

*The Human Environment During the Terminal
Pleistocene and Holocene in Northeastern
Thailand: Phytolith Evidence from Lake
Kumphawapi*



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THAILAND HAS LONG BEEN at the center of discussions on the nature and timing of tropical agricultural development. While early interest centered on tropical forest crops (e.g., Sauer 1952) and upland cave archaeology (Gorman 1972; Pookajorn 1981), in the last two decades the development of rice agriculture has become the focus of attention (e.g., Chang 1976, 1989; Higham 1984; White 1989, 1995). Only in the past several years has this emphasis on rice been questioned (Mudar 1995; White 1995). I will argue that while rice has certainly become a staple food in Asia today, it formed one part of a diverse set of subsistence strategies prior to the first millennium B.C. The focus on rice agriculture has limited our understanding of the diverse, complex, and nonlinear sequence of subsistence strategies pursued in Southeast Asia during the Late Pleistocene and Holocene.

Models for the origins of agriculture in Southeast Asia center on when, where, and how rice was domesticated. Because of the recent finds of early evidence for rice in southern China (Yan 1991), research in Thailand has recently shifted to answering questions regarding when and how rice became part of the subsistence regime (Higham 1995). The temporal discontinuity in the location of archaeological sites, from Early-Mid Holocene upland cave or rockshelter sites to Mid-Late Holocene lowland village sites, in very different regions, has made it difficult to address the development of agricultural communities based on archaeological evidence. Bellwood (1989), Higham (1994), and others have suggested therefore that Thailand was colonized by rice agriculturalists from China, migrating down the Mekong River in the third millennium B.C.

With few archaeological open-air sites dating to the Late Pleistocene and Early Holocene, it is difficult to test the validity of this hypothesis. One indirect, but potentially productive avenue is to investigate the evidence for environmental

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and landscape change from the Late Pleistocene to the present. Most fundamentally, the question is: Can we find environmentally based evidence for the presence of people in northeastern Thailand prior to the fifth millennium B.C.? Archaeological research to date has been unsuccessful in finding sites dating to this era. A second question is: If there is evidence for the cultural alteration of the landscape in the Early Holocene, what were these human groups doing, and how did their behavior change over time?

Recent palaeoclimatic data suggest the end of the Pleistocene was a period of considerable fluctuation in temperature and seasonality (Zahn 1994). This evidence has encouraged archaeologists to model the development of cultivation strategies as a response to high stress and high risk conditions (e.g., Price and Gebauer 1995). In order to assess the role of environmental fluctuations and instability in affecting the subsistence options chosen by complex hunter-gatherers, we need more detailed paleoenvironmental data, preferably from regions with pertinent archaeological data.

Over the last few years, the Thailand Paleoenvironmental Project (TPP)¹ has undertaken a multiregional study of Late Pleistocene and Holocene human environments. While interested in where and when rice agriculture fits into the subsistence systems of Thailand, we are more generally interested in understanding both the environmental context in which subsistence strategies changed and the complement of human activities that shaped and changed the landscape. This article presents the results of the phytolith analyses of a lake sediment sequence, 3KUM, from Lake Kumphawapi in northeastern Thailand (Fig. 1). The region has been the focus of archaeological research for more than 25 years, but little environmental evidence has been available until now for understanding the context of cultural development for northeastern sites like Ban Chiang (e.g., Higham and Kijngam 1979; Maloney 1992; White 1995).

The environmental data presented here reveal a complex interaction of human and environmental relationships that can not and should not be separated. Climatic change critically affected vegetation distributions, but it does not account for the patterns of burning throughout the sequence, nor the type and diversity of the vegetation beginning in the Mid-Holocene. People shaped and were shaped by this landscape at least by the Late Pleistocene. However, this is not a simple case of forest clearance, nor of a single dominant cultivation strategy. The oscillations present in this sequence reveal that diverse and changing subsistence strategies were chosen throughout the period studied. These options were responses not only to varying temperature, rainfall, and seasonality, but also to shifts in cultural interaction, demography, and technology.

While the results of this multidisciplinary project are not yet complete, the extant data do suggest that the unilinear views of the origins of rice agriculture in Southeast Asia need to be reconfigured in light of the current data on the palaeoenvironment and patterns of land use. Unilinear models of the development of tropical agriculture do not accommodate the multifaceted nature of the human environmental relationships that shaped Thai prehistory. Both the archaeological data and the environmental data would benefit from the application of models of nonlinear dynamics, where oscillations and perturbations are described as part of the system (e.g., McGlade 1995).

The use of phytolith analysis in archaeology, while relatively recent, has pro-

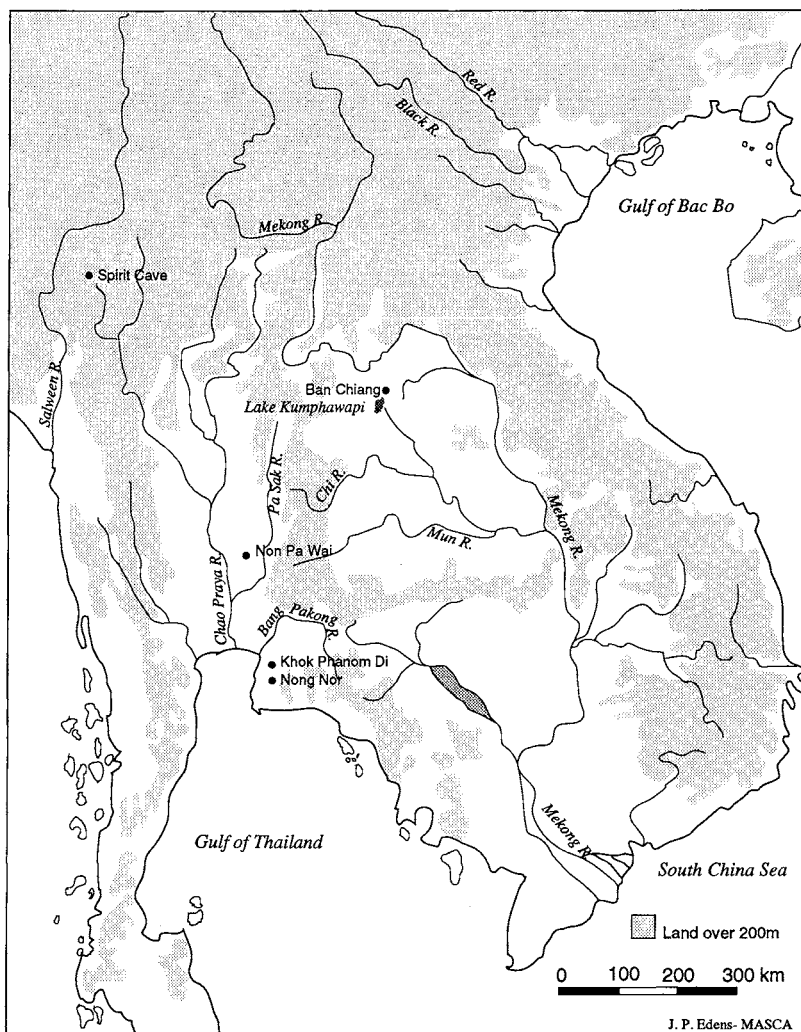


Fig. 1. Map of Southeast Asia showing site locations and Lake Kumphawapi.

ven to provide a unique and substantial record of vegetation and environmental change in a wide range of contexts around the world (e.g., Pearsall and Trimble 1984; Piperno et al. 1991; Rosen 1994). Phytolith data, while complementary to pollen data, document a different spectrum of plant taxa, allowing a more detailed understanding of grass and weed changes than pollen data. This advantage is particularly useful in northeastern Thailand, where open-forest to savanna-type environments have dominated since the Late Pleistocene (Heaney 1991).

