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Late-Holocene environmental variability at Munsa archaeological site, Uganda: a multicore, multiproxy approach

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Abstract: Palaeoenvironmental data, in the form of 113 counts of pollen, fungal spores and charcoal abundances, 121 counts of phytoliths and 15 AMS ^{14}C dates (11 macrofossil and 4 bulk sediment samples), have provided a means of reconstructing the late-Holocene environmental history of Munsa archaeological site, Uganda. The data were extracted from sediment cores from what is today a papyrus swamp, located within an area described by an outermost ring of earthworks at Munsa. Sediment core data indicate the general presence of forested conditions to *c.* AD 1100, although there is evidence for the local presence of food plants prior to this date. Deforestation from *c.* AD 1100 is marked in both the pollen and phytolith records, while fungal spores indicate the presence of increased numbers of herbivores post-deforestation. Indicators of deforestation and increased herbivore numbers broadly accord with the archaeological evidence for substantial occupation of the site at Munsa and the establishment of a mixed economy based on crops, cattle and iron working. Evidence for forest recovery and reduced herbivore numbers locally from *c.* AD 1780 could reflect abandonment of permanent settlement at the site, possibly during or following a period of drought and/or political upheaval in the region. Fungal spores and phytoliths provide evidence of agricultural activities at Munsa that have not left an imprint on pollen records, thus supporting the case for the use of multiproxies in palaeoenvironmental research, while intercore differences between the three sediment cores analysed, although relatively minor, confirm the benefits of a multicore approach. Tentative evidence for the very early presence of *Musa* (cultivated edible banana) is provided and warrants further study.

Key words: Africa, Uganda, archaeology, environmental variability, banana cultivation, charcoal, climate change, fire, fungal spores, pollen, phytoliths, late Holocene.

Introduction

Archaeologists attempting to understand the development of complex societies and associated socio-economic changes within what is today Uganda have focused on several major archaeological sites: the mounds and associated settlement debris at Ntusi (Reid, 1991, 1996; Sutton, 1993; Reid and Meredith, 1993); the salt-production site at Kibiro (Connah, 1996); the settlement and shrine sites of Mubende Hill and Kasunga (Robertshaw *et al.*, 1997; Robertshaw and Taylor, 2000) and the earthworks at Bigo and Munsa (Shinnie, 1960; Posnansky, 1969; Robertshaw, 1997; Robertshaw *et al.*, 1997, 2004). Data from excavations and associated surveys (Reid, 1991; Robertshaw, 1994; Connah, 1997), as well as historical linguistic research (Schoenbrun, 1993a,b), have resulted in several syntheses of the demographic, political and economic history of the region (Sutton, 1993; Schoenbrun, 1998; Robertshaw and Taylor, 2000). One focus of these syntheses has been the examination of interactions between environmental and socio-economic changes, such as changes in food production technologies and the rise of complex, hierarchical societies (e.g., Robertshaw and Taylor, 2000; Taylor *et al.*, 2000). Linking the palaeoenvironmental and archaeological evidence has proven problematic, however, in part because of the spatial separation of the various sources of evidence.

The research reported in this paper aims to solve the difficulties encountered in attempting to combine and interpret evidence from geographically and ecologically widely separated sources by providing new and comprehensive

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palaeoenvironmental data from a papyrus (*Cyperus papyrus* L.) swamp situated within the perimeter of a major archaeological site (Munsa) in Uganda. A reconstruction of late-Holocene environmental history is presented, based upon several proxies, encompassing the phase of occupation of Munsa with its evidence of iron working, human burials, food production and earthworks.

Location of the study site

Munsa is located in the southeastern part of the pre-colonial kingdom of Bunyoro, Uganda (Figure 1: 0°49′30″ N; 31°18′00″ E). The main basement rocks at Munsa are granite intrusions, argillites and quartzites of the Precambrian Bunyoro–Toro system (Harrop, 1970) that occasionally outcrop at the surface, forming isolated, rocky hills. Rainfall at Munsa is bimodal, with the onset, intensity and duration of the two wetter periods during the year determined by the solar-powered annual cycle of circulation over the Indian Ocean (Hastenrath *et al.*, 1993; Hastenrath, 2001). Rainfall is also influenced by irregularly occurring ENSO-related phenomena (Phillips and McIntyre, 2000). According to 68 years of rainfall data from the meteorological site at Masindi (the closest reliable meteorological station in the same climatic zone as Munsa (Atlas of Uganda, 1967), mean annual rainfall is 1330.5 mm. Excess rainfall in Bunyoro drains eventually into the Nile system, either directly or via lakes Albert and Victoria.

A patchwork of small farms, interspersed with remnants of Medium Altitude Semi-Deciduous Forest (*sensu* Langdale-Brown *et al.*, 1964), characterizes the sides of flat-topped outcrops of basement rocks, with intervening valley bottoms often occupied by papyrus swamps. Forest remnants include *Albizia* spp., *Celtis africana* Burm, *Ficus* spp., *Neoboutonia macrocalyx* Pax and occasionally *Sapium elipticum* (Horchst. ex Krauss) Pax. Patches of tall members of the Poaceae (elephant grass, *Pennisetum purpureum* Schumach. and guinea grass, *Panicum maximum* Jacq.) in association with shorter grasses such as spear grass (*Imperata cylindrical* Beauv.) may represent abandoned farmland, and an early stage in the recovery of forest. A range of perennial crops, such as banana, cassava and coffee, and annuals, e.g., beans and grains (mainly foxtail and finger millet, respectively *Setaria italica* (L.) Beauv. and *Eleusine coracana* (L.) Gaertn., maize, *Zea mays* L. and sorghum, *Sorghum bicolor* (L.) Moench), is cultivated. Cultivated bananas (varieties of the sweet banana, *Musa acuminata* Colla, and the cooking banana, *Musa paradisiaca* L. (both family Musaceae)) are also grown locally. Livestock, though valued, do not make a major contribution to food production; the main cattle-rearing areas are to the southwest and north.

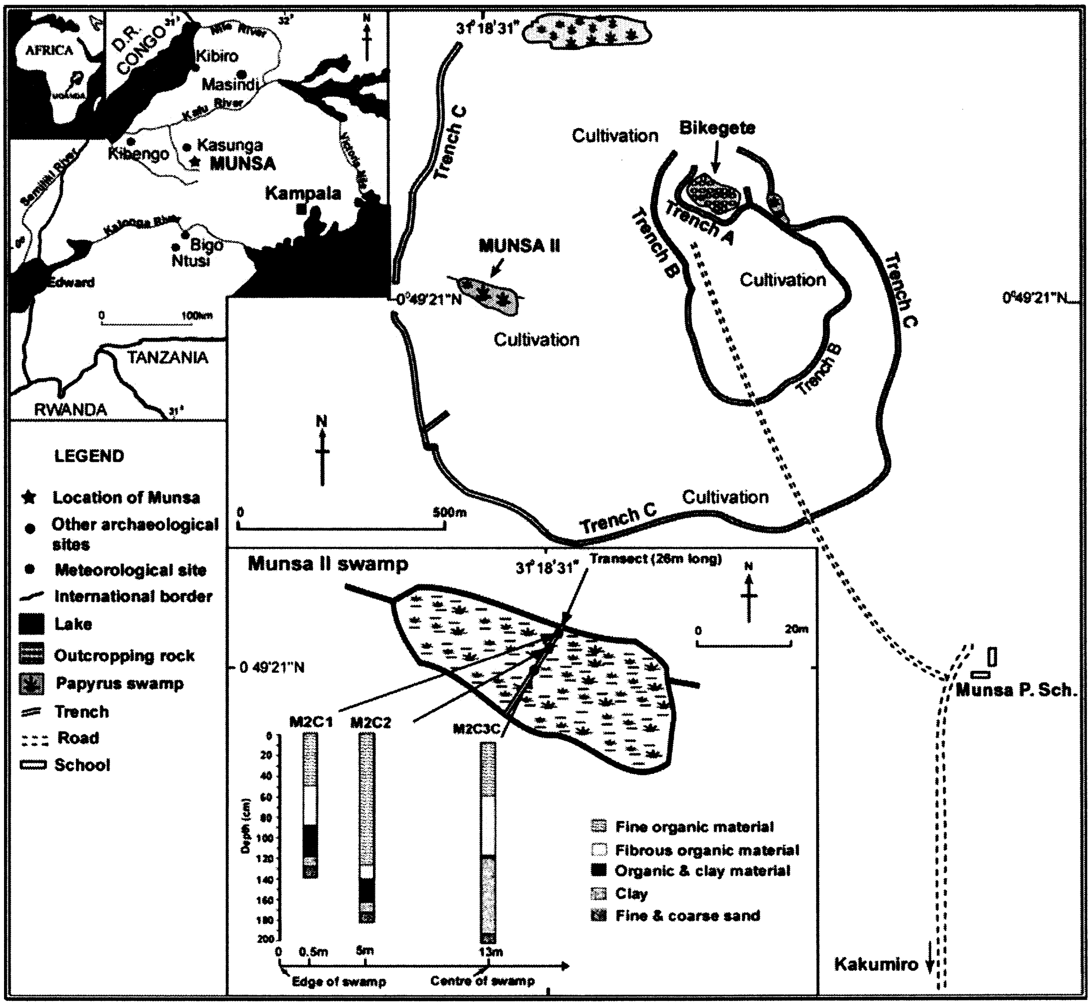

Figure 1 Map of Uganda showing the location of Munsa and other major archaeological sites mentioned in the text. The hill at Munsa (Bikegete) is set within concentric rings of earthworks (trenches) and cultivated land (after Lanning, 1955). The inset shows the coring sites for cores M2C1, M2C2 and M2C3C at Munsa II

