PALAEOENVIRONMENTAL ANALYSIS OF THE SAKON NAKHON BASIN, NORTHEAST THAILAND: PALYNOLOGICAL PERSPECTIVES ON CLIMATE CHANGE AND HUMAN OCCUPATION

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ABSTRACT

The northern Khorat Plateau has long been the focus of archaeological debate in Thai prehistory. The timing of the initial settlement of the region and the relationship between early communities and the environment, particularly in regard to rice cultivation, remains substantially unresolved. Despite this, there have been few attempts to provide a detailed environmental context. Palynological data from Nong Han Kumphawapi, a lake site in Sakon Nakhon basin, northeast Thailand, indicate a period of forest disturbance and increased fire frequency from c.6400-6600 years BP (Before Present). While it is impossible to be unequivocal regarding the cause of this disturbance, palaeoclimatic data from the region are difficult to reconcile with the patterns of vegetation change indicated here. Widespread burning and forest exploitation by human populations is the preferred interpretation at present.

Fifteen years ago, Higham and Kijngam (1984:1) attempted to distance themselves from what they described as the "sensation and polemic" associated with claims for early bronze technology in northeast Thailand. Since that time, more sophisticated dating techniques and a better resolved regional archaeological sequence have seen some of these early claims subside. Yet issues such as the timing of the arrival of people into the northern part of the Khorat Plateau, and the extent to which these early populations practised rice agriculture, remain unresolved.

The excavation and continuing analysis of Ban Chiang, first excavated in the late 1960s, remains emblematic of the controversy surrounding issues such as the appearance of metallurgical and agricultural technologies in northeast Thailand. Recently, Higham (1996) has suggested that the initial settlement of Ban Chiang may have occurred as late as approximately 2500 years BP, in contrast to earlier estimates of c. 5500 years BP (Bayard 1984; White 1982).

There have been few attempts to obtain detailed palaeovegetation data from the region, notwithstanding the clear success such analyses have had in tracing the development of agricultural technologies in other parts of the world. The need for such data has been recognised for several years. For example,

> ... the analysis of early farming communities in Northwest Europe ... or upland Mexico ... have been greatly enhanced by the availability of pollen spectra and macro-floral remains respectively. The student of culture history in Northeast Thailand is not so fortunate... (Higham and Kijngam 1979: 222).

Indeed, the archaeological, biogeographic and palaeoethnological literature pertinent to northeast Thailand is littered with references to this absence of data. The University of Pennsylvania Thailand Palaeoenvironmental Project (TPP) and affiliated research groups (Centre for Palynology and Palaeoecology, Monash University) have attempted to provide this palaeobotanical and palaeoenvironmental data.

Fifteen sediment cores were collected from three study areas in the northern Khorat Plateau (Figure 1); eleven cores from Nong Han Kumphawapi, two from Nong Pa Kho (17°06'N, 102°56'E), and two from Nong Han Sakon Nakhon (17°12'N, 104°11'E). Summary results of stratigraphic and palynological analysis of two of the Kumphawapi cores, KUM.1 and KUM.3, representing the period from approximately 14,300 years BP to the present are considered here. More detailed analyses of these palynological data are available (Kealhofer and Penny 1998; Penny 1998; Penny *et al.* 1996), and the complete findings of this research will be published in the near future. The locations of the two Kumphawapi core sites are given in Figure 2.

THE SITE AND ITS REGIONAL SETTING

Nong Han (Lake) Kumphawapi lies in a broad natural basin at *c.*170 m ASL (17°11'N, 103°02'E), some 36 km to the southeast of Udon Thani (Figure 2). The lake and fringing swamp cover an area of approximately 32 km^2. The southern part of the lake, close to the modern town of Kumphawapi, is characterised by a diapiric salt structure that rises some 10-15 m above the surrounding swamp. The lake itself is less than 4 metres deep and is fed by numerous seasonal streams rising in the surrounding low hills. The Huai Phai Chan Yai river flows into the lake to

Figure 1: Map of mainland Southeast Asia showing location of the three study regions.