THEORETICAL BACKGROUND

The origins of agriculture in Southeast Asia have been hotly debated over the course of the last half century (Gorman 1977; Hutterer 1983; Sauer 1952; Solheim

1972). A variety of interrelated issues have surfaced in these debates, including the relationship between the development of root- and cereal-based agriculture; permanent-field and swidden agriculture; forest, forest-edge, and open deciduous forest-savanna cultivation strategies; and the timing and techniques involved in the development of rice agriculture in Thailand and China (e.g., Brosius 1991; Chang 1976, 1989; Gorman 1977; Headland and Reid 1989; Higham 1995; White 1989, 1995). Often there has been a tendency to see these as dichotomous strategies or alternatives, rather than as interrelated and complementary (but see White 1995).

Recent discussions of agriculture have converged on a single scenario for the origins of rice agriculture. Chang (1976) proposed that domesticated rice derived from the annual rice, *Oryza nivara*, which expanded in its range at the end of the Pleistocene due to increased seasonality and aridity. Rice was first cultivated in the foothills of the Himalayas, across a broad belt extending from the Ganges River in India to the South China Sea. Domestication occurred as people forced out of this region due to aridity, ca. 7000 B.C., took *O. nivara* into new, lowland environments.

More recently, other scholars have supported the geographic part of Chang's model (e.g., Bellwood 1989; Higham 1994). Reconstructed protolanguage groups and their vocabularies (e.g., Benedict 1975; Blust 1988) indicate that rice agriculture began in subtropical southeastern China and subsequently spread through population movement down the major river systems of Southeast Asia. The earliest current evidence for rice cultivation occurs in southeastern China at sites such as Pengtoushan on the middle Yangzi River, which date to ca. 7500–5000 B.C. (Yan 1991).

However, the timing of the rice agriculturalists' expansion proposed by Chang has been questioned. Higham (1994) and Bellwood (1992) propose that segmentary groups of rice agriculturalists from China expanded down the Mekong River and colonized Thailand during the third millennium B.C. While recognizing that other, indigenous, nonintensive strategies may predate this expansion, they consider these strategies insignificant in the overall development of subsequent Thai societies. Sites such as Khok Phanom Di, Nong Nor, Non Pha Wai, in central Thailand, and Ban Chiang and adjacent sites in northeastern Thailand are all suggested to date to the third millennium B.C. and therefore support this model of demographic expansion and agricultural intensification (Fig. 1; Higham 1994).

The current distribution and importance of rice have driven much of this interest in finding the locational and chronological origins of rice agriculture (Swaminathan 1984). Despite this modern prevalence, however, there is little evidence that rice, at least in Thailand, was as significant prehistorically as our models would suggest (e.g., Mudar 1995). While the presence of rice remains in phytolith sequences and at a number of sites suggests that rice was widely distributed, the limited range of tools, as well as the prevalence of other foods, suggests its contribution was variable and may have been only part of a larger, diverse set of subsistence strategies (Higham and Kijngam 1979; Kealhofer and Piperno 1994; White 1995; Yen 1982).

Whether or not rice was the staple cultivar of Thailand prior to the historic period (first millennium A.D.), before we can understand its role in different regions we must understand the environment and land-use strategies of the Late

Pleistocene and Early Holocene. Both archaeologically and environmentally this period is virtually unknown in northeastern Thailand (Higham 1989; Maloney 1992). While considerable archaeological work has been undertaken in Thailand, there are only a handful of open archaeological sites that date to the relevant period. Palaeoenvironmental research in Thailand has focused on coastal geomorphology, and the sequence of sea-level changes and corresponding land-mass and coastal changes, or has been limited to mid to late Holocene sequences (e.g., Chappell and Thom 1977; Sinsakul 1992; Sinsakul et al. 1985; Somboon 1988). The sediment core from Lake Kumphawapi allows us not only to compare the Thai Late Pleistocene environments with those of China (and insular Southeast Asia and Malesia), but also to investigate the role of people in shaping those environments.

PREVIOUS DATA: PALAEOENVIRONMENTAL EVIDENCE

In order to interpret the 3KUM core phytolith sequence from northeastern Thailand, it needs to be placed with the context of the palaeoenvironmental work in the larger region, including South China and South Asia (An et al. 1993; Feng et al. 1993; Flenley 1984; Sun and Chin 1991). These sequences reveal that the Late Pleistocene environment of Southeast Asia and Thailand was considerably more arid and more seasonal than today (Verstappen 1975), due to a steep north-south temperature gradient creating stronger winter monsoons (colder, drier north-westerlies) than summer monsoons (warmer, wetter southeasterlies). During the Late Pleistocene and Early Holocene, Thailand was part of the larger Sundaland, a vast lowland plain connecting Thailand to Indonesia and Borneo. The vegetation in Sundaland was dominated by savanna and seasonal deciduous forest, with local concentrations of gallery forest in alluvial valleys and in the adjacent foothills (Heaney 1991).

In the last few years, reports of significant variability in Late Pleistocene climate and vegetation have become increasingly frequent. An and coworkers (1993), for example, discuss a geomorphological sequence from an area just east of the Tibetan plateau. The Baxie palaeosol from this sequence (11,000–9000 cal. B.C.) reveals the onset of stronger summer monsoons, bringing a warm and wet interruption in the Late Pleistocene, although cool and dry winter monsoons persisted, suggesting a more seasonal regime than the present. The authors interpret this interval as the Chinese Younger Dryas Event (11,000–9000 B.C.), but with conditions opposite those documented elsewhere (i.e., warm and wet vs. cold and dry). A 500–600 year return to glacial conditions followed, before the onset of the Holocene Optimum period (when both winter and summer were warmer and wetter than today).

The implications of this evidence for the vegetation, and in particular the distribution of rice, are that the strong seasonality of the Late Pleistocene was appropriate for the expansion of *annual* grass species including rice (Oka 1988; Second 1985). The further expansion of both perennial and annual grasses throughout Southeast Asia would be expected with the onset of the Holocene, without the aid of the human hand, in contrast to Chang's suggestion. Because rice was available does not mean that people cultivated it, however, so the timing and context in which it came to be cultivated are still at issue.

Climatic change has long been cited as a major cause for the development of agriculture (e.g., Childe 1952; Wright 1993; and Higham 1995 most recently). Climatic change undoubtedly shifted the range and life form (perennial vs. annual) of much of the vegetation at the end of the Pleistocene, affecting not only the species available for human exploitation but grasses' annual production of seeds. However, the sharp fluctuations in temperature and seasonality at the end of the Pleistocene, seen in recent ice core data, may have been more significant in creating high stress risk situations (Zahn 1994). Under these types of stress, humans chose a variety of new strategies to attempt to stabilize their resource base (Price and Gebauer 1995).

The rate and type of vegetation changes linked to both climate and human activities need to be defined for this critical period to understand whether or not either climatic change or increased climatic fluctuation could have played a significant role in changing subsistence options.

METHODOLOGY

The phytolith evidence presented here comes from the longest sediment sequence TPP recovered from Lake Kumphawapi, 3KUM, a 6.18 m core. Lake Kumphawapi is located in the Sakon Nakhon Basin of the Khorat Plateau in northeastern Thailand (Fig. 1). The lake is approximately 15 km long and is relatively shallow. Depth fluctuates both annually and seasonally, although a recent dam at the south end of the lake and the construction of levees have stabilized its area considerably. Geologically, the lake has been suggested to be a Pleistocene bed of the Mekong River, which was subsequently cut off by tectonic changes in the plateau (Moore 1988; Parry 1990). The lake edges are currently vegetated by sedges, lotus, and tall grasses (such as *Saccharum*).

In December 1993 four cores were taken with a modified Livingstone corer in the center of the lake, where water depth was ca. 1.5–2.0 m. Lake Kumphawapi has recently been cored by two teams, Penny and his colleagues from Monash University and the TPP. We are currently collaborating and synthesizing our independent projects and will eventually present an interdisciplinary study (pollen, phytoliths, geomorphology, soil chemistry) of a sequence of cores from Lake Kumphawapi. The 3KUM core extends into the Pleistocene, and therefore it is uniquely appropriate for studying the evidence for human landscape use during the late Pleistocene and early Holocene.