Munsa archaeological site

The archaeological site at Munsa occupies about 1 km^2 of land ranging in altitude from 1220 m above mean sea level (a.m.s.l.) to the highest point (Bikegete, a granite outcrop) at 1340 m a.m.s.l. (Lanning, 1955). The site consists of settlement debris, burials, rock-shelters and evidence of iron working, grain storage and the consumption of cattle centred upon Bikegete and surrounded by three concentric rings of earthworks in the form of trenches. According to the archaeological evidence, a substantial human population occupied the site at Munsa towards the end of the first millennium AD. Early inhabitants participated in long-distance exchange networks: glass beads and a copper bangle adorn skeletons in burials that are associated with radiocarbon dates falling between about AD 900 and 1200 (Robertshaw, 1997). The glass beads must have reached Munsa via the Indian Ocean, since chemical analysis points to a South Asian origin for the glass (Robertshaw, Glascock and Wood, unpublished data, 2004), while a possible source of the copper bangle is the Katanga region, some 2000 km to the south.

Iron working, including at least one furnace on Bikegete, is particularly evident between about AD 1200 and 1400 (Robertshaw, 1997). Excavations at Munsa have yielded animal bones dominated by those of cattle, in addition to the remains of other animals (D.A.M. Reid, personal communication, 2004), together with numerous pits, almost certainly used initially for grain storage, as well as grindstones and pottery, all of which indicate cereal agriculture. Stable C isotope analyses of the human remains from Munsa further confirm the importance of cereals in the diet, particularly that of women (A. Ambrose, personal communication, 2004). The earthworks at Munsa appear to have been constructed sometime between about AD 1400 and 1650 (Robertshaw, 1997, 2001) and, as at other sites in Uganda (e.g., Bigo and Kibengo), their construction may relate to the emergence in the region of complex chiefdoms (Robertshaw, 1999a,b; Robertshaw and Taylor, 2000), founded upon agriculture but with some cattle, possibly kept primarily for prestige.

According to the limited archaeological evidence available, permanent settlement at Munsa ceased around the end of the seventeenth century AD or slightly earlier. Abandonment of Munsa may have been part of major economic, political and social upheavals that brought about a shift in settlement patterns from nucleated villages to dispersed homesteads. The settlement foci of chiefdoms appear to have become more peripatetic as their rulers put more emphasis on the size and health of their herds. Indeed, the origin of the class distinction between noble cattle-keepers and peasant agriculturalists, which typified the state-level societies encountered by early European visitors to central Africa in the mid-nineteenth century (e.g., Steinhart, 1981; for a description of the Nyoro state, see Beattie, 1971), probably dates to this period.

Field methods

This paper is based on a series of overlapping cores collected using a Livingstone (piston) corer from three locations along a transect at Munsa II, which is a relatively small swamp (*c.* 130 × 26 m^2) in the westernmost part of the archaeological site enclosed by Trench C (Figure 1). Cores M2C1 (130 cm long), M2C2 (177 cm long) and M2C3C (185 cm long) were collected, respectively, 0.5 m, 5 m and 13 m from the northern edge of the Munsa II swamp. Sediments in the cores generally consisted of 1–1.5 m of fibrous peat and dark-coloured organic-rich clays overlying paler clays and fine to coarse basal sand deposits.

Laboratory methods and results

Sediment chronology and δ^{13}C values

The chronological framework for Munsa II cores is based upon a total of 15 AMS ^{14}C-dated plant macrofossil (11 dates) and bulk sediment (four dates) samples: M2C1 (four dates); M2C2 (four dates); and M2C3C (seven dates). Full details of AMS ^{14}C ages for Munsa II are given in Table 1; calibrated dates (cal. BC/AD) were obtained using the computer programme Calib 4.4 and the calibration curve INTCAL 98 (Stuiver and Braziunas, 1993; Stuiver *et al.*, 1998). Dates from Munsa II quoted in the text are in the form of median calibrated ages BC/AD ($\pm 2\sigma$). All AMS ^{14}C ages are stratigraphically consistent and range from cal. 3220 BC for a bulk sediment sample close to the base of M2C3C to cal. AD 1770 for macrofossils from 30–31 cm in M2C1. Extrapolated and interpolated ages referred to in the text and on some of the figures (*c.*) are based on age–depth relationships for the three cores (Figure 2). According to the age–depth relationships, sediments in M2C1 and M2C2 contain records of past environmental conditions at Munsa for about, respectively, the last 2000 and 1250 years. Core M2C3C covers the longest time period, and appears to contain at least one major hiatus in sedimentation between the AMS ^{14}C dates of cal. 2000 BC (137–138 cm) and cal. AD 1110 (117–118 cm), and possibly a second above 30 cm. Macrofossils from 31–32 cm in M2C3C yielded a date of cal. AD 1400.

δ^{13}C values established along with AMS ^{14}C dates are within the range expected for C_3 or C_4 sources for organic carbon (Cerling, 1999). The most negative values, indicating a predominantly C_3 source (such as forest taxa) for organic carbon, are generally for clays from towards the base of the three cores. Less negative values are generally associated with the uppermost organic-rich sediments and appear to represent a C_4 source, such as papyrus. One exception is the relatively negative δ^{13}C value for macrofossils from 26–27 cm in M2C2 ($-22‰$), which indicates a significant contribution from a C_3 source or sources.

Subfossil pollen, spores, phytoliths and microcharcoal

Subfossil pollen and spore counts and charcoal data are available from a total of 113 core samples from Munsa II. Pollen and spores were concentrated following the standard procedure described by Faegri and Iversen (1989). An additional step involving 5% sodium hexamophosphate (Bates *et al.*, 1978) was included in order to concentrate pollen in M2C3C, because of the higher clay content of many samples from the core. Identification of pollen and fern spores was based largely on the reference collection of African pollen types in the Department of Geography at Trinity College Dublin. Fungal spores were identified according to van Geel (1978, 1982, 1986). The level of confidence in identification follows the system of Stockmarr (1971). Variations in abundances of microscopic charcoal in samples previously prepared for pollen analysis and including a known quantity of exotic (*Lycopodium*) spores were quantified using the point count method (Clark, 1982). Enumeration of charcoal was restricted to black, completely opaque and angular fragments with a long axis greater than 7.5 μm (Waddington, 1969; Clark, 1982; Patterson *et al.*, 1987; Clark, 1988).

Phytoliths were extracted from 121 core samples following a slightly modified version of the standard procedures described

Table 1 AMS ^{14}C dates and δ^{13}C ‰ values for Munsa II cores

Sediment core	Lab number	Depth (cm)	Conventional ^{14}C age (BP)	Calibrated (cal.) ^{14}C age [$\pm 2\sigma$]	Relative area under probability curve	Median cal. ^{14}C age (to nearest 10 years)	δ^{13}C value (‰)	Type of material dated
M2C1	Beta-185992	30–31	180±30	AD 1654–1695	0.195	AD 1770	– 14.3	Plant macrofossils
				AD 1725–1813	0.591			
				AD 1843–1876	0.038			
				AD 1917–1949	0.176			
M2C1	Beta-185993	50–51	750±40	AD 1212–1300	0.991	AD 1270	– 13.2	Plant macrofossils
				AD 1373–1378	0.009			
M2C1	Beta-185994	74–75	900±40	AD 1032–1217	1.000	AD 1120	– 26.0	Plant macrofossils
M2C1	Beta-185995	106–107	1590±50	AD 356–368	0.014	AD 480	– 26.8	Bulk sediment
				AD 381–599	0.986			
M2C2	Beta-185996	26–27	240±30	AD 1527–1554	0.054	AD 1660	– 22.4	Plant macrofossils
				AD 1632–1678	0.602			
				AD 1743–1748	0.006			
				AD 1759–1804	0.306			
				AD 1936–1947	0.032			
M2C2	Beta-175374	50–51	430±40	AD 1412–1521	0.901	AD 1460	– 13.4	Plant macrofossils
				AD 1586–1625	0.099			
M2C2	Beta-175375	105–106	700±40	AD 1244–1250	0.007	AD 1300	– 10.9	Plant macrofossils
				AD 1256–1327	0.691			
				AD 1346–1393	0.302			
M2C2	Beta-175376	134–135	940±40	AD 1019–1189	0.995	AD 1100	– 28.8	Plant macrofossils
				AD 1203–1206	0.005			
M2C3C	Beta-175370	31–32	540±40	AD 1307–1365	0.361	AD 1400	– 11.9	Plant macrofossils
				AD 1386–1440	0.639			
M2C3C	Beta-168965	45–46	560±40	AD 1303–1368	0.523	AD 1370	– 15.6	Plant macrofossils
				AD 1383–1433	0.477			
M2C3C	Beta-175371	74–75	670±40	AD 1277–1330	0.493	AD 1340	– 24.4	Plant macrofossils
				AD 1342–1396	0.507			
M2C3C	Beta-168965	102–103	850±40	AD 1042–1092	0.131	AD 1200	– 27.8	Bulk sediment
				AD 1118–1140	0.065			
				AD 1154–1276	0.803			
M2C3C	Beta-175372	117–118	910±40	AD 1030–1211	1.000	AD 1110	– 23.9	Plant macrofossils
M2C3C	Beta-185997	137–138	3640±40	2136–2079 BC	0.202	2000 BC	– 23.5	Bulk sediment
				2066–1891 BC	0.798			
M2C3C	Beta-175373	162–163	4560±40	3492–3469 BC	0.042	3220 BC	– 23.8	Bulk sediment
				3373–3261 BC	0.390			
				3241–3100 BC	0.567			

The AMS dates were calibrated using the INTCAL 98 Radiocarbon Age Calibration and the computer programme Calib 4.4.