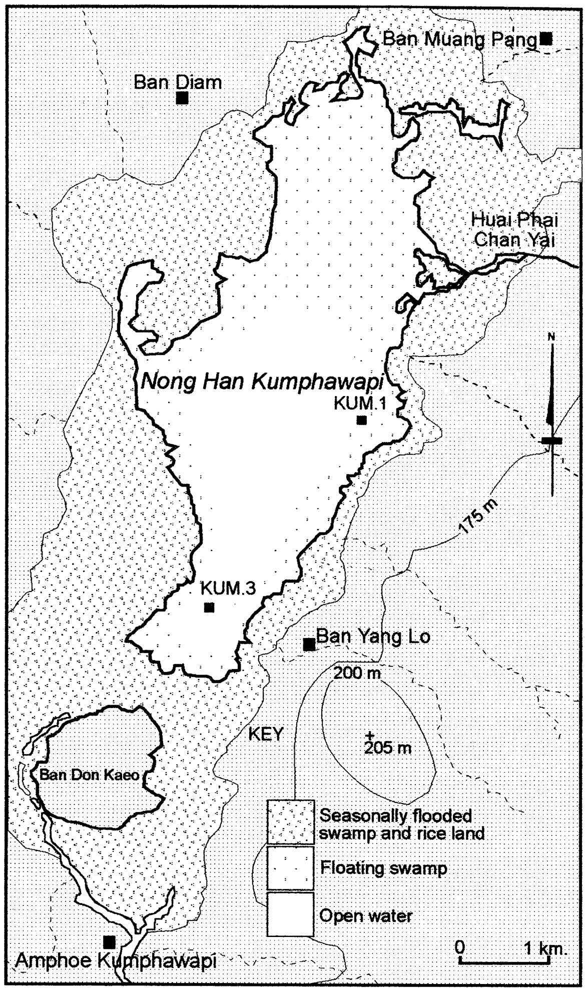


Figure 2: Nong Han Kumphawapi showing core locations.

the northeast, rising on the northwestern edge of the Phu Phan range.

The lake supports an extensive herbaceous swamp that adopts a floating habit towards the centre of the lake, while a mosaic of floating vegetation mats and sheltered channels covers much of the lake proper. Poaceae (Gramineae) and Cyperaceae are the dominant families (Penny 1998), with *Nelumbo nucifera* (Nymphaeaceae), *Ipomoea aquatica* (Onagraceae), *Ludwigia adscendens* (Onagraceae), *Nymphoides indicum* (Menyanthaceae), *Nymphaea lotus* var. *pubescens* and *Salvinia cucullata* (Salviniaceae). Much of the floodplain surrounding Kumphawapi has been converted to rice fields. Crops grown on the surrounding slopes include kenaf (*Abelmoschus manihot* var. *pungens*, Malvaceae), maize (*Zea mays*, Poaceae), cassava (*Manihot esculenta*, Euphorbiaceae), sugar cane (*Saccharum officinarum*, Poaceae), sorghum (*Sorghum vulgare*, Poaceae), castor bean (*Ricinus communis*, Euphorbiaceae), peanut (*Arachis hypogaea*, Papilionaceae), and sesame (*Sesamum indicum*, Pedaliaceae) (Arbhabhirama *et al.* 1988; Parnwell 1988).

Dipterocarpaceae dominate the regional dryland vegetation. Common plant community types in the northeast include savanna, which has a disjunct distribution to the southwest of the Khorat Plateau in Sakon Nakhon Petchabun and the Khao Yai National Park (Stott 1990; White 1995), dry deciduous forest, hill evergreen/lower montane forest (above 1000 m ASL), pine woodland (from 200-1300 m ASL), dry semi-evergreen forest, and mixed deciduous forests (Ogawa *et al.* 1965; Stott 1976, 1990; Bunyavejchewin 1983, 1985, 1986; Smitinand 1989). Presently a mosaic of highly disturbed dry deciduous, dry evergreen and lower mixed deciduous forest (*sensu* Smitinand 1989) occurs around Kumphawapi (White 1995).

The climate and hydrology of the region are predictably monsoonal. From November to February a dry, cool, continental northeast monsoon prevails, driven by high pressure over the Tibetan Plateau. Mean monthly rainfall at this time is around 2.6 mm (Khon Kaen) to 4.9 mm (Sakhon Nakon), with low relative humidity, low average temperatures and high evaporation (Ministry of Communications 1987). Evaporation exceeds precipitation for several months of the year between October and April. The wet, warm southwest monsoon prevails from May through October, driven by high pressure systems over the Indian Ocean. During the height of the wet monsoon mean monthly rainfall is around 273 mm, with high relative humidity, relatively low evaporation and moderately high temperatures. In total, the area receives around 1500 mm of rainfall annually (Ministry of Communications 1987). Flooding is common during September and October, with the discharge of the Mun River increasing by a factor of 28 from the dry season flows (Parnwell 1988; Parry 1992).

Nong Han Kumphawapi is ideally situated to record patterns of human/environment interaction over time. A number of archaeological sites are closely associated with the lake. Ban Na Di, for example, lies only *c*.8 km to the northeast of Kumphawapi, and Ban Chiang, approximately 30 km to the northeast. Many smaller historic and prehistoric sites have been mapped in the area (Kijngam *et al.* 1980; Higham and Kijngam 1984), some yielding prehistoric inhumation burials, and a number of which are equivalent to Early Period culture at Ban Chiang. Boundary stones, or *sema* stones, have been found on the Ban Don Kaeo salt dome within the lake itself, dated to approximately AD 800 based on the presence of Mon inscriptions (Kijngam *et al.* 1980:20). Given the close proximity of prehistoric populations, Kumphawapi may have been an important resource for communities in the region, particularly during the winter monsoon when other water resources may not have been available. Consequently, palynological analysis of sediment cores from this site has the potential to reveal the impact of human populations on the environment at both regional and local scales.