Twenty-three samples were processed from the 3KUM core, and of these, nineteen samples provided a sufficient number of phytoliths for analysis.² Approximately 80 g of sediment were analyzed for each sample. It is important to note that these samples conflate events of variable duration, so that intervals of time are "averaged." Phytoliths were extracted from the soils and fractionated following the protocol outlined by Piperno (1988), with only minor modifications. The processed samples were mounted on slides, and diagnostic phytoliths counted at 400× magnification. Counts were minimally 100 per sample and preferentially 200. Because of the specific focus on the Pleistocene-Holocene transition, the older sections of the core were sampled more intensively than the younger sections.

In order to assess the complex patterning in the phytolith samples, the counts

were subjected to correspondence analysis (BIGCOR1-3 in MV-ARCH; Wright 1991). The data were analyzed in several different formats (e.g., raw counts, presence or absence, and percentages) to assess the biases of each. All had their problems; the raw counts had sufficient variability, but samples with similar counts rather than similar patterning were grouped together, while the occurrence data too heavily weighted the rare samples in the assemblage. The percentage values are problematic in terms of the forced linkages between increases and decreases, but they provide a more revealing set of analyses. All three analyses shared the same basic groupings in the data, with only the transitional samples linked differently in several cases (e.g., sample 4.95 m, 1.80 m). Because percentage values were the most reliable set of patterns based on the known relationships of the phytolith types, they are discussed here. Given the way phytolith assemblages are created (cf. Piperno 1988), the results presented here must be considered as exploratory.

The phytoliths in the soil assemblages were interpreted with the aid of a modern reference collection of more than 1000 reference samples, from which nearly 400 diagnostic phytolith types have been identified (Kealhofer and Piperno in press). In continuing to expand this reference collection, most recently research has focused on sampling grasses and weeds specific to a variety of different agricultural habitats in Thailand in an attempt to more precisely identify changes both in human land use and in the ecological contexts in which subsistence strategies changed.

Since neither the full spectrum of pollen or phytoliths preserve in the sedimentary record, comparative soil samples from habitats with identified plant species are useful for defining the relationship between soil assemblages and vegetation complexes. Modern soil samples taken by Penny from the Kumphawapi region are currently under analysis by our teams for pollen and phytoliths. These samples are depositionally different from lake sediments. Phytoliths are primarily deposited in lake contexts through fluvial action, but some are also aerially deposited (reverse of pollen deposition). A sampling regime of modern mud-water interfaces in lakes will provide the only direct analog for lake sediment microfossil interpretation.

VEGETATION AND BURNING

The distribution of weeds and grasses today in northeastern Thailand is known in general terms. Detailed botanical studies of rice padis exist (e.g., Heckman 1979). The dominant species in Thailand are described by botanists such as Ashton (1995), Stott (1984), and Smitinand (1968), and the *Flora of Thailand* is in process (Smitinand and Larsen 1970-1987), but no systematic weed studies have been published. A summary catalog of weeds for Thailand records a number of (grass subfamily) Panicoid and Chloridoid species, but suggests Panicoid grasses dominate this region today (Noda et al. 1985; Radanachalee and Maxwell 1992).

These grass subfamilies are associated with coarse environmental differences; Chloridoid grasses tend to be found in disturbed hot dry locales, while Panicoids tend to be found in disturbed warm wet locales (Twiss 1992). Bamboos are more diverse, with taxa occurring in forest, open savanna to semievergreen forest contexts (Soderstrom and Ellis 1987). The large number of sedge species reflects the widespread presence of damp habitats in Thailand (Noda et al. 1985). Panicoids,

a few Chloridoids, and almost all the sedges are found in rice padis (Noda et al. 1985; Heckman 1979). All of these weeds have diagnostic phytoliths to at least the genus level, and when more detailed studies are completed, likely to the species level (Kealhofer and Piperno in press; Piperno 1988, 1989; Piperno and Pearsall in press). While the comparative data are incomplete, they still provide the only analogs for interpreting the sediment core sequences.

Northeastern Thailand is generally characterized by deciduous dipterocarp open forests. These forests are formed by a light canopy of various dipterocarp trees (*Dipterocarpus*, *Shorea*, and *Pentacme* as well as scattered *Terminalia*, *Xylocarpus*, *Lagerstroemia*, *Buchanania*, *Sindora*, etc.), with no intermediate storey (Blasco 1983). The understorey, in addition to grasses (*Eulalia* and *Themeda*) and dwarf bamboos (e.g., *Arundinaria*), can also contain legumes (*Crotalaria*, *Desmodium*, and *Indigofera*), palms (*Phoenix* and *Corypha*), and cycads (*Cycas*).

Interpretation of the human contribution to burned landscapes in the prehistoric period is a subject of some debate (Blasco 1983). Scholars in different regions accept very different perspectives on burning (e.g., Head 1994; Pyne 1991; Rambo 1979; Woodcock and Wells 1994). In Thailand much of the savanna forest is human-induced fire climax forest, where fire is almost an annual phenomenon (Ashton 1995:462; Sahunalu and Dhanmanonda 1995). The understorey of these fire climax forests is characterized by a more limited number of species, with bamboos and dwarf bamboos such as *Arundinella* sp. and *Arundinaria* sp. most common (Ashton 1995:463; Stott 1986). Typically they may also include a grassy understorey with scattered shrubs. The antiquity of this fire climax forest is unclear.

Stott (1986) described two main types of burn in these forests: typical litter burn and typical ground-cover burn, each with a more extreme variant when vegetation had not been burned off for an extended period. The two types of burn are distinguished by the amount and diversity of vegetation that is affected. The differences between these are significant: litter burn moves very quickly, is relatively low temperature, and only the litter burns; ground-cover burn moves more slowly, has higher temperatures, and affects a wider range of species (grasses, sedges, bamboos, saplings, and small shrubs). Extreme burns are less frequent, burn much hotter, commonly occur in dense regrowth bamboo stands, and can ignite logs and trees. Only the extreme burns damage the forest, as the lower temperatures of the typical burns and the insulating qualities of the trees and the soils protect the vegetation. These data suggest that burned phytoliths, including the identification of types and diversity of plants burned, can give us a clue to the burning regimes present in the past.

PHYTOLITH RESULTS FROM LAKE KUMPHAWAPI

Dates

Seven samples were dated: 0.85 m, 1.36 m, 1.52 m, 2.55 m, 3.55 m, 5.40 m, and 5.80 m. The lowest two dates were Late Pleistocene, 12,045–12,346 cal. B.C. and 8,039–8,347 cal. B.C. The first five samples fall within this range. The remaining samples date between c. 4500 cal. B.C. and 8000 cal. B.C., based on the upper five dates. Samples were selected for dating based on distinctive sedimentary changes in the cores (see below and Fig. 2).