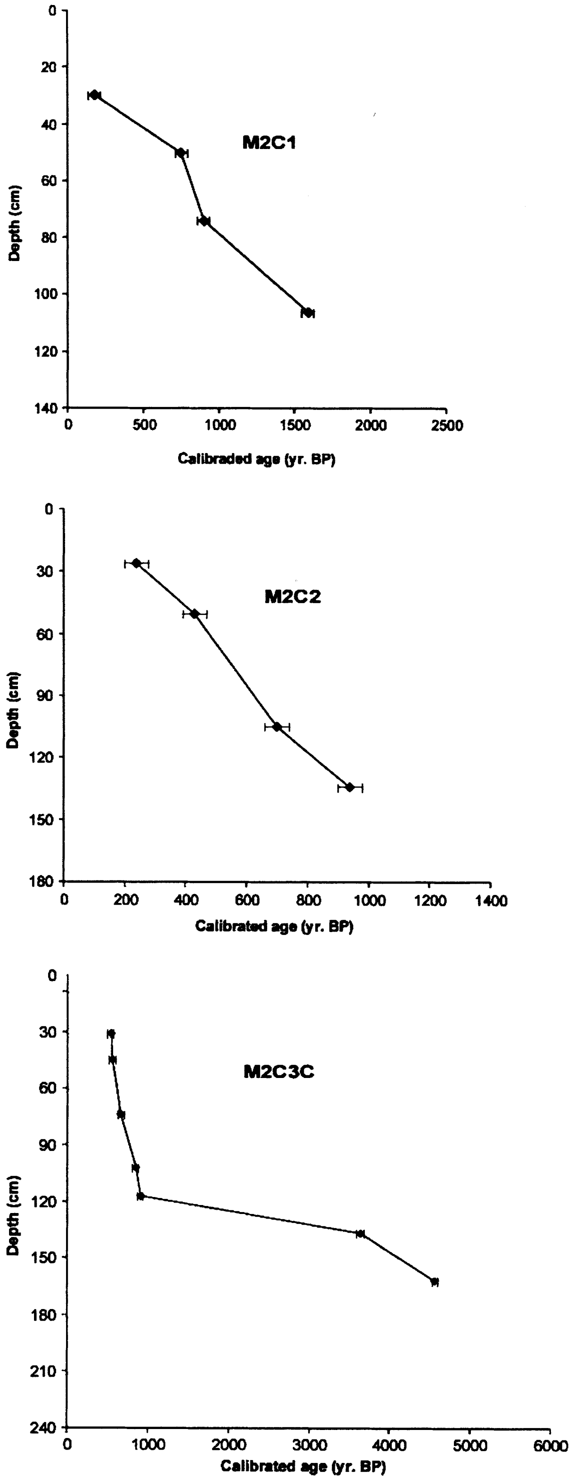

Figure 2 Age–depth curves for cores M2C1, M2C2 and M2C3C (see Table 1 for full details of ^{14}C AMS dates used in the construction of the curves)

Table 2 Plants found in the catchment for Munsa II and used as a source of type phytolith material

Cultivated variety	Non-cultivars/trees/shrubs/ grasses
Cajanus cajan (L.) Millsp. (pigeon pea)	*Commelina bengalensis* L.
Dioscorea villosa L. (yam)	*Cymbopogon afronadus* L.
Eleusine coracana (L.) Gaertn. (finger millet)	*Cyperus papyrus* L.
Ensete ventricosum (Welw.) E.E. Cheesman (wild or false banana)	*C. rotundus* L.
Ipomoea batatas (L.) Lam. (sweet potato)	*Dombeya goetzenii* L. Schum
Musa acuminata Colla (sweet (edible) banana)	*Erythrina abysinica* Lam. Ex. DC
Musa paradisiaca L. (cooking banana)	*Ficus asperifolia* Miq
Nicotiana tabacum L. (tobacco)	*F. ovata* Vahl.
Phaseolus vulgaris L. (common bean)	*Hyparrhenia rufa* (Nees) Stapf
Ricinus communis L. (castor bean)	*Imperata cylindrica* (L.) Palisot
Sorghum bicolor (L.) Moench (sorghum)	*Lantana trifolia* L.
Zea mays L. (maize)	*Miscanthus violaceus* K. Schum Pilg
	Ocimum suave Wild
	Panicum maximum Jacquin
	P. ratifolia (authority unknown)
	P. trichocladum K. Schum
	Paspalum scrobiculum, L.
	Pennisetum purpureum Schumach.
	Phoenix reclinata Jacq.
	Sapium elipticum (Hochst. Ex. Krauss) Pax
	Sesbania sesban (L.) Merrill
	Setaria sphacelata (Schumach.) Stapf
	Sorghum arundinaceum (Desv.) Stapf (wild sorghum)

in Piperno (1988) and Pearsall (2000). Phytolith morphotypes were identified according to Twiss *et al.* (1969), Rover (1971), Piperno (1988, 2001), Mbida *et al.* (2001), Denham *et al.* (2003), Vrydaghs and De Langhe (2003) and Carol Lentfer (personal communication, 2004), through the collection of type material at the Royal Museum of Central Africa and on the basis of voucher material extracted from specimens collected in the study area (Table 2). A wide range of voucher material was collected from the study area, including several plants that are of economic importance locally but are not usually recorded in pollen records. The latter is the case with cultivated members of the Musaceae (banana family).

Musaceae is today mainly represented in Africa by two genera; *Musa* and *Ensete* (Rossel, 1994–95). It is generally thought that *Musa*, which includes the cultivated, edible banana and plantains, was introduced to Africa from Asia. Varieties of *Musa acuminata*, as with other edible bananas in Africa, are seedless and therefore reproduce asexually via the production of suckers (ramifications of the rhizome). The genus *Ensete*, or false banana, is native to eastern, central and southern Africa. *Ensete* is widely cultivated in Ethiopia; Rossel (1994–95: 144) also reports that *Ensete* is collected as a food plant from the wild in central and eastern Africa. Additionally, parts of both *Musa* and *Ensete* (the fibres, stems and leaves) are widely used for binding and wrapping other objects, as a source of salt, in the production of soap and for various medicinal purposes (Rossel, 1994–95: 143).

Morphological criteria for distinguishing Musaceae leaf phytoliths and for discriminating between *Musa* and *Ensete* are provided in Mbida *et al.* (2001) and Vrydaghs and De Langhe (2003). Both *Musa* and *Ensete* produce chains of cone-shaped phytoliths that fragment into individual bodies comprising a base and a raised cone with a crater, or trough, at the summit. In *Musa* the cone has concave slopes in equatorial view and a saddle-shaped crater containing up to one indentation. Under SEM the surface of the cone appears verrucate (with wart-like sculpturing), although it appears smooth under an optical microscope, while the rim of the crater appears smooth to crenate (with rounded teeth). The form of the base in polar view also provides a means of distinguishing *Musa*: the base usually supports obvious protuberances along all sides, and SEM reveals the base to have verrucate sculpturing. According to Carol Lentfer (personal communication, 2004), there is some overlap in morphology of the base of phytoliths produced by Asian (New Guinean) *Musa* and *Ensete glaucum* (Roxb.) Cheesman. However, *Ensete glaucum* is not native to Africa, and phytoliths from African members of the *Ensete* genus possess a base without protuberances, a cone with convex slopes in equatorial view and verrucate sculpturing visible under both optical and SE microscopes. Furthermore, the crater is flat (i.e., not saddle-shaped), without crenations but with two to three indentations. Although it seems possible to distinguish phytoliths produced on the leaves of *Musa* plants from those produced on the leaves of *Ensete*, no obvious intragenus morphological differences exist (and see Mbida *et al.*, 2004). Figure 3A, C, E and F shows examples of leaf phytoliths extracted from voucher specimens of members of the Musaceae: also shown is Musaceae-type subfossil material extracted from Munsa II sediments (Figure 3B, D, G and H). Figure 3I shows a leaf phytolith from a voucher specimen of *Zea mays*, with its distinctive cross-shaped morphology, while Figure 3J shows subfossil material from the same taxon.