MATERIALS AND METHODS

Core KUM.1 (1.41 m total length) was collected with a D-section corer, while core KUM.3 (6.18 m total length) was extracted using a Livingstone corer (Kealhofer, 1996). Samples of 2 cm^3 samples were taken from the cores for palynological analysis. These were disaggregated in 10% sodium pyrophosphate, or 10% potassium hydroxide if highly organic. After several washes with distilled water, the disaggregated sediment was sieved through a 120μ wire sieve and an 8μ fabric sieve. The >120μ and <8μ fractions were discarded. The remaining material was then digested in acetic acid and an acetolysis mixture (9 parts acetic anhydride: 1 part sulphuric acid). The organic fraction was then isolated from the remaining minerogenic material using heavy liquid separation (sodium polytungstate at s.g. 2.0 for 20 minutes at 2000 rpm). The organic fraction thus isolated was washed several times with distilled water, dehydrated (ethanol), and mounted on microscope slides.

Identification of pollen and spore taxa was undertaken using an Olympus BH light microscope at x600 and x1500 magnification. Identifications were based on published descriptions (including Erdtman 1969; Huang 1972; Vasanthy 1976; Moore and Webb 1978; Maloney 1979; Hooghiemstra 1984; Stuijts 1993; Tissot *et al.* 1994), and reference material collected from the Rijksherbarium, Leiden; Department of Botany Herbarium, Chiang Mai University; and the School of Archaeology and Palaeoecology, Queen's University, Belfast.

All taxa, excluding grasses, sedges, ferns, aquatics and unknown types, were included in the pollen sum. An *a priori* minimum limit of 100 dryland pollen grains was set for each sample, but in many cases this total could not be achieved due to the paucity of dryland taxa. Thus, while an average of 484 pollen grains and spores were counted for each sample, the dryland component ranged between 20 and 122 grains, with a mean of 57.2. The lowest dryland pollen counts occurred at 80-90 cm (*c*.6400-6300 years BP).

The calculation of sedimentary charcoal particle values is based on particles greater than 5μ (longest axis) within pollen samples. The total charcoal particle values per unit volume are based upon the dilution of a known value of *Lycopodium* marker spores introduced into the sample before chemical processing. In order to evaluate the reliability of this technique, the "point-count" method (Clark 1982) was also applied to cores KUM.1 and KUM.2 (not shown). A comparison of the results of the two techniques, and with the burnt phytolith data for core KUM.3 (Kealhofer 1996), indicates relatively good agreement between cores over a standardised timescale (Penny 1998).

The chronology for both cores is provided (Table 1) by a total of 13 AMS and conventional radiocarbon determinations (Kealhofer 1996; Penny *et al.* 1996; White 1997; Penny 1998). All AMS determinations (excluding BETA-72097) are based on pollen. Protocols employed in the laboratory pre-treatment of pollen samples for AMS dating follow Regnell (1992). Radiocarbon years were calibrated to years BC/AD and years BP with the program OxCal 2.18 (Bronk Ramsey 1994). Unless otherwise stated, all radiocarbon determinations are presented at the 2σ calibrated range, or the median of that range.

RESULTS

Summary palynological results for cores KUM.3 and KUM.1 are given in Figures 3 and 4 respectively. The KUM.3 data presented here have been substantially revised since their initial publication by Kealhofer and Penny (1998). An additional sixteen pollen/charcoal samples have been included and one more AMS radiocarbon date (OZC319; see Table 1).

These data indicate that the Sakon Nakhon basin has witnessed substantial environmental change since the late glacial period. Sediments deposited within the Kumphawapi basin from around 14,350 years BP show clear mottling, implying periodic wetting and drying and thus a strong seasonal contrast in the prevailing climate. Pollen does not preserve in these sediments, suggesting oxidisation as a result of periodic drying. Anaerobic conditions