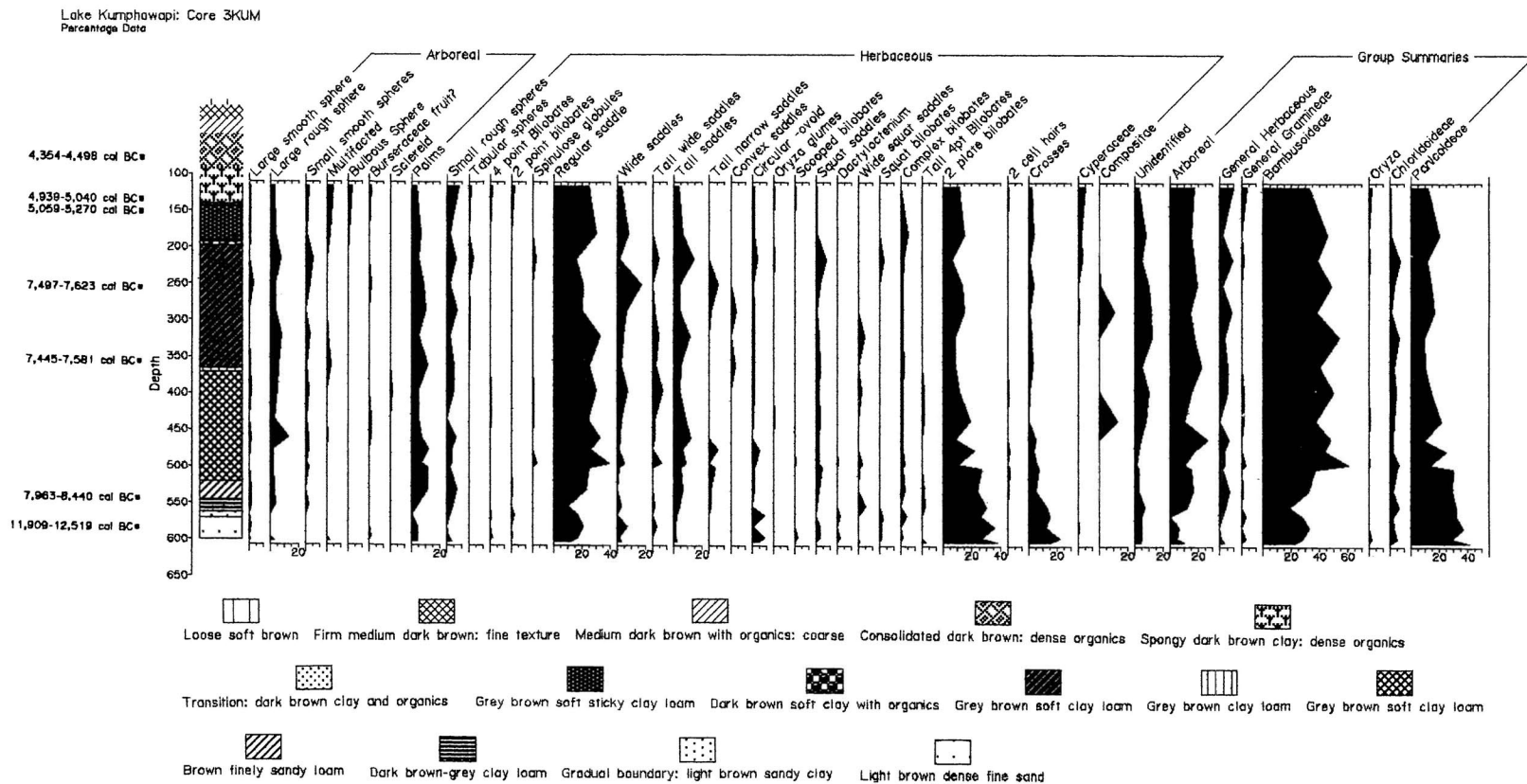


Fig. 2. Diagram of phytolith relative frequencies throughout the Lake Kumphawapi Core 3.

Sedimentary Sequence

The core's sediment changes are schematically presented in Figure 2. The sediments change dramatically in the lowest section, from fine sands in the Late Pleistocene to a soft organic rich clay loam by the Early Holocene. The sediments in the middle part of the sequence are extremely uniform, with a transition from 1.40–0.47 m (c. 5000 B.C.) to sediments very rich in organics. These upper sediments did not preserve phytoliths well. This transition likely relates to a complex set of factors including human impact, and geomorphological changes in the surrounding basin affecting depositional conditions. The rate of deposition changed dramatically during this sequence, with accumulation slowest during the Late Pleistocene, increasing during the Early Holocene, and slowing again by the Mid-Holocene.

Phytolith Sequence

The 3KUM sequence can be divided into several general phases: Late Pleistocene (6.0–5.3 m), Early Holocene (5.3–2.2 m), Mid-Holocene (2.2–1.2 m; see Fig. 2). The diagram includes a set of summary categories of vegetation types that will be used to simplify this synopsis. Bambusoideae phytoliths (the various "saddle" and many fan bulliform types) are the most common in these soil samples, reflecting the very high silica deposition in bamboos. Arboreal taxa, and more generally Dicotyledons, produce fewer and less diverse assemblages of phytoliths (Kealhofer and Piperno in press; Piperno 1988, 1989).

Late Pleistocene 6.2–5.3 m — During the Late Pleistocene the vegetation included fewer trees (mainly palms), bamboos, general herbaceous and general grass types, but abundant and diverse Panicoid grass types. The lack of trees suggests that the climate, as expected, was more arid than today, although the earliest sample shows more arboreal taxa than subsequent Late Pleistocene samples. The presence of Panicoid grasses indicates that some locales were at least seasonally damp, even during the driest periods.

Several shifts occur during this phase, when trees and Panicoid grasses decrease and bamboos increase. This may reflect a short (seasonally?) cold, dry interval. Interestingly, both the arboreal and the bamboo component begin to increase prior to the end of the Pleistocene, while the Panicoid grasses decline slightly. A seasonally dry forest may have developed at this time.

The presence of Panicoid grasses in these early samples is somewhat anomalous. In general, Panicoid grasses are found in open habitats in subtropical to tropical warm habitats, where damp conditions are at least seasonally present. As noted above, they are common in this monsoonal region today. Their abundance may be attributed to the lake or riverine environment of Kumphawapi itself, which may have created more favorable, locally damp conditions for Panicoid species than an otherwise arid Late Pleistocene might indicate. The presence of sedge (Cyperaceae) and rice phytoliths at this interval also supports this suggestion.

Early Holocene 5.3–2.2 m — The Early Holocene, after 8,000 B.C., commenced with a marked change in many of the taxa. Panicoid grasses declined significantly (in diversity and abundance), bamboos increased sharply, and the arboreal component was unstable. For example, palm taxa initially increased but then declined.

Other arboreal taxa vary inversely with palms, suggesting that the palms represent a more open savanna forest (typical of dry deciduous dipterocarp forest), while the other arboreal taxa indicate a more mixed or mesic deciduous forest (Blasco 1983; Stott 1986).

Sharp fluctuations in the curves show substantial vegetation shifts during this period (7800–8000 B.C.). Panicoid and arboreal declines are linked to increases in bamboos, perhaps reflecting human activities, such as broadcast burning (see discussion below). Several species of bamboos are secondary regrowth species in Thai forests (Stott 1984). The increase in bamboo taxa may therefore be linked to regrowth after broadcast burning. The changing frequency of burned phytoliths follows the same timing of changes as the trees. No evidence has been found for cooler intervals during the Early Holocene (Feng et al. 1993), indicating that these fluctuations are unlikely due to climatic change.

By about 7800 B.C. the vegetation settles into a more stable cycle of fluctuations in arboreal and (secondary growth) bamboo composition, and Panicoid grasses reach a low for this sequence. Bamboo taxa diversity increases, indicating an increase in the diversity of forest habitats during this period. The Unidentified group in the diagram is likely to include arboreal species, since neither grasses nor herbaceous types are represented. If this group is included in the Arboreal sum, the Early Holocene was substantially more forested than earlier or later periods, which fits with the warmer and wetter conditions known for this Holocene Optimum period (7000–3000 B.C.). Increased forest cover is also supported by the decline in Panicoid grasses, which are less common under forest canopy.

By 3 m (c. 7500 B.C.), sedges reappear in the sequence in conjunction with *Sativae* rice phytoliths (likely a progenitor of domesticated rice), increasing up to the top sample. This suggests that the lake edge conditions began to change at this time, with more shallow damp zones nearby. Geomorphological and lake-shore cores are currently being studied to see whether the changes were geomorphological or human-induced (Penny, pers. comm.). Adjacent dry open zones were also present, as Chloridoid phytoliths increased toward the end of this phase.

