta</i>	0	0	0	0	0	0	0	0
<i>Dosinia juvenilis</i>	0	0	0	0	0	0	0	0
<i>Dosinia trailli</i>	0	0	0	0	0	0	0	0
<i>Ruditapes philippinarum</i>	0	0	0	0	0	0	0	0
<i>Nerita articulata</i>	1	1	1	1	1	1	1	1
<i>Nerita violacea</i>	0	0	0	0	0	0	0	0
<i>Rehderiella parva</i>	0	0	0	0	0	0	0	0
<i>Fairbankia cochinchinensis</i>	0	0	0	0	0	0	0	0
<i>Melanoides tuberculata</i>	0	0	0	0	0	0	0	0
<i>Sermyla riqueti</i>	0	0	0	0	0	0	0	0
<i>Cerithidea cingulata</i>	0	0	0	0	0	0	0	0
<i>Nassarius olivaceus</i>	0	0	0	0	0	0	0	0
<i>Coecella horsfieldi</i>	0	0	0	0	0	0	0	0
<i>Pila pesmei</i>	0	0	0	0	0	0	0	0
<i>Filopaludina javanica</i>	0	0	0	0	0	0	0	0
<i>Filopaludina sumatrensis</i>	0	0	0	0	0	0	0	0
<i>Littoraria melanostoma</i>	0	0	0	0	0	0	0	0
<i>Littoraria undulata</i>	0	0	0	0	0	0	0	0
<i>Stenothyra polita</i>	0	0	0	0	0	0	0	0
<i>Terebralia palustris</i>	0	0	0	0	0	0	0	0
<i>Assiminea brevicula</i>	0	0	0	0	0	0	0	0
<i>Cerithidea obtusa</i>	0	1	1	1	1	1	1	1
<i>Telescopium telescopium</i>	1	1	1	1	1	1	1	1
<i>Strombus canarium</i>	1	1	0	0	0	0	0	0
<i>Strombus luhuanus</i>	0	0	0	0	0	0	0	0
<i>Cypraea errones</i>	0	0	0	0	0	0	0	0
<i>Cypraea helvola</i>	0	0	0	0	0	0	0	0
<i>Cypraea miliaris</i>	0	0	0	0	0	0	0	0
<i>Cypraea onyx</i>	0	0	0	0	0	0	0	0
<i>Cypraea sp.</i>	0	0	0	0	0	0	0	0
<i>Natica tigrina</i>	0	1	1	1	1	1	1	1
<i>Cymia lacera</i>	0	1	1	1	1	1	1	1
<i>Cymia tissoti</i>	0	1	1	1	1	1	1	1
<i>Auriculastra elongata</i>	0	0	0	0	0	0	0	0
<i>Auriculastra subula</i>	0	0	0	0	0	0	0	0
<i>Laemodonta siamensis</i>	0	0	0	0	0	0	0	0
<i>Melampus flavus</i>	0	0	0	0	0	0	0	0
<i>Melampus nucleolus</i>	0	0	0	0	0	0	0	0
<i>Melampus siamensis</i>	0	0	0	0	0	0	0	0
<i>Cassidula aurisfelis</i>	0	1	1	1	1	1	1	1
<i>Cassidula mustelina</i>	0	0	1	0	0	0	0	0
<i>Ellobium aurisjudae</i>	0	1	1	1	1	1	1	1

TABLE 56: *The relationship between the species of shell at Khok Phanom Di and their preferred habitat. 1: marine mudflats, 2: marine, sandy mud, 3: intertidal/subtidal clean sand, 4: coral/clear marine water, 5: marine, hard substrate, 6: mangal, seaward edge, 7: mangal, landward edge, 8: estuarine, 9: freshwater, 10: land snails*