Down-core variations in subfossil data were zoned according to differences in pollen content apparent in the results of ordination analysis (detrended correspondence analysis, DCA), which involved use of the computer program CANOCO (ter Braak and Smilauer, 1998). The ordination results for DCA axes 1 and 2 are displayed in Figure 4. Three major groups (pollen zones) are recognizable across the three cores analysed (Z1–Z3), although they are most distinct for core M2C1, which was located closest to the margins of Munsa II swamp. The groups are least distinct for core M2C3C, which also yielded a fourth group of samples (Z0) from the lowermost part of the core. Down-core variations in subfossil data, together with the boundaries of the pollen zones Z0–Z4, are shown on Figures 5–10 and described below.

Pollen zone Z0 is least well-represented and the most imprecisely dated of the four pollen zones. It is approximately dated in core M2C3C from pre cal. 3220 BC to between cal. 2000 BC and cal. AD 1110. Preservation was generally very poor in the samples comprising Z0, which were largely inorganic, although the pollen and spores that are present indicate the occurrence of forest in the catchment for Munsa II. The low amount of charcoal in these samples suggests that fires were relatively rare events. The boundary between Z0 and Z1 in M2C3C lies within a part of the core that failed to yield pollen data and may coincide with the location of the hiatus mentioned previously. Indeed, differences in pollen assemblages between Z0 and Z1 in M2C3C are probably mainly due to differential preservation.

Pollen zone Z1 is dated > *c.* AD 0 to *c.* AD 1100 in M2C1, > *c.* AD 700 to AD 1220 in M2C2, and > cal. AD 1110 to *c.* AD 1240 in M2C3C. The zone represents the continued occurrence of forest in the catchment for Munsa II, prior to the development of a papyrus-dominated swamp, with relatively little burning of vegetation locally. The zone is characterized by relatively high proportions of pollen (> 50% of the pollen sum) from taxa that are today associated with Medium Altitude Semi-Deciduous Forest, such as *Alchornia*, *Celtis*, *Croton*, *Neoboutonia*, *Olea*, *Podocarpus* and *Teclea*. Relatively small amounts of *Acalypha* and Poaceae characterize non-arboreal pollen counts. *Ustulina* dominates fungal spore counts: *Ustulina* causes soft-rot of dead wood (van Geel, 1986).

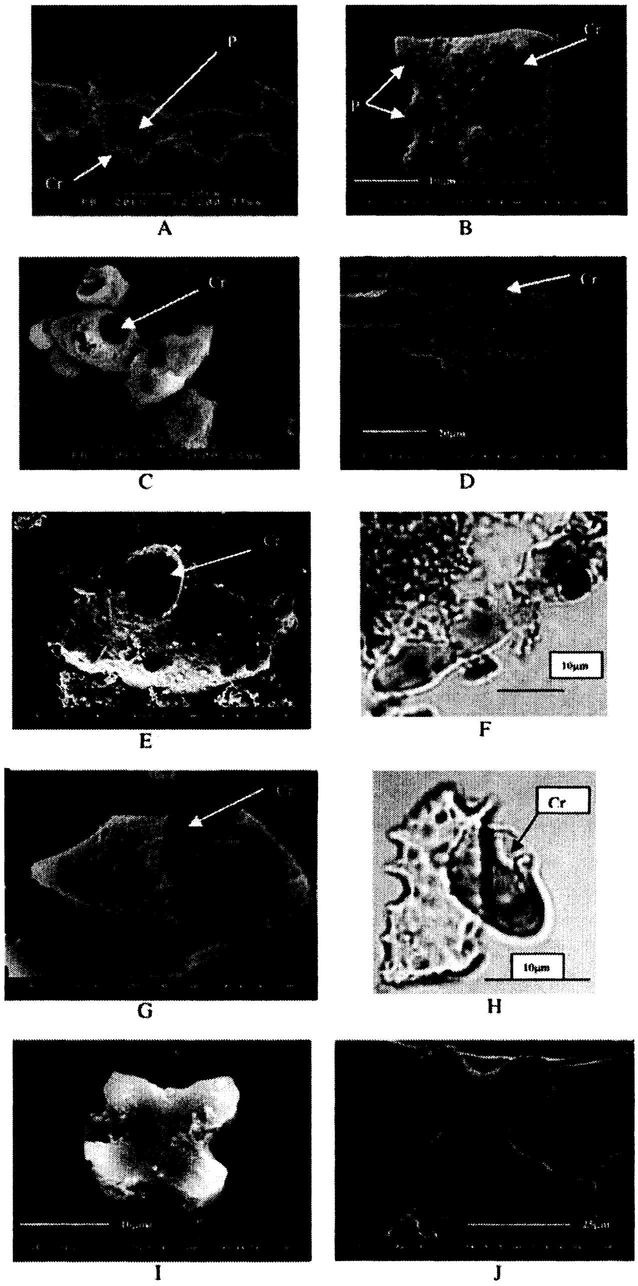

Figure 3 SEM and light micrographs of phytolith morphotypes. A. SEM: equatorial view of chain of *Musa paradisiaca* L. (type material) phytolith morphotype showing crater (Cr) and projections (P); B. SEM: polar view of individual subfossil phytolith of *Musa* sp. (*c.* AD 1050) showing rectangular shape base with projections on the sides (P). The raised surface is smoothly verrucate and supports a crater at the summit (Cr); C. SEM: *Ensete ventricosum* (Welw.) E.E. Cheesman (type material) morphotype. The arrow indicates the crater; D. SEM: subfossil phytolith of *Ensete* sp. (*c.* AD 1050) showing crater (Cr) and verrucate sculpturing; E. SEM: phytolith from type material of *Musa acuminata* Colla showing crater (Cr); F. light micrograph (× 400) of chain of phytoliths from *Musa acuminata* Colla (type material); G. SEM: subfossil phytolith of *Ensete*-type, > cal. 3220 BC; H. light micrograph (× 400): subfossil phytolith of *Musa*-type, > cal. 3220 BC; I. SEM: variant 1 cross-shaped morphotype of *Zea mays* L. (type material); J. SEM: variant 1 cross shaped micrograph of subfossil phytolith of *Zea mays* (cal. AD 1780)

Phytolith counts are available for sediment samples in Z0 and Z1 (Figures 7 to 10). Generally phytoliths resembling

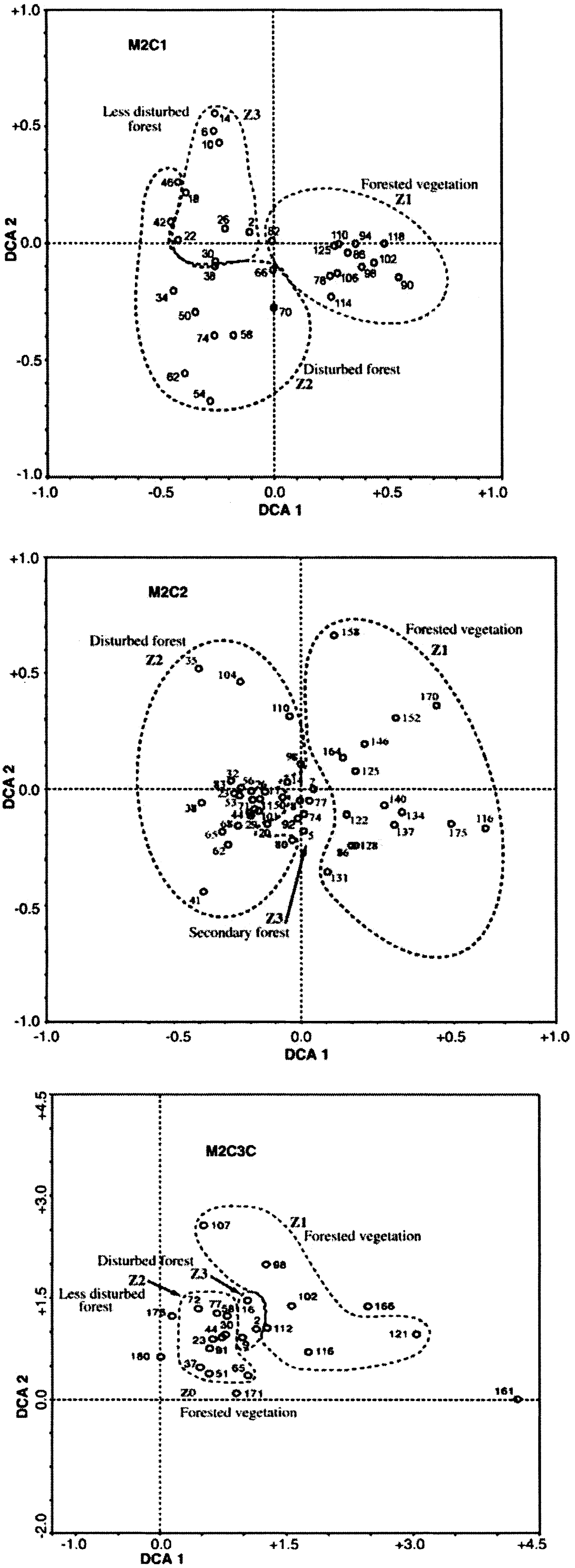

Figure 4 Ordination bi-plots for pollen samples from three Munsa II cores. Bi-plots show results for axes 1 and 2: samples placed close together according to axes 1 and 2 have a similar pollen content, while those placed further apart are more dissimilar (Kent and Coker, 1992)