Sample depth (cm)	Lab. No.	^{14}C Age ± error	Calibrated age AD/BC	Calibrated age yr BP	Method
KUM.1					
40-41	NZA-5765	2010±110	1σ: BC 160-130 2σ: BC 400-250 AD	1σ: BP 2110-1820 2σ: BP 2350-1700	AMS/P
77-79	WK-2366	4950±80	1σ: BC 3800-3640 2σ: BP 3950-3620	1σ: BP 5750-5590 2σ: BP 5900-5570	CONV
80-81	NZA-5766	5650±110	1σ: BC 4600-4350 2σ: BC 4800-4250	1σ: BP 6550-6300 2σ: BP 6750-6200	AMS/P
100-101	NZA-5768	6010±100	1σ: BC 5000-4780 2σ: BC 5250-4650	1σ: BP 7000-6970 2σ: BP 7200-6600	AMS/P
140-141	OZB070	5320±60	1σ: BC 4230-4040 2σ: BC 4330-3280	1σ: BP 6180-5990 2σ: BP 6210-5940	AMS/P
KUM.3					
45-46	OCZ319	2690±70	1σ: BC 910-800 2σ: BC 1020-760	1σ: BP 2860-2750 2σ: BP 2970-2710	AMS/P
80-85	BETA 93027	5540±70	1σ: BC 4460-4340 2σ: BC 4520-4240	1σ: BP 6410-6290 2σ: BP 6470-6190	CONV
136-141	BETA 93028	6080±60	1σ: BC 5060-4910 2σ: BC 5140-4830	1σ: BP 7010-6860 2σ: BP 7090-6780	CONV
152-157	BETA 93029	6270±100	1σ: BC 5290-5260 2σ: BC 5430-4950	1σ: BP 7240-7010 2σ: BP 7380-6900	CONV
255-230	BETA 93030	8610±100	1σ: BC 7710-7500 2σ: BC 7920-7480	1σ: BP 9660-9450 2σ: BP 9870-9430	CONV
355-340	BETA 93031	8570±100	1σ: BC 7710-7480 2σ: BC 7950-7300	1σ: BP 9660-9430 2σ: BP 9900-9250	CONV
540-545	BETA 72096	9170±130	1σ: BC 8270-8040 2σ: BC 8550-7950	1σ: BP 10220-9990 2σ: BP 10500-9900	CONV
580-581	BETA 72097	12270±70	1σ:BC 12560-12220 2σ:BC 12750-12050	1σ: BP 14510-14170 2σ: BP 14700-14000	AMS

Ages are reported here at 1σ (68.2%) and 2σ (95.4%) confidence.
NZA = Institute of Geological and Nuclear Sciences Ltd., Lower Hutt, New Zealand. OZ = Australian Nuclear Science and Technology Organisation, Menai, NSW, Australia. WK = Waikato Radiocarbon Dating Laboratory, University of Waikato, Hamilton, New Zealand. BETA = Beta Analytic Inc., Miami, Florida, U.S.A. AMS = Accelerator Mass Spectrometry. AMS/P = AMS determination based on pollen concentrates. CONV = conventional radiocarbon determination.

Table 1: Results of radiocarbon dating for cores KUM.1 and KUM.3.

are established at the KUM.3 core site from approximately 11,200 years BP, implying that it was inundated or permanently water-logged. Pollen and spores preserved within these sediments indicate that the regional vegetation was species-poor, with only seventeen arboreal pollen types recorded. Dominant among these taxa are *Pinus*, *Celtis*, and *Uncaria/Wendlandia* type. The ecological significance of this association is difficult to define precisely, as there is no modern equivalent in Thailand (Penny 1998). However, it does appear that vegetation was relatively open and