Species	1	2	3	4	5	6	7	8	9	10	Species	1	2	3	4	5	6	7	8	9	10
Nerita albicilla	0	0	1	0	1	0	0	0	0	0	Naquetia capucina	0	0	0	0	0	1	0	0	0	0
Hemifusus ternatanus	0	0	1	1	0	0	0	0	0	0	Turricula javana	0	0	1	0	0	0	0	0	0	0
Scelidionarca pectunculiformis	1	0	0	0	0	1	0	0	0	0	Mytilid sp. B	0	0	0	0	0	1	0	0	0	0
Mytilid sp. B	0	0	0	0	0	1	0	0	0	0	Pinctada sp. A	0	0	0	0	0	1	0	0	0	0
Pinctada sp. B	0	0	0	0	0	1	0	0	0	0	Pinctada sp. C	0	0	0	0	0	1	0	0	0	0
'Lucina' philippinarum	1	0	0	0	0	1	0	0	0	0	Chama reflexa	0	0	0	1	0	0	0	0	0	0
Atactodea striata	0	0	1	0	0	0	0	0	0	0	Apolymetis spectabilis	1	0	0	0	0	1	0	0	0	0
Tellina capsoides	1	1	1	0	0	1	0	1	0	0	Tellina opalina	1	1	1	0	0	1	0	1	0	0
Tellinid sp. A	1	0	0	0	0	1	0	0	0	0	Anomalocardia squamosa	0	1	1	0	0	0	0	0	0	0
Bassina parva	0	1	0	0	0	0	0	0	0	0	Circe scripta	0	0	1	1	0	0	0	0	0	0
Dosinia juvenilis	0	0	1	0	0	0	0	0	0	0	Dosinia trailli	0	0	1	0	0	0	0	0	0	0
Ruditapes philippinarum	0	1	1	0	0	0	0	0	0	0	Nerita articulata	0	0	0	0	0	1	0	0	0	0
Nerita violacea	0	0	0	0	0	0	1	1	1	0	Rehderiella parva	0	0	0	0	0	0	0	1	0	0
Fairbankia cochinchinensis	0	0	0	0	0	0	1	1	0	0	Melanoides tuberculata	0	0	0	0	0	0	0	1	1	0
Sermylea riqueti	0	0	0	0	0	0	0	1	0	0	Cerithidea cingulata	1	0	0	0	0	1	0	1	0	0
Nassarius olivaceus	1	0	0	0	0	1	0	0	1	0	Coecella horsfieldi	0	0	0	0	0	0	0	1	0	0
Pila pesmei	0	0	0	0	0	0	0	0	1	0	Filopaludina javanica	0	0	0	0	0	0	0	0	1	0
Filopaludina sumatrensis	0	0	0	0	0	0	0	0	0	1	Littoraria melanostoma	0	0	0	0	1	1	1	0	0	0
Littoraria undulata	0	0	0	0	0	1	0	0	0	0	Stenothyra polita	1	0	0	0	0	1	0	0	0	0
Terebra palustris	0	0	0	0	0	1	0	0	0	0	Assiminea brevicula	0	0	0	0	0	1	1	1	0	0
Cerithidea obtusa	1	0	0	0	0	1	0	1	0	0	Telescopium telescopium	1	0	0	0	0	1	0	0	0	0
Strombus canarium	0	0	1	1	0	0	0	0	0	0	Strombus luhuanus	1	0	1	1	0	0	0	0	0	0
Cypraea erroneas	0	0	0	1	1	0	0	0	0	0	Cypraea helvola	0	0	0	1	0	0	0	0	0	0
Cypraea miliaris	1	0	0	0	0	1	0	0	0	0	Cypraea oryx	1	0	1	1	0	0	0	0	0	0
Cypraea sp.	0	0	1	0	1	0	0	0	0	0	Natica tigrina	1	1	1	0	0	0	0	0	0	0
Cymia lacera	1	0	0	0	0	0	0	0	0	0	Cymia tissoti	0	0	0	0	0	1	0	0	0	0
Auriculastra elongata	0	0	0	0	0	0	1	0	0	0	Auriculastra subula	0	0	0	0	0	0	1	0	0	0