Mid-Holocene 2.2–1.2 m — The transition to the Mid-Holocene is relatively subtle in this sequence, but nevertheless distinctive. Grass species are the major indicator here, as *Oryza* becomes more common, Chloridoid grasses decline significantly, other grass species increase in abundance, and both Panicoid and bamboo types decline. The arboreal component shows little evidence of this shift when viewed in sum, but if the individual taxa are separated out the forest cover changes substantially. New species appear (possibly some Annonaceae and Flacourtiaceae as seen by the multifaceted forms) while palms decrease. These changes in the forest may represent cultural selection or changes in forest modification. While there was a short cooler interval, 5800–5500 B.C., just prior to these samples, the noted increase in *Oryza*, sedges, and specific arboreal taxa do not correlate with the known climate changes elsewhere. These changes are likely to reflect a combination of changing lake-edge conditions and human subsistence activities.

Correspondence Analysis — In order to sort the relationships between different sediment samples and their complex phytolith assemblages, the data were subjected to correspondence analysis. The results are first presented in two scattergrams (Figs. 3 and 4) and Table 1 based on the same data set. Several groupings occur in these

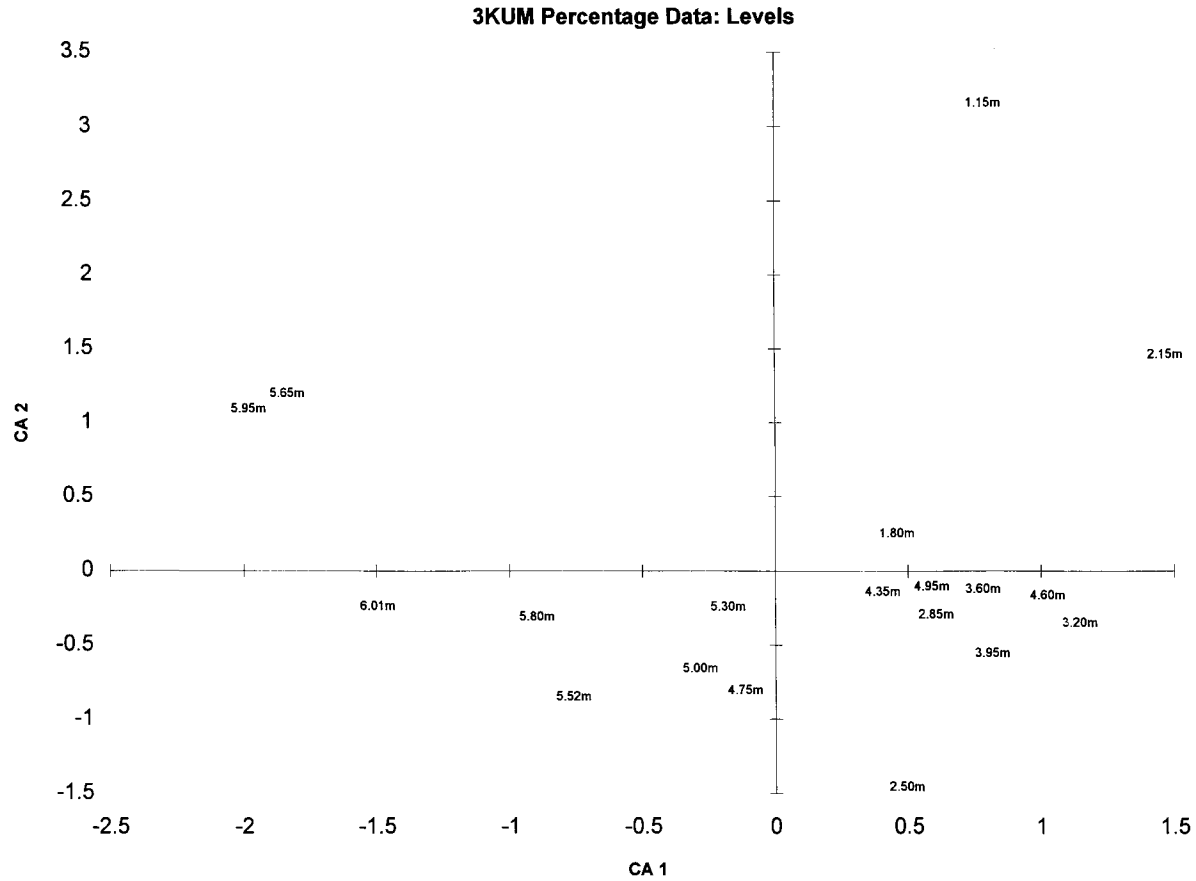


Fig. 3. Bivariate plot of correspondence analysis scores based on percentages of phytoliths at different levels of Lake Kum-phawapi Core 3.

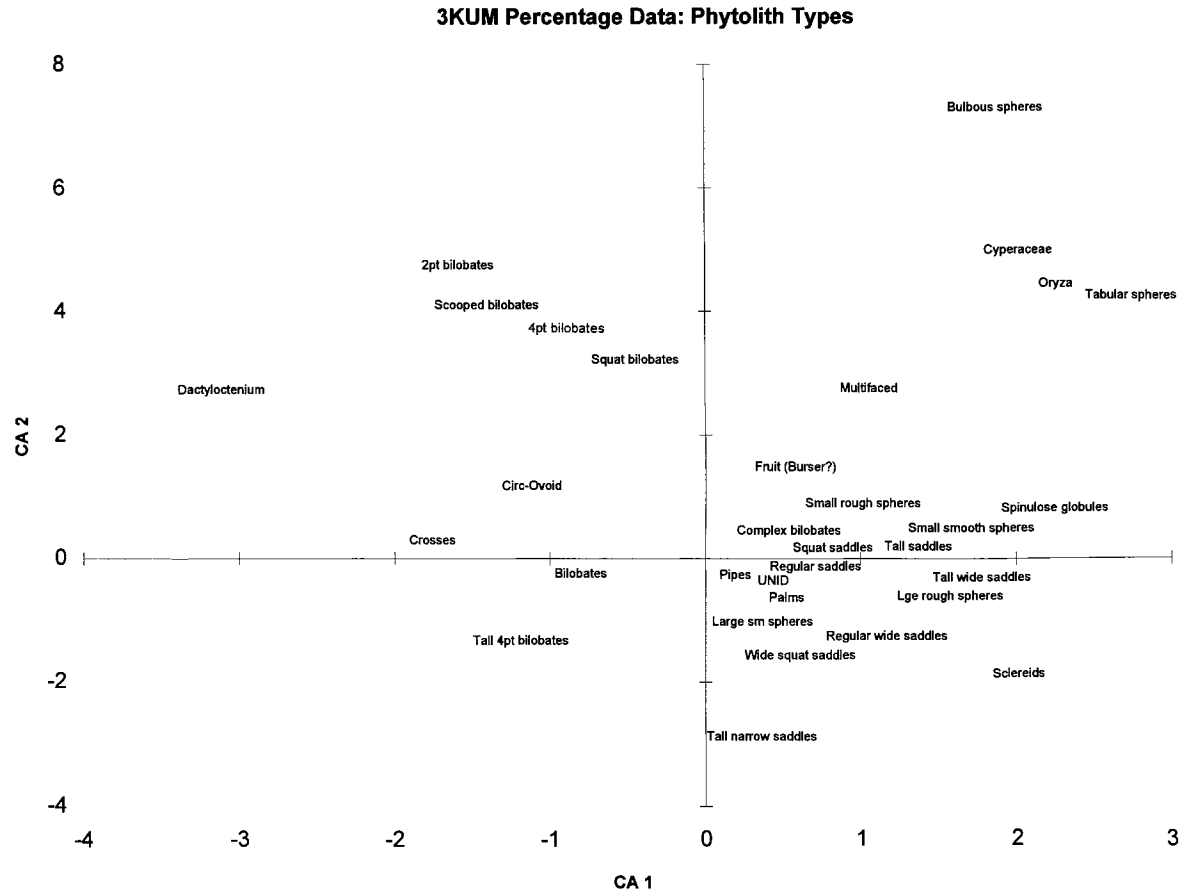


Fig. 4. Bivariate plot of correspondence analysis based on percentages of burned phytolith types from Lake Kumphawapi Core 3.