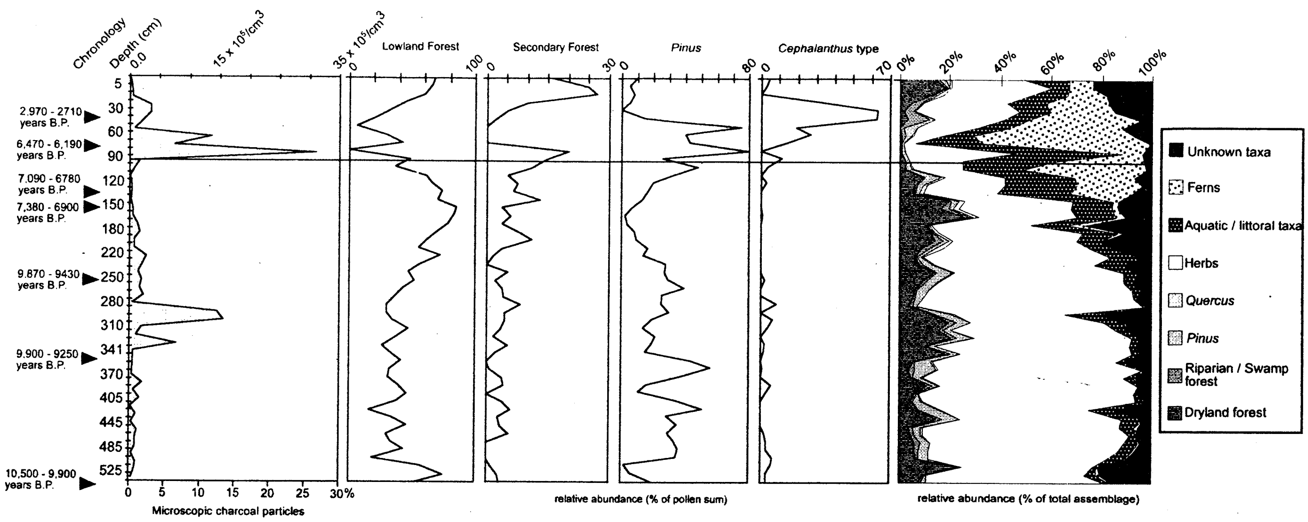


Figure 3: Summary pollen diagram, core KUM.3.*

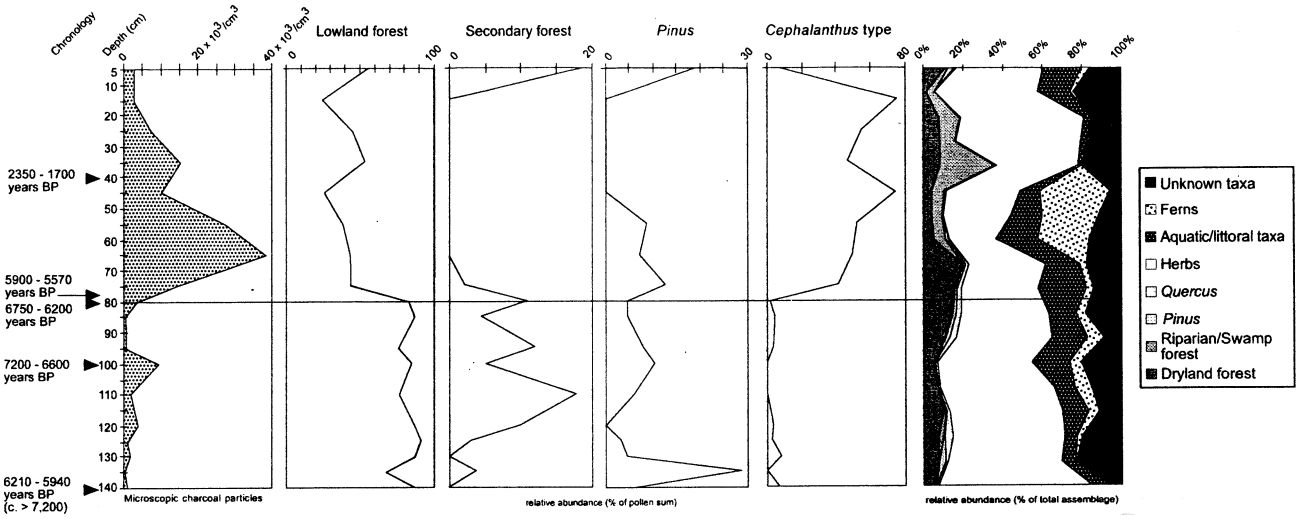


Figure 4: Summary pollen diagram, core KUM 1.*

*The lowland forest group includes all arboreal taxa excluding *Pinus, Cephalanthus, Macaranga, Mallotus and Trema* (the last three taxa being the "secondary forest" group.)

dry, with *Barringtonia* forest along streams feeding into the lake and some swamp/floodplain vegetation (principally grasses, but also Cyperaceae, Asteraceae, Chenopodiaceae/Amaranthaceae, *Nymphoides*, *Ludwigia*, *Azolla*, and *Ceratopteris thalictroides*).

Permanent open water conditions were established at the KUM.3 core site from around 10,200 years BP, indicated by a change to homogenous fine-grained lacustrine clay. Sedimentation rates increase markedly, suggesting high sediment mobility within the Kumphawapi catchment. Sedimentation was so rapid that radiocarbon dates on core KUM.3 at 255 cm (BETA 93030) and 355 cm depth (BETA 93031) are not significantly different according to Ward and Wilson's (1978) T^1 test (Penny 1998). This period of high-energy sediment transport to the lake, centred around 10,200 to 9500 years BP, is possibly a reflection of increased precipitation from this time due to a relatively stronger southwest monsoon circulation, exacerbated by the sparse and relatively open vegetation cover.

Due to the inversion of OZB070 (Table 1) the age of initial lacustrine sedimentation at the KUM.1 core site remains problematic. However, extrapolation from the stratigraphically coherent NZA-5768 (100-101 cm depth) implies a basal age of >7200 years BP. The development of permanent standing water on the eastern fringe of the lake from this time suggests the northward expansion of the lake margins as the Kumphawapi basin progressively filled.

There is a clear change in the character of the regional vegetation from *c.*9800 years BP, with the diversity of arboreal pollen taxa more than doubling the number recorded during the late Pleistocene. Increases in the representation of taxa such as *Altingia*, Combretaceae/Melastomataceae, Dipterocarpaceae, *Dipterocarpus obtusifolius*, *Elaeocarpus*, *Mallotus* and others, suggests an expansion of dry deciduous or semi-deciduous forests. Comparison of these fossil assemblages to modern pollen data reveals that between *c.*8000 years and 6900 years BP, vegetation around Lake Kumphawapi was comparable to modern mixed deciduous/dry evergreen forests (Penny 1998), suggesting conditions substantially more humid than present.