TABLE 57: Species listed in the order that maximizes the correlation between the difference in the order and the difference in occurrences of pairs of species

Species	L11	L10	L9	L8	L7	L6	L5	L4
<i>Anadara granosa</i>	1	1	1	1	1	1	1	1
<i>Polymesoda erosa</i>	1	1	1	1	1	1	1	1
<i>Cerithidea obtusa</i>	0	1	1	1	1	1	1	1
<i>Natica tigrina</i>	0	1	1	1	1	1	1	1
<i>Meretrix lusoria</i>	1	1	1	1	1	1	1	1
<i>Cassidula aurisfelis</i>	0	1	1	1	1	1	1	1
<i>Telescopium telescopium</i>	1	1	1	1	1	1	1	1
<i>Nerita articulata</i>	1	1	1	1	1	1	1	1
<i>Pseudodon</i> spp.	0	0	1	0	1	0	1	0
<i>Placuna placenta</i>	0	0	1	0	1	0	1	0
<i>Pelecypora trigona</i>	1	1	1	1	1	1	1	1
<i>Ellobium aurisjudae</i>	0	1	1	1	1	1	1	1
<i>Donacilla nitida</i>	0	0	1	0	0	1	0	0
<i>Cymia tissoti</i>	0	1	1	1	1	1	1	1
<i>Marcia hiantina</i>	0	1	1	1	1	1	1	1
<i>Asaphis violascens</i>	0	0	1	0	1	0	1	0
<i>Saccostrea cucullata</i>	0	1	1	0	0	0	0	0
<i>Scelidionarca p.</i>	0	0	1	0	0	0	0	0
<i>Assimineae brevicula</i>	0	0	0	0	0	0	0	0
<i>Anadara nodifera</i>	0	0	0	0	0	0	0	0
<i>Anadara secticostata</i>	0	1	0	0	1	1	0	1
<i>Cymia lacera</i>	0	1	1	1	1	1	1	1
<i>Strombus canarium</i>	1	1	0	0	0	0	0	0
<i>Ellobium aurismidae</i>	0	1	0	0	0	0	0	0
<i>Isognomon</i> sp.	0	0	0	0	0	0	0	0
<i>Nassarius livescens</i>	0	0	0	0	0	0	0	0
<i>Pseudodon mouhoti</i>	0	0	0	0	0	0	0	0
<i>Placuna sella</i>	0	0	0	0	0	0	0	0
<i>Paphia undulata</i>	0	1	0	0	0	0	0	0
<i>Turricula javana</i>	0	0	0	0	0	0	0	0
<i>Cerithidea cingulata</i>	0	0	0	0	0	0	0	0
<i>Anadara gubernaculum</i>	0	0	0	0	0	0	0	0
<i>Polinices tumidus</i>	0	0	0	0	0	0	0	0
<i>Anomalocardia squamosa</i>	0	0	0	0	0	0	0	0
<i>Strombus luhuanus</i>	0	0	0	0	0	0	0	0
<i>Dosinia trailli</i>	0	0	0	0	0	0	0	0
<i>Pilsbryconcha exilis</i>	0	0	0	0	0	0	0	0
<i>Bassina parva</i>	0	0	0	0	0	0	0	0
<i>Dosinia juvenilis</i>	0	0	0	0	0	0	0	0
<i>Tridacna squamosa</i>	0	0	0	0	0	0	0	0
<i>Melampus siamensis</i>	0	0	0	0	0	0	0	0
<i>Nassarius pullus</i>	0	0	0	0	0	0	0	0
<i>Cypraea errones</i>	0	0	0	0	0	0	0	0
<i>Littoraria undulata</i>	0	0	0	0	0	0	0	0
<i>Atactodea striata</i>	0	0	0	0	0	0	0	0
<i>Coecella horsfieldi</i>	0	0	0	0	0	0	0	0
<i>Nassarius foveolatus</i>	0	0	0	0	0	0	0	0
<i>Naquetia capucina</i>	0	1	0	0	0	0	0	0
<i>Mytilid</i> sp. A	0	0	0	0	0	0	0	0
<i>Terebralia palustris</i>	0	0	0	0	0	0	0	0
<i>Nerita albicilla</i>	0	0	0	0	0	0	0	0
<i>Tellinid</i> sp. A	0	0	0	0	0	0	0	0
<i>Ruditapes philippinarum</i>	0	0	0	0	0	0	0	0
<i>Margaritanopsis laosensis</i>	0	0	0	0	0	0	0	0
<i>Corus</i> sp. A	0	0	0	0	0	0	0	0
<i>Oliva</i> sp.	0	0	0	0	0	0	0	0
<i>Cymbiola nobilis</i>	0	0	0	0	0	0	0	0
<i>Apolymetis spectabilis</i>	0	0	0	0	0	0	0	0
<i>Crepidula walshi</i>	0	0	0	0	0	0	0	0