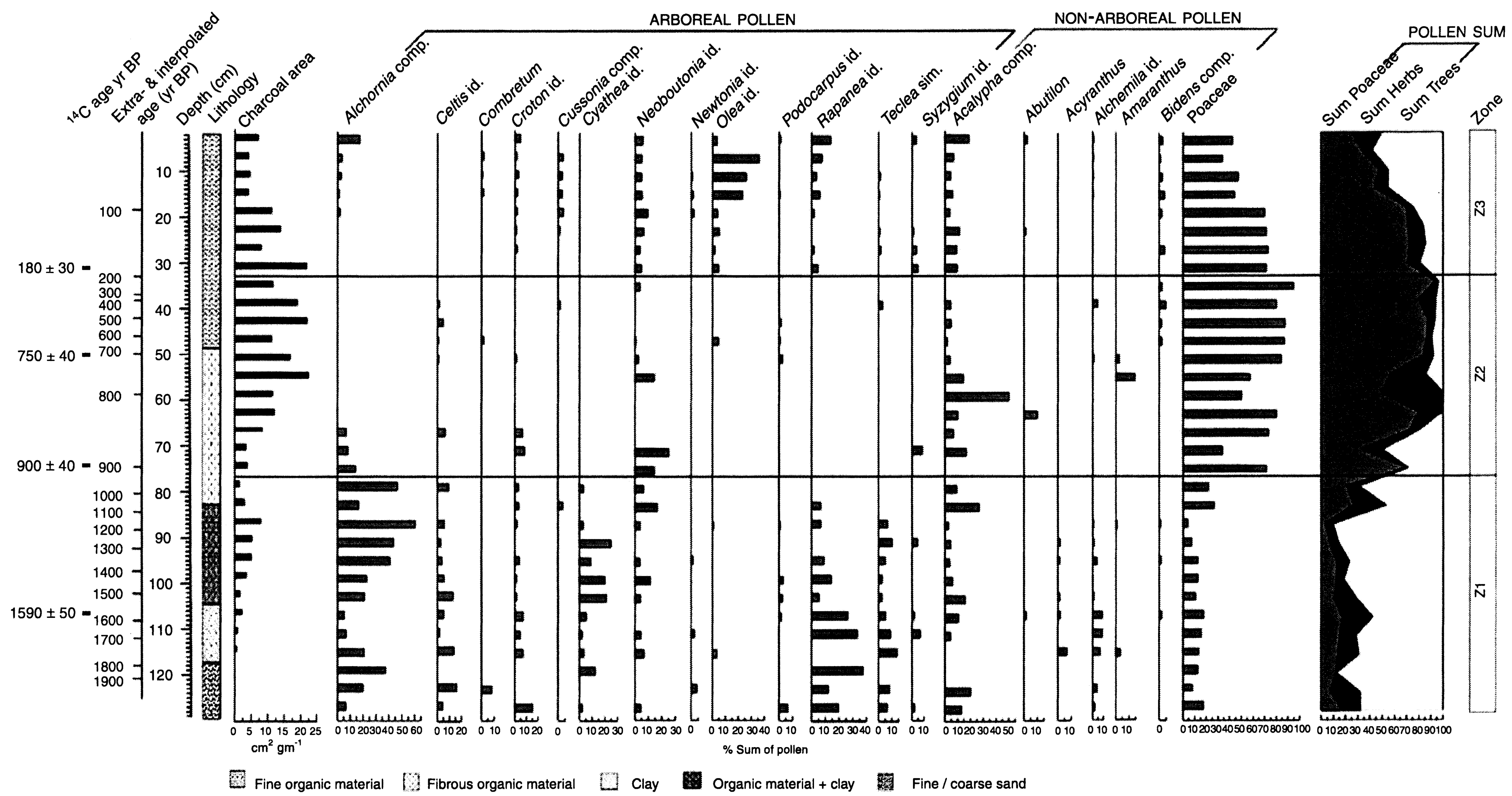

Figure 5 Summary of down-core variations in abundances of major subfossil pollen taxa, excluding Cyperaceae and filicales, and charcoal for core M2C1. A total of 32 samples were analysed; pollen counts ranged from 503 to 746 (mean = 544) grains per sample

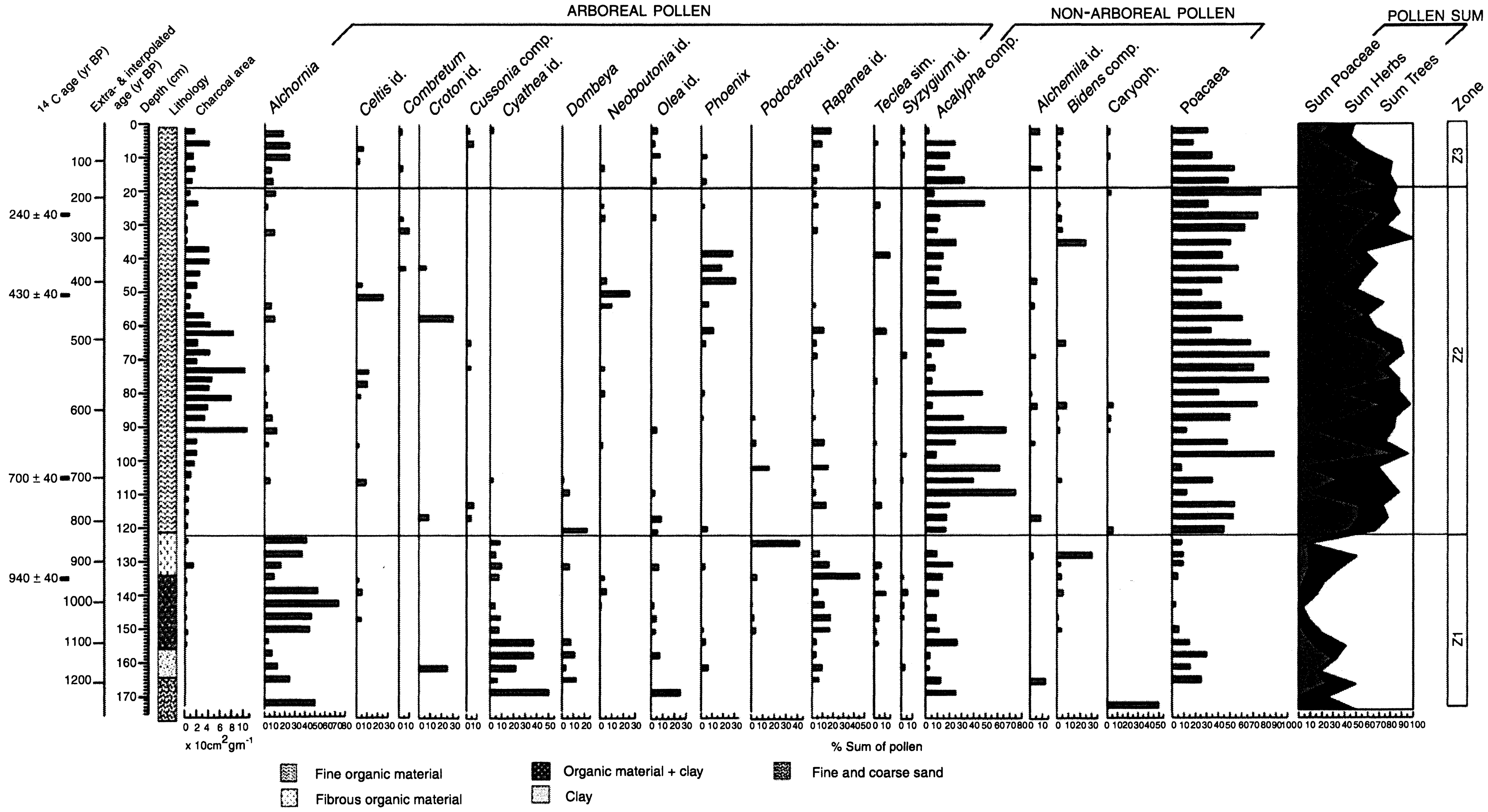

Figure 6 Summary of down-core variations in abundances of major subfossil pollen taxa, excluding Cyperaceae and filicales, and charcoal for core M2C2. A total of 49 samples were analysed; pollen counts ranged from 495 to 525 (mean = 510) grains per sample