TABLE 1. TYPES OF BURNED PHYTOLITHS AND THEIR EIGENVECTOR SCORES FROM THE KUMPHAWAPI 3 CORE

PHYTOLITH TYPES	FIRST	SECOND
	EIGENVECTOR SCORES	EIGENVECTOR SCORES
Large sm spheres	-1.685	-0.985
Lge rough spheres	1.37	-0.345
Small smooth spheres	1.023	-0.523
Palms	-0.904	-0.463
Small rough spheres	0.299	-0.837
4pt bilobates	-0.95	6.14
2pt bilobates	-0.641	8.135
Regular saddles	0.134	0.514
Regular wide saddles	1.545	-0.616
Tall wide saddles	1.127	-0.068
Tall saddles	1.703	0.245
Tall narrow saddles	-1.018	-0.021
Convex saddles	2.812	0.063
Circ-Ovoid	-0.967	0.925
Oryza	0.784	5.459
Scooped bilobates	-2.017	-0.994
Squat saddles	-0.065	-0.233
Dactyloctenium	-1.06	-1.215
Wide squat saddles	-0.062	-0.184
Complex bilobates	-0.435	-0.718
Tall 4pt bilobates	-1.414	-0.968
Tall 2pt/4pt cross	-1.501	-1.341
Bilobates	-0.533	-0.022
Crosses	-1.214	-0.668

scattergrams of the first two eigenvectors (see Table 1). The Pleistocene samples fall to the left of the vertical axis, with a small cluster of the 5.95 m and 5.65 m samples (Fig. 3). The Early Holocene samples cluster tightly together, although a couple of samples diverge from the cluster (e.g., 2.50 m). The Mid-Holocene samples fall in the upper right quadrant, not particularly similar, but different from the other groups.

If we compare the phytolith type (Fig. 4) with the previous scattergram (Fig. 3), the taxa distinguishing these groups can be identified. The two Late Pleistocene groups are defined by a specific group of grass species (non-Panicoid, non-Chloridoid), a type of rice (not in the *Sativae* group), and a specific genus of Chloridoid grasses (*Dactyloctenium*). This complement of grasses is quite different from any later period and confirms a distinctive temperature and humidity regime. In the last few Pleistocene samples, certain Panicoid taxa become more common, represented by the (2-plate) Bilobates.

The Early Holocene taxa are distinguished by bamboos ("saddles"), palms, and trees. Panicoid and Chloridoid grass forms are present, but not dominant. This assemblage reveals the increased forest cover of this Holocene Optimum period. The Mid-Holocene samples include a different set of arboreal types (multifaceted and sphere forms), with the addition of sedges and rice. The Late Holocene taxa

changes make little sense in purely climatic terms (e.g., no known climatic shifts relate to changing arboreal composition), although local changes in the lake are also likely reflected here.

The extent of clustering in these groups is also variable. Both the Late Pleistocene and the Mid-Holocene samples are much less tightly grouped and more variable than the Early Holocene samples. What determines this variability is a key issue. The fluctuations in the Late Pleistocene seem to represent rapid changes in seasonality and, to some extent, temperature increases (e.g., similar to the Chinese Younger Dryas Event). In the Mid Holocene, the variability is likely in part linked to economic strategies adjacent to the lake. The tight cluster of the Early Holocene samples suggests that the climate and land-use patterns were relatively stable through this period.

Burning — One other set of data is considered in conjunction with the changing vegetation patterns. Phytoliths uniquely reveal evidence of burning, and in determining which taxa and which parts of the plants are burned, a great deal of information is gathered about how, when, how often landscapes were burned and the relationship between burning and vegetation. Overall, burned phytoliths were predominantly grasses, and to a lesser extent, arboreal spheres and palms.

Table 2 shows the percentage of burned phytoliths by type in the sequence. The number of phytolith types burned is considerably smaller than the full range of assemblage types, but includes taxa from all categories. The pattern of burned phytoliths fluctuates through the sequence, from a low of 5 percent (4.35 m, early Holocene) to a high of 29 percent (2.5 m, transitional Early-Mid Holocene). The sharpest peaks occur at the end of the Early Holocene (3.2 m and 2.5 m), but substantial burning occurred in the Late Pleistocene as well (5.95 m, 5.30 m, and 5.00 m).

These fluctuations can be more clearly understood when tied to the specific taxa burned. While the frequencies are low for arboreal types, the types of trees burned changes from the Late Pleistocene to the Early to Mid-Holocene, and again in the Mid-Holocene. The types of phytoliths burned and the diverse composition of the grass assemblage indicate that this was likely a mixed deciduous to dry deciduous forest, with composition oscillating over time. The low frequency of burned trees suggests, based on Stott's (1986) data, that extreme burns were relatively rare, and therefore the ground cover was regularly burned off.

Less subtle are changes in the grass taxa burned. Panicoid grasses were most commonly burned in the Late Pleistocene, while bamboo taxa were most often burned from the mid Early Holocene on. The burning of taxa which track the climatic and vegetation changes from the Late Pleistocene through the Holocene suggests that the landscape itself was being burned, not a more limited and controlled burn of weedy fields. The cultural component of the burning regime was most likely related to strategies such as hunting, clearing of undergrowth, and selective habitat maintenance, as has been documented locally and in other regions of the world (cf. Blasco 1983; Head 1994; Pyne 1991; Stott 1986; White 1995).

Correspondence Analysis — These patterns are more clearly revealed through correspondence analysis. Figure 5 is a scattergram of the first two eigenvectors of a correspondence analysis of burned phytolith types. The burning patterns are visible

TABLE 2. PERCENTAGE OF BURNED PHYTOLITHS FROM DIFFERENT DEPTHS OF THE KUMPHAWAPI 3 CORE

PHYTOLITH TYPES		1.15 M	1.80 M	2.15 M	2.50 M	2.85 M	3.20 M	3.60 M
ARBOREAL	Large sm spheres	0	0	0	0	0	0	0
	Lge rough spheres	0	0	1	2	1	0	0
	Small smooth spheres	0	0	0	1	0	1	0
	Fruit (Burser?)	0	0	0	0	0	1	0
	Palms	0	3	0	1	0	0	1
HERBACEOUS	Small rough spheres	0	0	0	1	2	1	0
General Gramineae	4pt bilobates	1	0	0	0	0	0	0
	2pt bilobates	1	0	0	0	0	0	0
Bambusoideae	Regular saddles	4	1	3	4	2	6	4
	Regular wide saddles	0	4	0	10	2	3	1
	Tall wide saddles	0	0	1	0	0	1	0
	Tall saddles	0	0	1	0	0	1	0
	Tall narrow saddles	0	0	0	2	0	0	0
	Convex saddles	0	0	0	0	4	0	0
Bambuseae	Circ-Ovoid	0	0	0	0	0	0	0
Oryzaeae	Oryza	1	0	0	0	0	0	0
	Scooped bilobates	0	0	0	0	0	0	0
Chloridoideae	Squat saddles	0	0	1	1	0	0	0
	Dactyloctenium	0	0	0	0	0	0	0
	Wide squat saddles	0	0	0	0	0	1	0
Panicoideae	Squat bilobates	0	0	0	0	0	0	0
	Complex bilobates	0	0	0	0	0	1	0
	Tall 4pt bilobates	0	0	0	0	0	0	0
	Tall cross-pt	0	0	0	0	0	0	0
	Bilobates	5	2	0	7	3	4	0
A/P	Crosses	0	0	1	1	1	1	1
	TOTAL	12	10	8	29	15	21	7

in the clustering of levels: the Late Pleistocene samples form a group on the lower left side of the graph, revealing a unique burning regime. The most recent Mid-Holocene sample stands out as very different from the rest of the assemblage. The Early Holocene samples are more loosely clustered, revealing cyclical fluctuations in burning regimes and forest composition.