Species listed in the order that maximizes the correlation between the difference in the order and the difference in occurrences of pairs of species (cont.)

Species	L11	L10	L9	L8	L7	L6	L5	L4
<i>Hemifusus ternatanus</i>	0	0	0	0	0	0	0	0
<i>Scalptia crosseii</i>	0	0	0	0	0	0	0	0
<i>Tellina capsoides</i>	0	0	0	0	0	0	0	0
<i>Polinices didyma</i>	0	0	0	0	0	0	0	0
<i>Pinctada</i> sp. A	0	0	0	0	0	0	0	0
<i>Pinctada</i> sp. B	0	0	0	0	0	0	0	0
<i>Cypraea onyx</i>	0	0	0	0	0	0	0	0
<i>Circe scripta</i>	0	0	0	0	0	0	0	0
<i>Nassarius</i> sp.	0	0	0	0	0	0	0	0
<i>Melampus flavus</i>	0	0	0	0	0	0	0	0
<i>Chama reflexa</i>	0	0	0	0	0	0	0	0
<i>Duplicaria duplicata</i>	0	0	0	0	0	0	0	0
<i>Corbula erythron</i>	0	0	0	0	0	0	0	0
<i>Oliva oliva</i>	0	0	0	0	0	0	0	0
<i>Nautilus pompilius</i>	0	0	0	0	0	0	0	0
<i>Filopaludina sumatrensis</i>	0	0	0	0	0	0	0	0
<i>Tellina opalina</i>	0	0	0	0	0	0	0	0
<i>Nuculana</i> sp.	0	0	0	0	0	0	0	0
<i>Acrosterigma flavum</i>	0	0	0	0	0	0	0	0
<i>Rhiostoma housei</i>	0	0	0	0	0	0	0	0
<i>'Lucina' philippinarum</i>	0	0	0	0	0	0	0	0
<i>Nassarius olivaceus</i>	0	0	0	0	0	0	0	0
<i>Teredinid</i> sp.	0	0	0	0	0	0	0	0
<i>Pila pesmei</i>	0	0	0	0	0	0	0	0
<i>Volutid</i> sp.	0	0	0	0	0	0	0	0
<i>Polinices cumingianus</i>	0	0	0	0	0	0	0	0
<i>Tridacna derasa</i>	0	0	0	0	0	0	0	0
<i>Nerita albicilla</i>	0	0	0	0	0	0	0	0
<i>Rehderiella parva</i>	0	0	0	0	0	0	0	0
<i>Auriculastra subula</i>	0	0	0	0	0	0	0	0
<i>Sermyla riqueti</i>	0	0	0	0	0	0	0	0
<i>Cypraea</i> sp.	0	0	0	0	0	0	0	0
<i>Laemodonta siamensis</i>	0	0	0	0	0	0	0	0
<i>Architectonica perspectiva</i>	0	0	0	0	0	0	0	0
<i>Auriculastra elongata</i>	0	0	0	0	0	0	0	0
<i>Conus</i> sp. B	0	0	0	0	0	0	0	0
<i>Mytilid</i> sp. B	0	0	0	0	0	0	0	0
<i>Tridacna maxima</i>	0	0	0	0	0	0	0	0
<i>Pinctada</i> sp. C	0	0	0	0	0	0	0	0
<i>Melo</i> sp.	0	0	0	0	0	0	0	0
<i>Melampus nucleolus</i>	0	0	0	0	0	0	0	0
<i>Cypraea miliaris</i>	0	0	0	0	0	0	0	0
<i>Spondylus</i> sp.	0	0	0	0	0	0	0	0
<i>Anadara helvola</i>	0	0	0	0	0	0	0	0
<i>Anadara uropigimelana</i>	0	0	0	0	0	0	0	0
<i>Stenothyra polita</i>	0	0	0	0	0	0	0	0
<i>Conus betulinus</i>	0	0	0	0	0	0	0	0
<i>Littoraria melanostoma</i>	0	0	0	0	0	0	0	0
<i>Enid</i> sp.	0	0	0	0	0	0	0	0
<i>Cecilioides</i> sp.	0	0	0	0	0	0	0	0
<i>Unianadra contradens tumidula</i>	0	0	0	0	0	0	0	0
<i>Macrochlamys</i> sp.	0	0	0	0	0	0	0	0
<i>Bacillum</i> sp.	0	0	0	0	0	0	0	0
<i>Unianadra contradens rustica</i>	0	0	0	0	0	0	0	0
<i>Nerita violacea</i>	0	0	0	0	0	0	0	0
<i>Cassidula mustelina</i>	0	0	0	0	0	0	0	0
<i>Filopaludina javanica</i>	0	0	0	0	0	0	0	0
<i>Melanoides tuberculata</i>	0	0	0	0	0	0	0	0
<i>Fairbankia cochinchinensis</i>	0	0	0	0	0	0	0	0