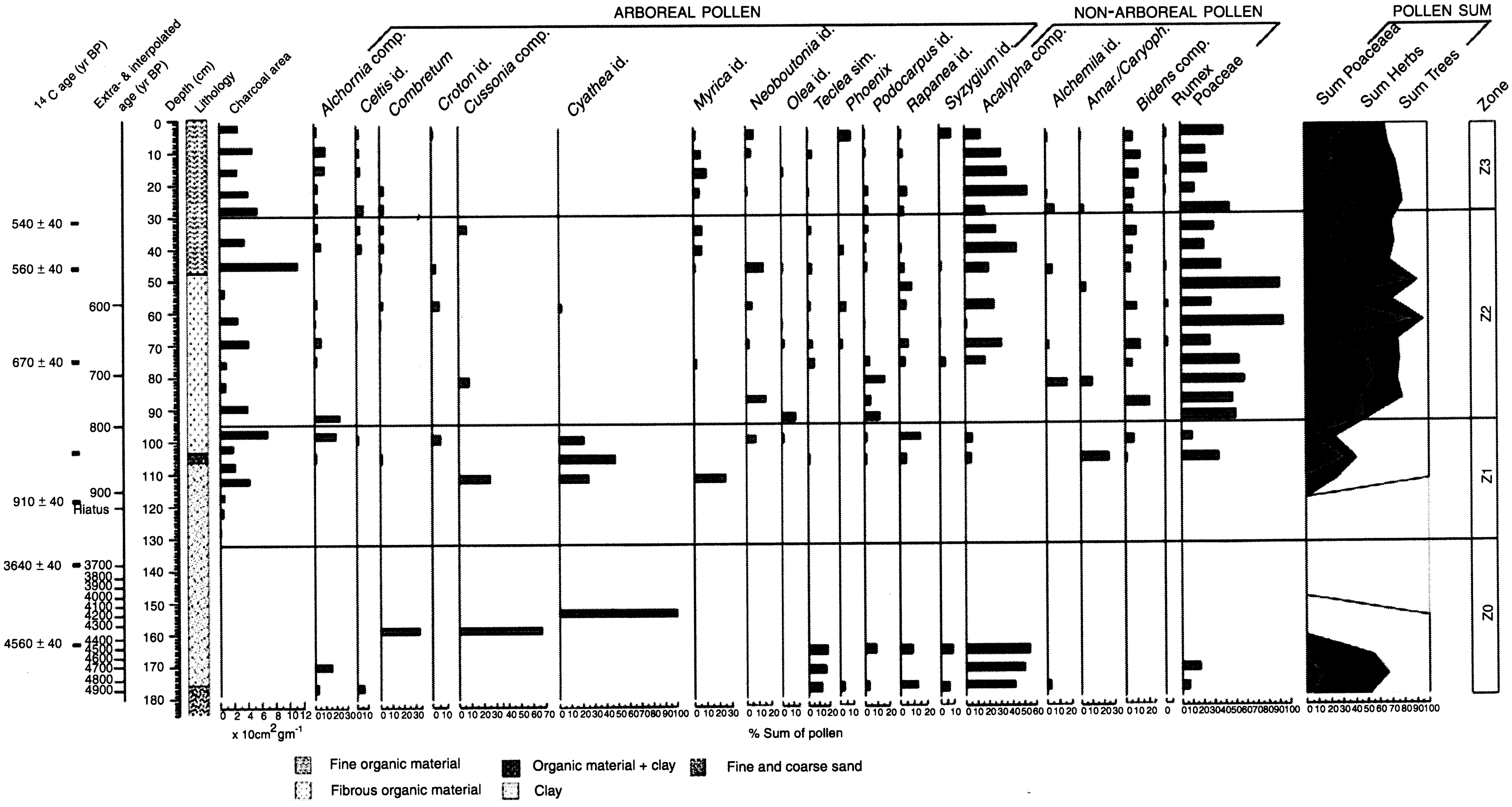

Figure 7 Summary of down-core variations in abundances of major subfossil pollen taxa, excluding Cyperaceae and filicales, and charcoal for core M2C3C. A total of 32 samples were analysed; pollen counts ranged from 496 to 1849 (mean = 585) grains per sample. (Hiatus = possible location of a break, or breaks, in sedimentation (see text for more details))

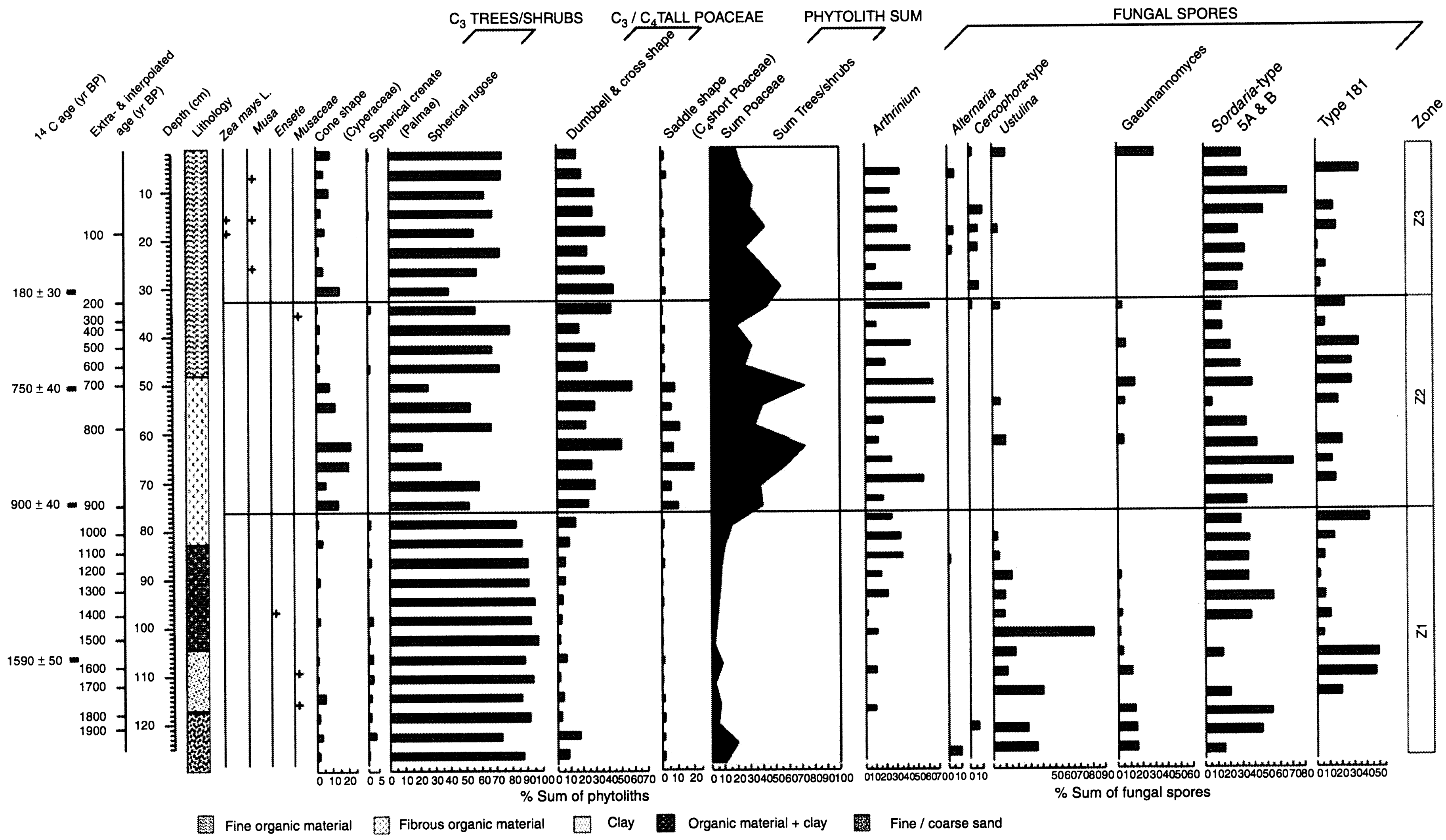

Figure 8 Summary of down-core variations in abundances of subfossil phytoliths and fungal spores for core M2C1. 32 samples were analysed for their phytolith content; counts ranged from 503 to 582 (mean = 544) phytoliths per sample. 32 samples were analysed for their fungal spore content, with counts ranging from 205 to 211 (mean = 209) spores per sample