The taxa associated with these level correlations are plotted in Figure 6. The Late Pleistocene samples reveal, as mentioned, a unique range of burned Panicoid, Oryzoid, and Chloridoid grass taxa, as well as palms. The Early Holocene samples are dominated by bamboo types and a different range of arboreal taxa. A Mid-Holocene sample (1.15 m) shows a unique pattern of burning both weedy grasses and rice, suggesting burning *in* fields.

DISCUSSION

These data suggest that there are gaps in the archaeological evidence for north-eastern Thailand. Human populations began modifying the landscape by the Early Holocene. Given the lack of archaeological evidence, however, it is very difficult to reconstruct which strategies, or combination of strategies, were being

(Extension of Table 2)

	3.95 M	4.35 M	4.60 M	4.75 M	4.95 M	5.00 M	5.30 M	5.52 M	5.65 M	5.80 M	5.95 M	6.01 M
0	0	0	0	0	0	0	0	1	0	0	0	0
1	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	1	2	2	1	0	0	0	1
1	0	0	0	0	0	0	2	0	0	0	0	1
0	0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	3	5	5	2	2	1	1	1	1	2	0
0	4	1	0	0	0	0	0	0	0	0	0	0
1	1	0	0	1	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	1	0	0	0	0	0	0	0
0	4	0	0	0	0	0	0	0	0	0	0	0
1	0	0	1	0	0	0	0	0	1	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
2	3	1	4	2	8	7	5	3	6	6	7	6
0	0	0	1	1	1	1	2	1	2	7	4	4
13	17	5	13	9	13	15	11	9	9	17	12	12

pursued in burning the ground cover, although ethnographic data do provide some suggestions (Stott 1986; White 1989, 1995).

If, using this evidence, we attempt to evaluate the role of climatic instability in encouraging people to choose new subsistence strategies to reduce their subsistence risks, we see some evidence for sharp fluctuations in this sequence. During the Late Pleistocene several abrupt vegetation shifts occur, affecting both grass and tree assemblages. We cannot as yet, however, resolve change at a temporal scale, linking long-term fluctuations to human decision-making responses.

More precipitous changes occur in the vegetation at the beginning of the Holocene, between 5.0–4.5 m (ca. 8000–7800 B.C.), suggesting this interval may reflect human subsistence changes. The Chinese climatic data reveal a fairly stable warming trend during this interval (Feng et al. 1993), suggesting that climatic change can not explain the sharp changes in the assemblage. These changes are most likely related to human impact on the vegetation. The problem of time resolution is much less applicable here as the rapid accumulation of sediment allows for finer chronological resolution.

Unlike many regions, where tropical forests were cleared with slash-and-burn techniques, there is no single marker for agriculture in this sequence. The fluctu-

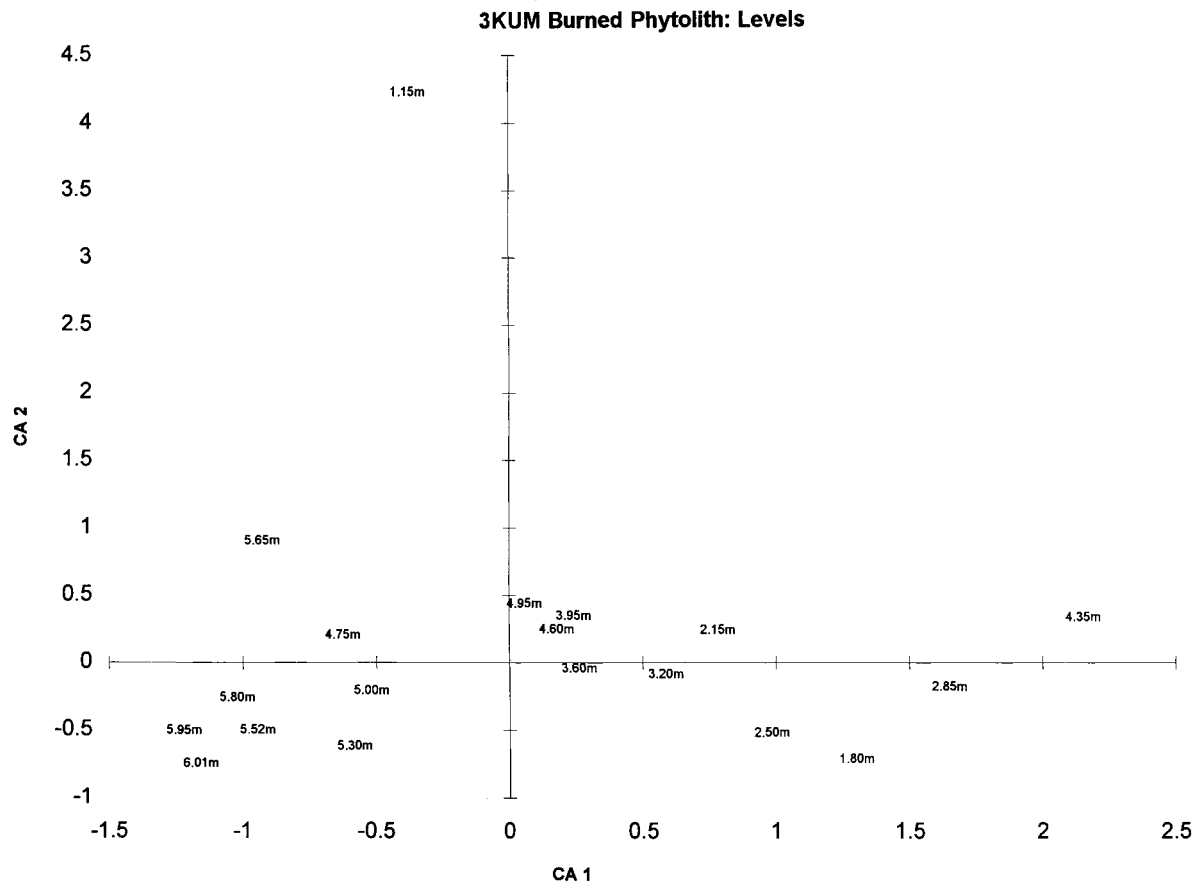


Fig. 5. Bivariate plot of correspondence analysis scores based on percentages of burned phytoliths at different levels of Lake Kumphawapi Core 3.