XX. SUMMARY

By C. F. W. Higham and R. Bannanurag

This summary of the principal findings presented in this book must take into account the fact that the final volume of the report on Khok Phanom Di will present a detailed interpretation of the site in its environmental setting. This reflects the fact that the chapters above represent only a proportion of the data bearing on the environment and economy. Conclusions presented here, therefore, represent a way station in the course to a more complete understanding of Khok Phanom Di.

Contributions to this volume cover at least four basic issues. The first concerns the environment, and any evidence for human activity, antedating initial settlement. This important matter is clarified by Maloney's presentation of the plant and sediment remains from the cores taken from the vicinity of the site. He has considered the incidence of pollen from different taxa, fern spores, leaf fragments and charcoal, together with their condition, as indices of local origins or redeposition.

It is evident from the pollen and sediment sequence that the area of Khok Phanom Di was subjected to a fluctuating sea level during at least four millennia prior to the documented occupation of the site. During this period, there were interludes when a sharp rise in charcoal in the cores was accompanied by increases in grass pollen. This grass pollen matches in size that from modern rice fields, and it was accompanied by increases in fern spores. Maloney has correlated these incidents across cores, and noted that, although by no means conclusive, these modifications in the frequency of charcoal, grass pollen and fern spores could be the result of human activity. Clearly, identifying a site or sites with human occupation dating from the sixth to the third millennia will be necessary before more definitive conclusions can be obtained on the nature of early subsistence in this area, but if rice cultivation is documented, it would match in date the earliest evidence for this innovation in the Yangtzi valley (Yan Wenming 1990).

The second topic considered above is the nature of the environment during the settlement phase, which lasted from 2000 BC for at least five centuries. Maloney has suggested that, during its early settlement, Khok Phanom Di lay within an intertidal area. In his analysis of the foraminifera and ostracodes, McKenzie not only points to brackish-water species of ostracodes, but also remains from freshwater species which suggest the presence of ricefields in the vicinity of the site. Again, the foraminifera derive from both brackish and open marine contexts. He concludes that the site was located on or near an estuary with a 'low-lying, marshy hinterland'.