Despite the apparently humid climate that prevailed through much of the early Holocene, regional vegetation appears to have been rapidly and severely reduced from *c.*6600-6400 years BP. The representation of lowland forest elements decreases dramatically from this time, with taxa such as *Celtis*, *Dipterocarpus*, *Elaeocarpus*, *Lagerstroemia*, *Lithocarpus/Castanopsis*, *Macaranga*, *Mallotus* and others temporarily disappearing from the record. Synchronous with this is an increase in charcoal particles, indicating a change to more frequent, more widespread, or more intense fires. While many taxa are reduced at this time, the representation of *Pinus* and *Cephalanthus* type pollen increases dramatically. This is in large part due to statistical exaggeration in the absence of other arboreal pollen types within the pollen sum, exacerbated by low arboreal pollen counts. However, it may also reflect the tolerance of *Pinus merkusii* for frequent, low intensity fires and exposed soils (Stott 1986; de Laubenfels 1988; Koskela *et al.* 1995; Werner 1997). Furthermore, *Pinus* is a prolific pollen producer and can distribute its pollen very widely. As such, the strong representation of *Pinus* at Kumphawapi may represent a long-distance or extra-regional element of the pollen rain. *Cephalanthus* type, originally identified as Naucleaceae type by Penny *et al.* (1996), belongs to a tribe of the Rubiaceae known to include disturbance indicators and swamp forest trees (Irvine 1961; Garrett-Jones 1979; Riddoch *et al.* 1991). Increases in the representation of this taxon within pollen assemblages may reflect the development of a riparian or swamp forest community in the Kumphawapi basin in the mid-late Holocene.

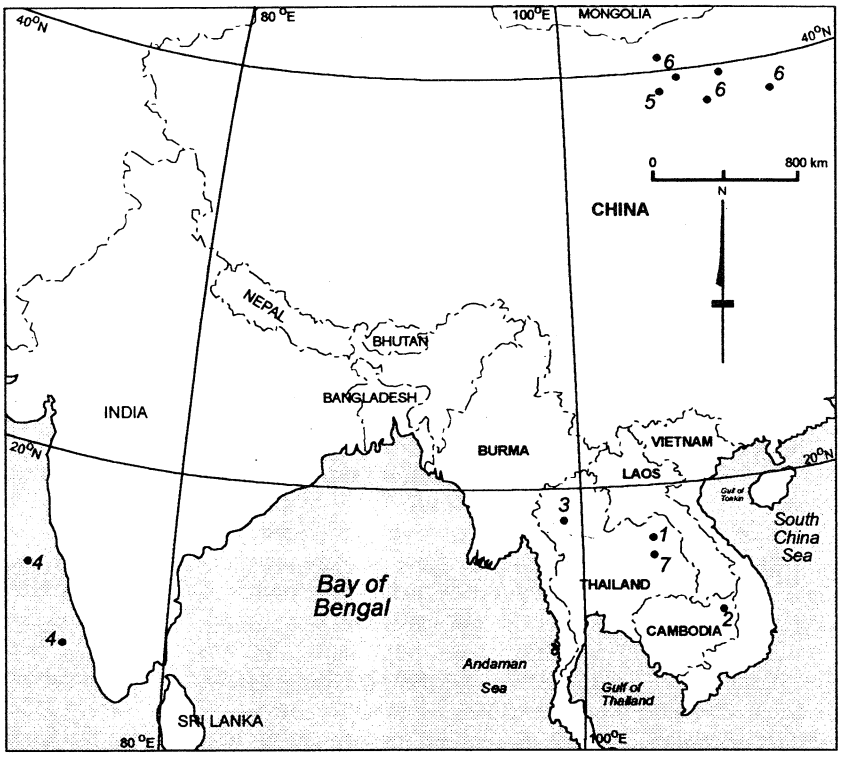
The palynological data indicate that this period of forest disturbance persists for approximately 3500 years. After this time (*c.*2840 years BP), dryland forest is re-established, although taxa such as *Pinus*, *Cephalanthus* type, *Elaeocarpus*, *Podocarpus*, and *Uncaria/Wendlandia* type, which variously characterised the mid and mid-late Holocene dryland communities are reduced or absent. In contrast, taxa frequently associated with secondary forests such as *Trema* and *Macaranga* (van Zeist 1984; Stuijts 1993; Maloney 1994; Kussipalo *et al.* 1996) are more common. Charcoal particle values decline rapidly from the very high values recorded in the initial phase of disturbance, but remain high relative to modern and early Holocene values until approximately 2-2500 years BP. The very low values of charcoal particles in modern and (sub)recent sediments at Kumphawapi is curious and counter-intuitive given the widespread and endemic use of fire in modern Thai landscape management practices (Stott 1988; Rabinowitz 1990). A possible explanation for this late Holocene decline involves a shift from the widespread burning of forests in the initial phase of disturbance toward more restricted burning in open, possibly herbaceous vegetation types.

DISCUSSION

The Kumphawapi pollen data indicate a period of forest disturbance associated with increased burning during the middle Holocene, yet these data are mute in regard to the cause of this disturbance. Simplistically, two options present themselves to account for the data presented here. First, an anthropogenic cause and, second, an external climatological cause related to global scale climate changes during the Holocene. Given that this issue cannot be resolved by these pollen records alone, other lines of evidence must be drawn into the debate.