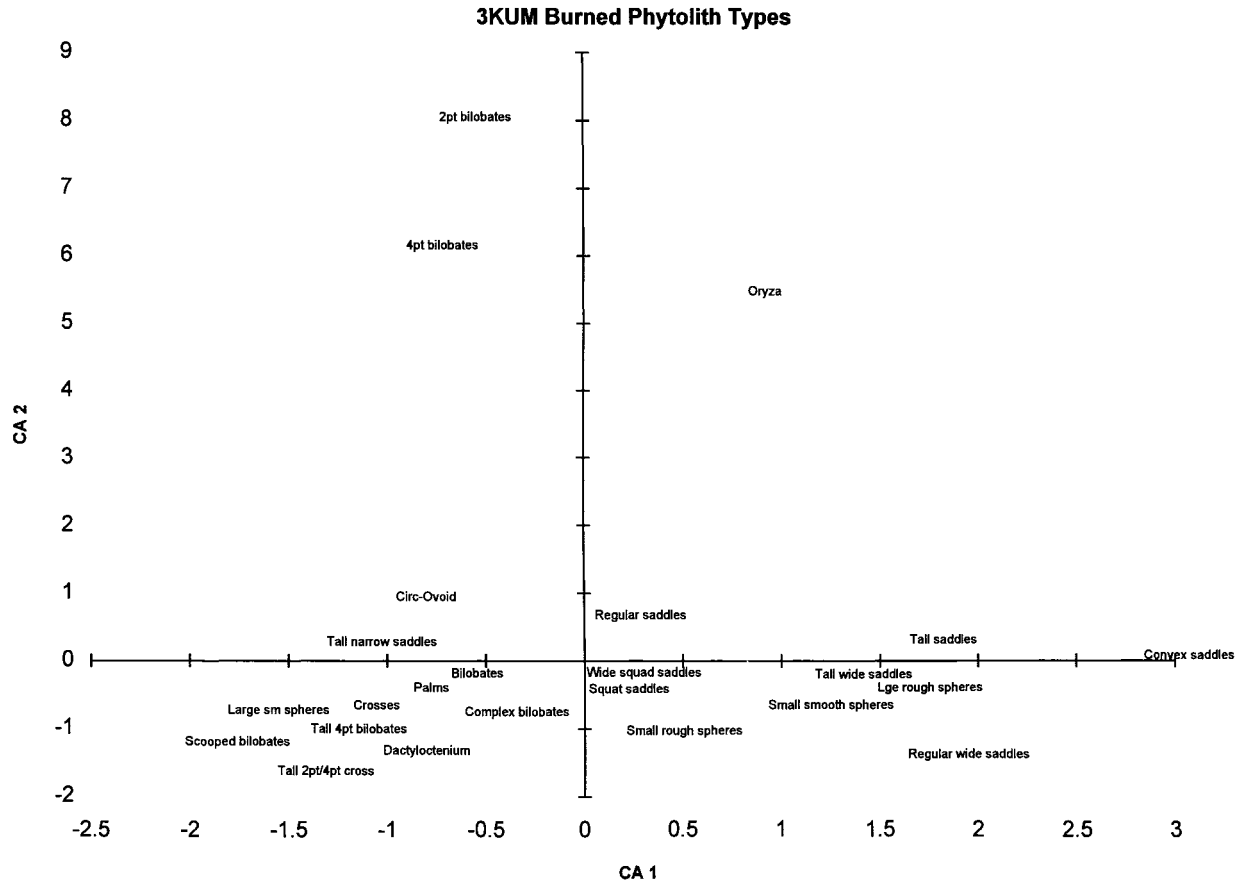


Fig. 6. Bivariate plot of correspondence analyses scores based on percentages of burned phytolith types from Lake Kumpha-wapi Core 3.

ating pattern of burning in the phytoliths, the cyclical oscillations in trees and secondary bamboos, and the very distinctive changes during the Early Holocene (ca. 7500 B.C.) suggest that a complex of subsistence strategies were used in this region during the Early Holocene and that these changed in a nonlinear fashion. This is expected given our understanding of the complexity, diversity, and breadth of subsistence strategies known from this region archaeologically and ethnographically (Higham 1984; White 1995).

During the Early Holocene, the overall patterning, despite some oscillation, stays relatively stable until between 3.0 and 2.50 m in the sequence (ca. 7500 B.C.). At this time there is a significant change in the vegetation and in the burning regime: palms begin a long decline, and sedges and rice reappear. The 2.5 m sample is anomalous, and later samples reveal a significant shift to new grass species, a decline in bamboos, Chloridoid grasses, and palms. These data strongly suggest that agriculture expanded at the expense of the open dry deciduous forest. These changes predate known climatic changes, although subsequent changes may relate in part to the cooler, drier conditions of the Late Holocene. The pollen data for KUM.1 (Penny et al. this issue) also support a significant shift in land use by the fourth millennium B.C.

If we turn to the issue of the role rice agriculture plays relative to other subsistence strategies in this region, the phytolith data suggest that rice may well have been used during the late Early Holocene, but it likely did not become a dominant strategy until much later. While diagnostic rice phytoliths are underrepresented in the samples, the pattern of burning and the abundance of weeds provide indirect data to address this issue. The changes that occurred after 7500 B.C. may have been the precursors of this later intensification. This timing predates sites in the Sakon Nakhon Basin such as Ban Chiang, which were settled by the fourth millennium B.C. (White 1986). The pattern of change represented in the uppermost samples likely corresponds to settlement expansion at this time and also with the adoption of water buffalo for rice agriculture in the first millennium B.C. (Higham 1989; Higham and Kijngam 1979). Rice cultivation or management was apparently one of a diverse set of overlapping gardening, cultivating, and collecting strategies until the Late Holocene. The use of diverse subsistence, including collecting and cultivating, strategies continues to some extent today, despite the dramatic economic changes of the recent decades (White 1995).

The possibility of using burned phytoliths to directly assess patterns of vegetation burning allows us to address fire histories in the past. The pattern revealed here suggests that while burning increased in the late Early Holocene, this burning appears most in Bambusoid taxa. This represents burning or clearance of the dry deciduous forest understorey (based on species composition). Dry deciduous forest soils can rarely support swidden agriculture, and therefore it is unlikely that swidden was an important component of human land use during the Mid-Holocene. These data support White's (1995) suggestion that swidden was not a primary component of long-term agricultural systems in this region. It is significant, however, that the highest burned phytolith percentages correlate with the general period of settlement for Ban Chiang and other sites in the nearby region. The decline in burned grasses in the Mid-Holocene may represent an intensification of rice agriculture, corresponding with a decline in the fire management of dry deciduous forest resources.

SUMMARY

This sequence contains two interwoven signatures of landscape changes that can not be separated. Climatic changes clearly affected the range of species present and their distribution, but climatic change does not account for the patterns of burning, nor the changes in species or species diversity from the Early Holocene on. I suggest that human activities were critical in transforming this landscape. The relatively high level of burning in the terminal Pleistocene may be early evidence for cultural landscape modification. This is not a simple case of forest clearance, however, nor of a single dominant cultivation strategy. The ambiguity and cyclicity in the record reveals that diverse and changing strategies were in use during the Holocene, responding not only to shifts in temperature, rainfall, and seasonality, but also to cultural interaction, demographic changes, and technological innovation (cf. White and Pigott 1995).

Finally, we are in the process of trying to evaluate the environmental context for the development of agriculture in Thailand. While the results are not yet complete, it seems clear that current models for the origins of rice agriculture in Southeast Asia need to be reevaluated to reflect current data on the palaeoenvironment and patterns of land use. As Hutterer (1983) suggested over a decade ago, unilinear models for the development of tropical agriculture do not take into account the intricacy of either the human environmental relationships or the horizontal cultural/ethnic relationships that shape Thai prehistory. A model of non-linear dynamics, where evolution occurs through principles of self-organization (structured disorder), and which views perturbations as part of the system, might repay further attention (e.g., McGlade 1995). More importantly, however, we need systematic regional surveys and archaeological data for the Early and Mid-Holocene from open-air sites. Environmental sequences provide broad-brush average changes across a region, but do not satisfy the archaeologist's need to understand how and why these changes occurred.

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NOTES

1. In 1993–1994 the Thailand Paleoenvironmental Project included Lisa Kealhofer, Joyce White, Bernard Maloney, and Mauro Cremaschi.
2. The 0.55 m, 0.85 m, and 1.50 m samples contained few phytoliths; the 5.20 m sample was lost in processing.

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ABSTRACT

Regional environmental reconstruction is used to address the issue of human environmental relationships in northeastern Thailand from the Late Pleistocene through the Mid-Holocene. A 6.18 m core from Lake Kumphawapi was analyzed for phytoliths, and reveals a long sequence of complex climatic, geomorphological, and cultural changes in the landscape. Distinctive fluctuations in vegetation, as well as

direct evidence from burned phytoliths, suggests broadcast burning of the mixed deciduous-dry deciduous forest began early in the Holocene. Subsistence strategies changed, often cyclically, until the Mid-Holocene when indirect evidence indicates agriculture became increasingly important and burning declined initially, shifting to vegetation commonly found in rice fields. The patterning and chronology of these data suggest that current models of agricultural development for the region need to be reevaluated. **KEYWORDS:** subsistence, palaeoenvironment, phytoliths, rice, burning, Thailand, Southeast Asia.