If the foraminifera and ostracodes reached the site without direct human intent, the same cannot be said of the larger faunal remains. These, however, are unanimous in suggesting that, between layers 11-5, the site was located with access to a series of habitats from the open sea to an estuary, mangal and freshwater ponds. The majority of the larger mammals found in these earlier layers are at home in a mangrove environment and with the exception of the dog, all could come from hunted animals. No mammalian species could be described as being present in abundance. West has added further confirmation to this reconstruction by noting that the bird and small mam-

malian remains suggest that the site provided access to freshwater marshes, coastal mangroves and estuarine conditions.

The fish identified by Kijngam came from the open sea, the estuary and from freshwater contexts. Fish, along with the crab and to a lesser extent the turtle, predominate numerically in all layers at the site.

In order to portray the relative frequencies in the various species of fish, mammals, invertebrates, birds and reptiles at the site, their distribution has been set out in figure 77. This figure can only present the most general pattern of relationships when it is considered that it reflects such a wide range of data. In the case of crabs, for example, the number of chelae has been divided by four to obtain the minimum number of individuals. For fish, the data rely on the right or left numbers of bones of the head whenever possible. Estimating the number of turtles accurately on the basis of fragments of carapace and plastron is virtually impossible. Rather than leave them out of consideration, however, it has been assumed that a single turtle or tortoise is represented by twenty pieces of carapace or plastron.

This figure allows a consideration of time trends. Clearly, there was a predominance of aquatic food sources throughout. We encounter no consistent evidence, other than the presence of the dog, for a domestic animal. The chicken is very rarely represented and the pig remains could easily derive from hunted animals. The water buffalo bones are large enough to fall within the known range for the wild animal, while there are insufficient bones of cattle to be able to be sure as to their status.