The monsoon climate of northeast Thailand has already been described. Given that much of the Asian (sub)tropics lie under the same climatological regime, records of palaeomonsoon variability throughout the area affected by the monsoon can be used to evaluate the Kumphawapi data. A similar theoretical approach has been applied successfully by Bishop *et al.* (1996) and Godley (1997), in the comparison of flood histories from north-central Thailand with Chinese drought and flood records, and their relationship with El Niño Southern Oscillation events. In the case of Kumphawapi, if the Indochinese monsoon signal indicates a significant weakening of the summer monsoon at the time forest disturbance occurs in northeast Thailand, then climatic change may be the most likely ecological forcing mechanism. On the other hand, if the patterns of vegetation disturbance presented here are asynchronous with the broader monsoon record, then an anthropogenic cause may be the preferred interpretation.

Turning first to the northern limit of the monsoon range (Figure 5), rainfall reconstructions derived from the analysis of palaeosol development on the Loess Plateau of China (Maher *et al.* 1994; Maher and Thompson 1995; Thompson and Maher 1995) indicate that summer monsoon rainfall was 25-80% greater than present values during the early Holocene. At 9000 years BP, for example, rainfall is estimated to have been 215 mm/year greater than the area receives currently (Maher *et al.* 1994). An *et al.* (1991, 1993) date the formation of a Holocene palaeosol complex on the southwest margins of the Loess Plateau, representing the strengthened summer monsoon, to between 10,559-10,039 and 6865-6316 years BP. This latter date, representing the termination of the strengthened summer monsoon, appears to accord with the evidence of forest disturbance at Kumphawapi, but was taken 35 cm below the top of the palaeosol complex and as such is an overestimate of the return to drier conditions. A simple extrapolation of sedimentation rates up the Baxie profile, using the median age of the 1σ calibrated range, provides an estimated date of 6070 years for the termination of the monsoon optimum at this site. Reviews of Chinese palaeoclimate data (Sun and Chen 1991; Feng *et al.* 1993; Winkler and Wang 1993) place the Holocene "hypsi-thermal" period between 9000 and 3000 years BP, with temperatures approximately 2-3° C higher than present (Feng *et al.* 1993). Evergreen forests expanded in response to these higher temperatures and higher rainfall, ice caps retreated more rapidly, and lake levels were high, with peak precipitation for the Holocene occurring at around 6000 years BP (Winkler and Wang 1993).



1. Nong Han Kumphawapi (Kealhofer 1996; Kealhofer and Penny 1998; Penny 1998; Penny *et al.* 1996). 2. Yeak Kara (Maxwell 1996; Maxwell and Colm 1997; Maxwell pers. comm.). 3. Doi Inthanon (Hastings and Liengsakul 1984). 4. Arabian Sea Cores MD76131 and MD77194 (van Campo 1986). 5. Baxie palaeosol (An *et al.* 1993). 6. Loess Plateau sequences (Maher *et al.* 1994; Thompson and Maher 1995; Maher and Thompson 1995). 7. Khon Kaen loess dates (Nutalaya *et al.* 1989; Sonsuk and Hastings 1984; Udomchoke 1989).

Figure 5: Sites mentioned in the text.

At the other end of the monsoon range, upwelling records of planktonic foraminifera in the western Arabian Sea (Naidu 1996) suggest that the southwest monsoon did not weaken until 5000 years BP, with a marked weakening at approximately 3500 years BP. Van Campo (1986) used mangrove pollen preserved in marine sediments in the eastern Arabian Sea to record the weakening of the southwest monsoon, which was related to a change to more arid climates in India from around 4500 years BP. Maxwell and Lui (1996), in a substantial review of palaeomonsoon evidence from southern and eastern Asia, conclude that monsoon weakening occurred as early as 7000 years BP (to the northwest of the monsoon range in western Tibet), but most commonly from 4400-3800 years BP. Palynological data from Yeak Kara, northeasterm Cambodia (Maxwell 1996; Maxwell and Colm 1997; Maxwell pers. comm.), a site with a similar bio-climate and vegetation to Kumphawapi, reveals a notable vegetation change at approximately 8500 years BP, thought to reflect a change to wetter conditions. After 5000 years BP the pollen record implies a return to drier conditions (Maxwell pers. comm.). Climatic modelling (Kutzbach and Street-Perrott 1983; COHMAP Members 1988) accords with these data, indicating a period of strengthened low-level monsoon flow and associated increases in precipitation between 9000 and 6000 years BP.