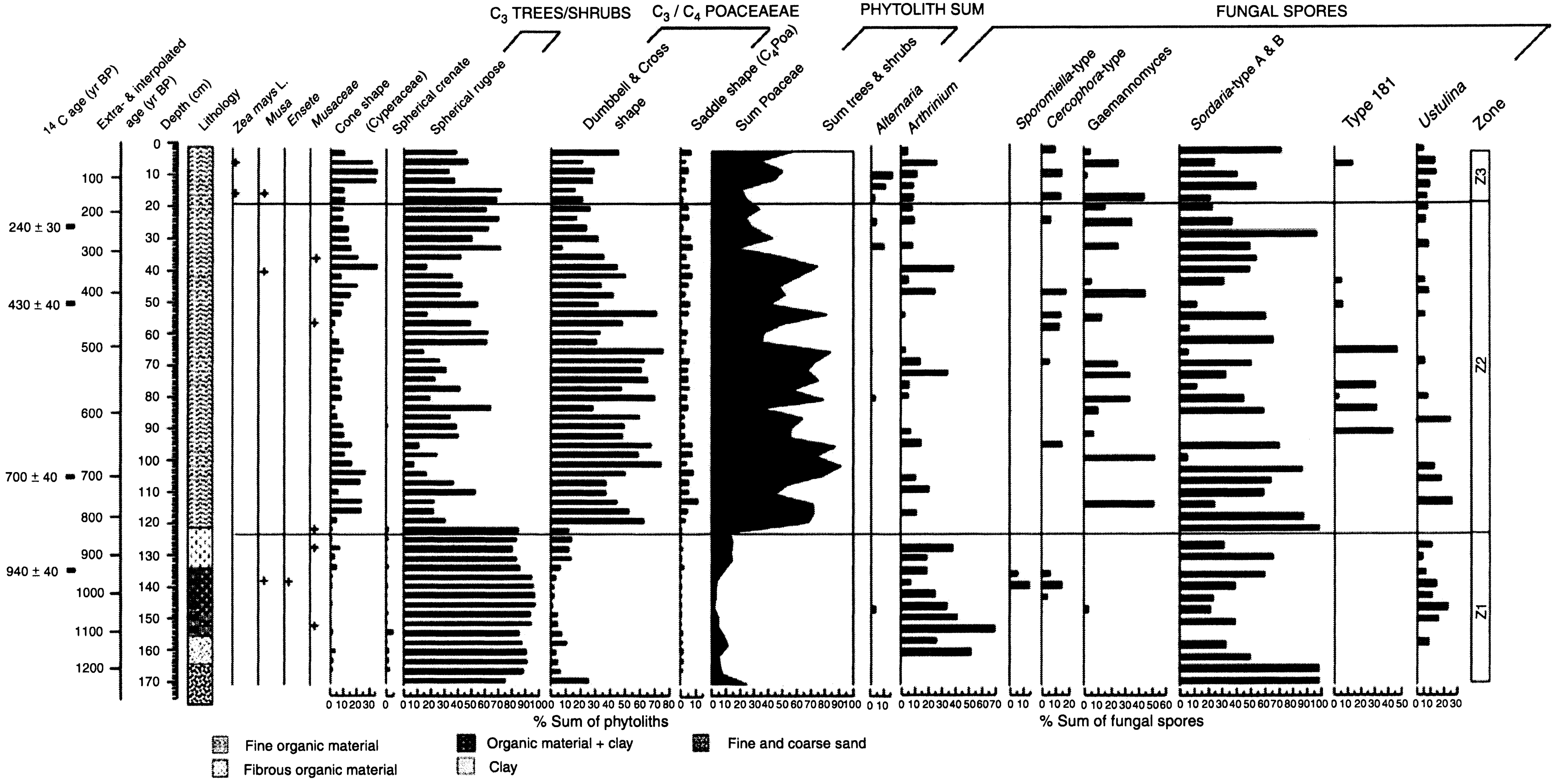

Figure 9 Summary of down-core variations in abundances of subfossil phytoliths and fungal spores for core M2C2. 57 samples were analysed for their phytolith content; counts ranged from 506 to 759 (mean = 577) per sample. 49 samples were analysed for their fungal spore content, with counts ranging from 210 to 223 (mean = 205) spores per sample

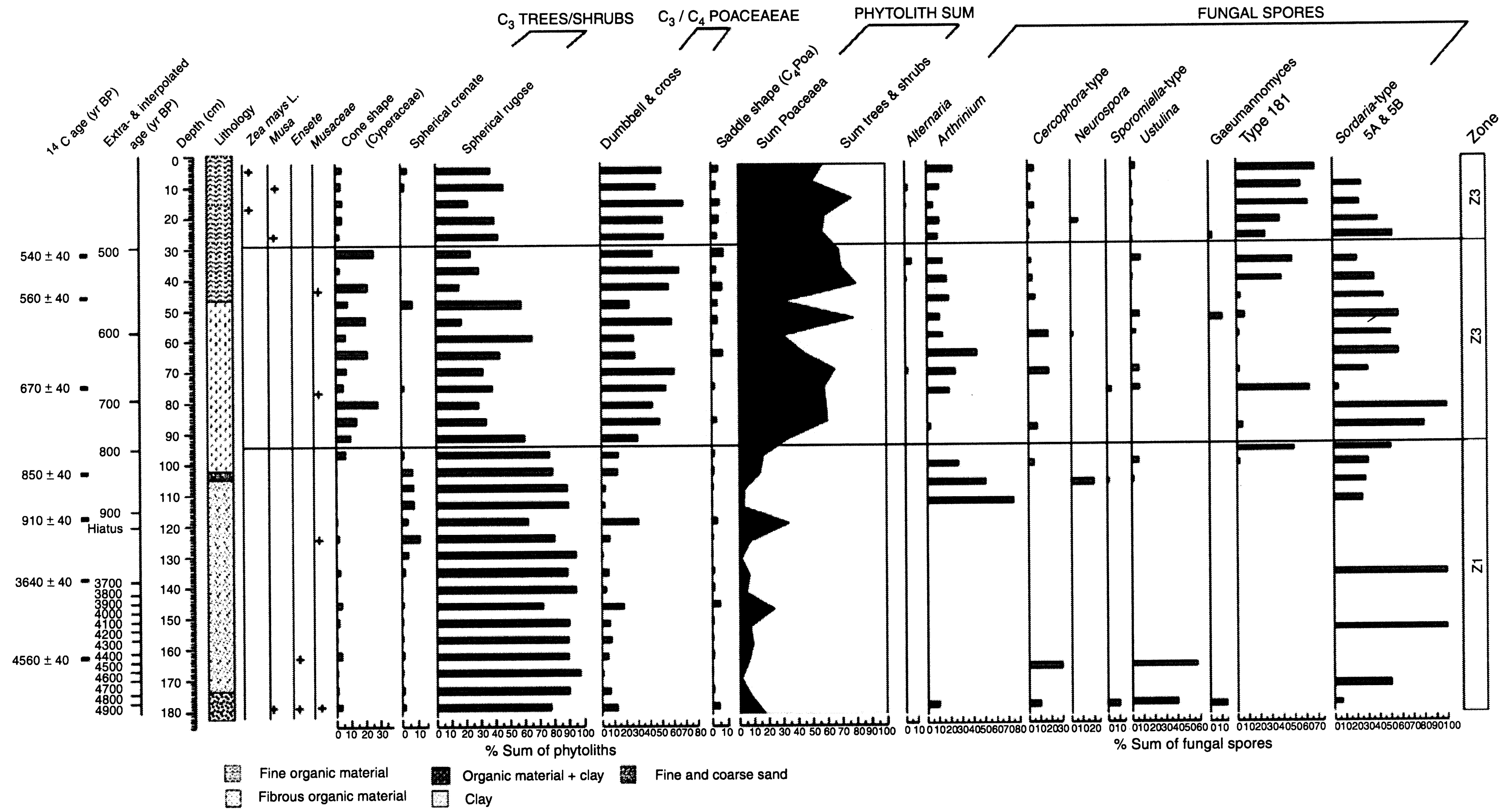

Figure 10 Summary of down-core variations in abundances of subfossil phytoliths and fungal spores for core M2C3C. 32 samples were analysed for their phytolith content; counts ranged from 540 to 1180 (mean = 573) per sample. 32 samples were analysed for their fungal spore content, with counts ranging from 200 to 340 (mean = 271) spores per sample. (Hiatus = possible location of a break, or breaks, in sedimentation (see text for more details))

those produced by forest taxa (spherical rugose morphotypes) are abundant, thus supporting the pollen evidence for the presence of forest in the catchment. The proportions of morphotypes associated with members of the Palmae (spherical crenate) and C_4 members of the Cyperaceae (cone-shaped) are very low, as are Cyperaceae pollen counts (not shown). Poaceae morphotypes are also poorly represented. Phytoliths with morphologies similar to those of *Musa* and *Ensete* were occasionally recorded in samples dating to Z0 and Z1. Significantly, the basal sample analysed from core M2C3C (i.e., from Z0 and older than cal. 3220 BC), yielded a total of 14 Musaceae-type phytoliths. Of these, eight were identified as *Musa*-type (size range: long axis = 6–12 μm, short axis = 6–8 μm) and three were identified as *Ensete*-type (size range: long axis = 10–24 μm, short axis = 6.5–12 μm) (see Figure 3E and F). Three could not be identified below Musaceae.

Charcoal concentrations are generally very low, reflecting a low incidence of burning, although they increase from *c.* AD 650 in M2C1.

Pollen zone Z2 is dated *c.* AD 1100 to *c.* AD 1780 in M2C1, *c.* AD 1220 to *c.* AD 1780 in M2C2, and *c.* AD 1240 to < cal. AD 1400 in M2C3C. According to the pollen and spore data, the zone represents the replacement of forest with more open forms of vegetation, superimposed upon which were relatively minor phases of forest recovery. Spores of the fungi *Ustulina* decline relative to Z1; counts in the lower part of Z2 are instead dominated by fungal spores from *Cercophora* and *Sporomiella*, which today are associated with the dung of herbivores (van Geel, 1982, 1986; Davies, 1987). The phytoliths show similar fluctuations to the pollen; varying though generally lower abundances of spherical rugose morphotypes than Z0 and Z1 reflect a significant reduction in the extent of forest around Munsa, interrupted by phases of forest recovery. The abundances of Cyperaceae phytoliths and pollen increase in this zone, representing the occurrence of papyrus-dominated swamp at the coring sites, as does the dumbbell bilobate morphotype of tall members of the Poaceae (both C_3 and C_4 types). Phytoliths with morphological similarities to Musaceae are absent from the lower part of this zone and only reappear after *c.* AD 1290. Increased abundances of charcoal overall suggest that fires were associated with the reduction in forest cover.