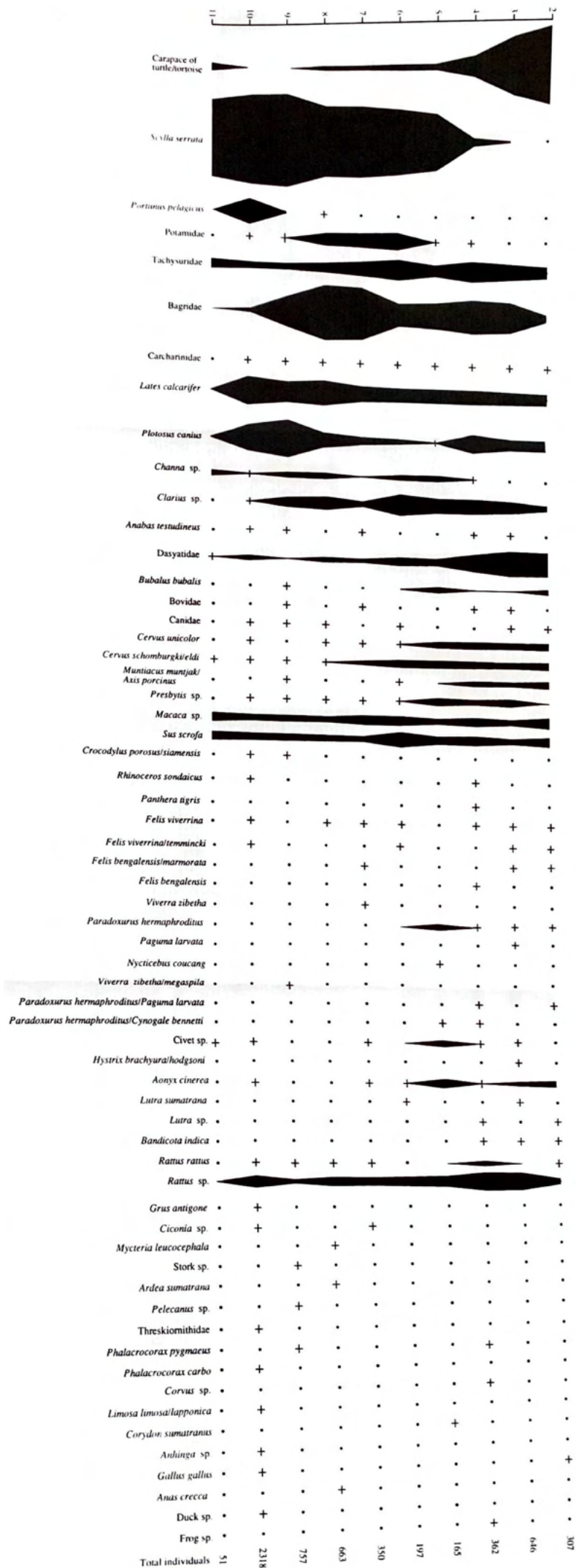
Perhaps molluscan remains are the most sensitive reflection of the changing environment at Khok Phanom Di. Mason's penetrating analysis has indicated a series of modifications to the habitat. The site, it seems, was founded near the estuary proper at a time when mangrove forests were established along a coast which included room for species which preferred the clear conditions associated with clean sand and coral. As might be expected in an environment dominated by a large and doubtless turbid river, the coastline actively prograded such that the settlement became significantly removed from the open sea. Nevertheless, the presence of mangrove along the tidal stretch of the lower river persisted. Freshwater species, too, were always available. Mason suggests that, by the beginning of layer 6, and possibly as early as layer 8, there was a major and probably sharp environmental change. This might well have involved a change in the river bed and, in consequence, the end of easy access by boat to both the main river and the sea. Certainly the colonization of the site by landsnails in layers 8–6 indicates the onset of more terrestrial conditions. This finding has interesting parallels in the distribution of the other species. The crab *Scylla serrata* which was particularly dominant numerically in layer 11–5 contexts, but then suddenly declines and disappears from the record. The marine–estuarine species *Plotosus canius* declined quite sharply in relative frequency from layer 9 but, curiously, increased again from layer 5. Bagrid catfish, however, which frequent lakes, swamps and ricefields, increased markedly in layers 8–7. Again, from layer 9 the marine crab *Portunus pelagicus* declined as the land crabs of the family Potamidae, which is adapted to clear streams, increased. The persistence of *Lates calcarifer*, which is essentially anadromous, might reflect expeditions to an increasingly remote locale. The numerical dominance of the turtle or tortoise remains during zone C is noted. It seems highly likely that land species became available, but to confirm this requires further research.

Mammalian remains seemed to become slightly more important numerically with the assumed removal of the sea from the site's vicinity, but it is surprising that there remains no compelling

evidence for reliance on any domestic stock. Macaques and deer became more frequent, but cattle and water buffalo remains were always very rare. Throughout the occupation of Khok Phanom Di, some interest was shown in small mammals and birds. Some of the burials, most notably burial 15, contained the pierced canines of such small mammals as ornaments.

The analyses of a wide range of biological material presented above portrays a settlement and cemetery situated in a most favourable location for self-replenishing food resources: the estuary. Marine species dominated, particularly fish and crabs. The inhabitants eschewed reliance on domestic stock. We must defer until a later volume, a review of the remains of plants and their cultivation, but it is quite clear that rice comprised an important part of the diet. Indeed, the remains of the beetle *Oryzophilus surinamensis* hints at the storage of rice. The tropical estuary is one of the world's richest habitats for the human species. The cultural behaviour among those with access to this cornucopium, and the reaction to the changes identified, will be addressed fully in future volumes of this report on the 1985 excavation of Khok Phanom Di.

FIG. 77. The distribution of mammalian, fish, bird, crustacean and reptilian species identified at Khok Phanom Di by layer



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