Palaeoenvironmental evidence from northeast Thailand is sparse, yet instructive. For example, the deposition of organic lacustrine clays on the Khorat Plateau is dated to between 7650±120 BP and 5230±130 years BP (Udomchoke 1989), which is thought to be a corollary of the Chinese "humid cycle" (Nutalaya *et al.* 1989). Dated charcoal within widespread "loess" deposits around Khon Khaen is thought to represent vegetation development between 8190±120 years BP and 6620±160 years BP, subsequent to the deposition of the "loess", under a relatively humid climate (Hastings 1984; Nutalaya *et al.* 1989; Sonsuk and Udomchoke 1989). While these data are inconclusive, they do support the suggestion that humid conditions occurred in the northeast from the early Holocene to approximately 5000 years BP or later. Importantly, sea levels in the Gulf of Thailand through the mid Holocene are estimated to have been as much as 3-5 m above the current datum (Supajanya 1983), falling to modern levels after 4000 years. This is of significance to monsoon precipitation in the northeast, as higher sea levels allowed the penetration of a warm shallow sea into central Thailand, possibly as far north as the ancient capital of Ayutthaya (Supajanya 1983; Dheeradilok 1987), directly in the path of the southwest monsoon track. Indeed, Hastings and Liengsakul (1984) interpret biogeographic changes at Doi Inthanon, northwest Thailand, dated to 4300 years BP, as a result of increased precipitation associated with high sea levels in the Gulf of Thailand. If this is the case then one might expect broad shallow seas in combination with a steeper-than-present pressure gradient between land and ocean, to result in increased precipitation on the Khorat Plateau until as late as 4000 years BP.

Clearly, there is strong evidence that the Asian monsoon was substantially strengthened during the early to mid Holocene. To summarise this evidence in the most conservative manner, it appears that the onset of forest disturbance at Kumphawapi occurs toward the end of a period of increased temperature and precipitation. However, it may be argued that the termination of this period of strengthened summer monsoon circulation over mainland southeast Asia commonly post-dates the restriction and disturbance of forest communities in northeast Thailand. Thus, the application of a simple climate mechanism to account for the biogeographical changes described here is difficult to reconcile with the pollen data.

Yet if an anthropogenic cause is the preferred interpretation, then the Kumphawapi pollen data imply the presence of human populations some 2000 years prior to the earliest cultural materials. It may be argued then, that an anthropogenic cause seems as irreconcilable to the pollen data as is a climatic explanation. However, it may be argued that mid fifth millennium BC populations are simply not represented in the existing archaeological record. Issues of archaeological invisibility are particularly pertinent for northeast Thailand for a number of reasons. First, the open, gently undulating topography of the Khorat Plateau means that there are few sandstone or limestone caves, such as those which characterise older archaeological sites in the northwest and south of the country, which may facilitate the location and preservation of cultural materials. Second, the lowland areas of northeast Thailand have been thoroughly disturbed by agriculturists for millennia, raising the possibility that traces of early occupation, particularly if that occupation was transient or small scale, have been destroyed or obscured. Third, while meticulous surveys have been conducted in the Sakon Nakhon basin (Kijngam *et al.* 1980; Higham and Kijngam 1984) they were focused upon mounds, ceramics and burials, and it may be that earlier populations did not leave such traces in the landscape.

The issue of agricultural development in northeast Thailand remains one of the most unyieldingly thorny issues in Thai archaeology, and is not substantially clarified by the Kumphawapi pollen data. This is not entirely unexpected, as direct palynological evidence of rice cultivation is unlikely (but see Pearsall *et al.* 1995 in respect of phytoliths), and indirect evidence remains equivocal (Maloney 1991; 1989). However, the nature of mid-Holocene forest disturbance at Kumphawapi, where widespread burning of lowland forest was maintained, is arguably more consistent with a slash/burn type economy than one with a substantive wet rice agricultural base. Importantly, the decline in charcoal particles and the re-establishment of lowland, dry/mixed deciduous forests from approximately 2800 years BP (890 years BC) observed within the KUM.1 and KUM.3 pollen records is indicative of changing land-use practices, which is most probably associated with the intensification of inundated rice cultivation. This is in good chronological agreement with the appearance of iron and water buffalo at Ban Chiang (White 1986), thought to represent a change toward wet rice agriculture in permanent bunded fields. In summary, while palynological evidence suggestive of intensive wet rice agriculture is in good agreement with the existing archaeological data, the palynological evidence for the intensification of human land use in the Sakon Nakhon basin predates the archaeological record significantly.

CONCLUSION

The data presented here provide an intriguing picture of environmental change and human/environment interaction from the late Pleistocene to the present. These data propose a number of hypotheses regarding human/environment interactions in the Sakon Nakhon basin, but it is only through more detailed analysis into the palaeoenvironment of the region that these hypotheses can be tested properly. Until such corroborative or confuting evidence is presented, the interpretations presented here remain provisional. As with similar debates in other parts of the world where the archaeological and palaeoenvironmental records are discrepant (Kershaw *et al.* 1997), the proof of the pudding (at least for archaeologists) is inevitably in the excavation. Nevertheless, the author contends that further palaeoecological analyses may help clarify, or indeed yield answers to, some of the more intractable issues of Thai prehistory.

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