Pollen zone Z3 is dated from *c.* AD 1780 in M2C1 and M2C2 to the present. The zone occurs above an AMS ^{14}C date of cal. AD 1400 in M2C3C, where, according to the AMS ^{14}C age–depth relationship, at least part of the zone appears to be missing. Z3 represents some recovery of forests around Munsa and a reduced importance of burning. Pollen and spore assemblages are marked by increases in pollen and spores from taxa associated with Medium Altitude Semi-Deciduous Forest and some form of riverine/swamp forest in the area today, including *Alchornia*, *Combretum*, *Cyathea*, *Olea* and *Rapanea*, together with a concomitant decline in pollen from non-arboreal sources, notably *Acalypha* and Poaceae. The fungal spore and phytolith data provide further evidence of forest recovery, while reduced abundances of charcoal indicate a decreased importance of vegetation fires. Spores of *Cercophora* and *Sporomiella* become scarce, while those of *Ustulina* become more abundant. Phytoliths produced by forest taxa are common, although less so in M2C3C, while those representing members of the Poaceae are less abundant than in zone Z2. Also sporadically present in this zone are phytoliths from members of the Musaceae and, for the first time in the sequences from Munsa, maize.

Discussion

Sediment-based proxies from Munsa II provide a record of environmental history that extends from before cal. 3220 BC to the present. The record is discontinuous, however, and intercore variations, though relatively minor, exist. The record is most continuous and reliable for the last *c.* 1000 years, which incorporates the main period of occupation of the Munsa site according to the available archaeological evidence.

Intercore comparisons

Despite the close proximity of the coring sites for M2C1, M2C2 and M2C3C, intercore comparisons of sedimentary evidence reveal several inconsistencies. For example, a gradient of sensitivity is apparent from M2C1 (least complacent/most responsive), which is closest to the margin of the swamp, to M2C3C (most complacent/least responsive): deforestation is detected in M2C1 (*c.* AD 1100) before M2C3C (*c.* AD 1240). Similarly, forest recovery during the mid to late eighteenth century AD is recorded at M2C1 and M2C2, but is less evident at M2C3C, presumably because of a hiatus in sedimentation and a stronger signal from local vegetation towards the centre of the swamp. A second example concerns the time-transgressive onset of papyrus-dominated swamp conditions at the three coring sites, beginning at M2C1 *c.* AD 1000 and overwhelming the centre of the swamp at M2C3C by *c.* AD 1200. It is likely that the spread of papyrus was influenced by reduced discharge from the valley and may thus represent the onset of lower levels of effective precipitation in the study area. The process could have been triggered or accelerated by the impeding of drainage; one possible cause of the latter, given the timing of spread of papyrus swamp conditions at the coring sites, was the blocking of the outlet from Munsa II as a result of the accumulation of soils eroded from surrounding hillsides cleared of their vegetation cover.

Environmental conditions before *c.* AD 1100

Sediment-based evidence from Munsa II attests the local presence of forested conditions from before cal. 3220 BC to shortly after the beginning of the second millennium AD. The local presence of food plants is indicated by the occurrence of phytoliths produced by members of the Musaceae (both *Musa* and *Ensete*). Cultivation of bananas could have been taking place on forest margins and within relatively small forest gaps in the period preceding the main occupation phase at Munsa, although plants found naturally within surrounding areas of forest could have produced the phytoliths identified as *Ensete*. The present-day range of *Ensete ventricosum* (Welw.) E.E. Cheesman, which occurs in forested ravines and riparian forest between 1000 m and 3000 m a.m.s.l., extends north from the northern shoreline of Lake Victoria (De Langhe *et al.*, 1994–95). Phytoliths resembling *Musa* were encountered at the base of the record from Munsa II, and thus predating by a considerable length of time the earliest empirical evidence of the genus in Africa: phytoliths, believed to be from *Musa*, were recovered from a pit deposit at an archaeological site in Cameroon from which a piece of charcoal yielded a ^{14}C date of cal. 610 BC (Mbida *et al.*, 2000, 2001, 2004).

There is still much debate over whether *Musa* was in fact introduced from Asia, where the earliest date for its cultivation (possibly pre-*c.* 4880 BC) is from the highlands of New Guinea (Denham *et al.*, 2003) and, if it was, the date of its introduction. There is some evidence that several plant domesticates of African origin were cultivated in India more than 3500 years ago (Fuller, 2003), while the bones of chicken (an Asian domesticate) and other indications of ancient links between eastern Africa and Asia and the Middle East have reportedly been found on Zanzibar in cave deposits that predate the Early Iron Age (Chami, 2001). Presumably if *Musa* was introduced, then the date of its introduction could be at least as early as this archaeological evidence of contact between Asia and Africa. Indeed, De Langhe *et al.* (1994–95) suggest that it is conceivable that *Musa* reached the coastline of eastern Africa more than 3000 years ago, from where it was transported throughout much of intertropical Africa. This early date concurs with the genetic diversity of edible bananas in Africa today (about ten times the number in Asia) (Rossel, 1994–95), and with the phytolith evidence from Cameroon, although Vansina (2004) has recently cast doubt on the latter while re-emphasizing that genetic diversity among African varieties of edible bananas today could be due to an increased likelihood of mutations because of their intensive cultivation over large parts of the continent. According to Rossel (1994–95:144), the northern shoreline of Lake Victoria was the most likely transportation route from the coast into interior Africa because extensive tracts of arid and semi-arid conditions elsewhere would have presented a formidable barrier. Clark (1976) and De Langhe *et al.* (1994–95) have also suggested that the spread of *Musa* cultivation may have been facilitated by an existing familiarity with *Ensete* as a source of food. Thus, it is conceivable that cultivation of *Musa* commenced in the study area at an early date. It is possible, however, that the two oldest AMS ^{14}C dates so far obtained for Munsa sediments are erroneous, although we see no reason why this should be the case, and therefore that the Musaceae phytoliths at the base of M2C32 are younger than indicated. An alternative explanation is that the morphological criteria used to discriminate between *Musa* and *Ensete*, and even to distinguish Musaceae, are not sufficiently resolved (Vansina, 2004). Clearly the identification and dating of Musaceae phytoliths at Munsa, and elsewhere in Africa, require further study.

Climatically the period to *c.* AD 1100 accommodates a transition to drier conditions that commenced in the mid-Holocene and that appears to have been widely felt in central and eastern Africa (Nicholson and Flohn, 1980; Gasse, 2000, 2002; de Menocal *et al.*, 2000; Russell *et al.*, 2003a; Stager *et al.*, 2003), although there is little evidence of such a trend in basal sediments at M2C3C.

Environmental conditions after *c.* AD 1100

The onset of deforestation and concomitant increased burning *c.* AD 1100, and their coincidence with the earliest phase of occupation of the site at Munsa, suggest a significant role for humans in driving vegetation change. Major clearance of mid-altitude forest at Munsa appears to have commenced about the same time as around Lake Kasenda (Ssemmanda *et al.*, 2005), but somewhat earlier than around Kabata Swamp where it followed evidence of increased burning (Taylor *et al.*, 1999, 2000). Since Lake Kasenda and Kabata Swamp are both located *c.* 140 km to the west of Munsa, deforestation and associated burning appear to have been widespread in western Uganda early in the second millennium AD. The timing of deforestation in western Uganda corresponds with archaeological data from excavations (Reid, 1991; Sutton, 1993; Robertshaw, 1997) and surveys (Reid, 1991; Robertshaw, 1994), as well as with historical linguistic evidence (Schoenbrun, 1993b, 1998), all of which indicate that there was considerable immigration to the region at this time by people who were reliant on cattle and food plants and thus demanding of land for farming (see also Taylor *et al.*, 2000).

The expansion of farming around the beginning of the second millennium AD, associated with the Later Iron Age, seems to have been relatively rapid, widespread and, hence, successful and may have been partially in response to changes in environmental conditions (Robertshaw and Taylor, 2000). However, political and economic factors should not be discounted. Perhaps in contrast with the Early Iron Age, expansion during the early second millennium AD may have been linked to new ways of coping with fluctuations in the food supply engendered by perturbations in weather, climate, pests and disease. These coping strategies probably included increased food storage and long-distance exchange networks under the control of newly emergent chiefs. Networks of interaction established across the Great Lakes region of Africa by chiefs keen to acquire prestige goods, such as glass beads and copper, could also have been used to move foodstuffs, such as dried fish and bananas from the shores of Lake Victoria, into the region during times of local food scarcity (Schoenbrun, 1998; Robertshaw, 1999a,b; Robertshaw and Taylor, 2000; Taylor *et al.*, 2000).

Although it has proven impossible to distinguish pollen and phytoliths produced by sorghum and millet from the remains of wild members of the Poaceae preserved in the cores from Munsa II, it has been possible to identify phytoliths from maize. Maize-like, cross-shaped phytoliths were encountered in sediment samples postdating *c.* AD 1780. Maize was introduced to East Africa during the sixteenth century and was commonly grown in western Uganda by the mid-nineteenth century when Europeans first ventured into the region. It has also been possible to identify what appears to have been a marked increase in the population sizes of herbivores at Munsa, based on the abundant occurrence of the spores of the coprophilus fungi *Cercophora* and *Sporomiella* (van Geel, 1982, 1986; Davies, 1987) in sediment samples dating to the post-deforestation period. These herbivores were presumably mostly domestic animals, notably cattle.

Discrepancies exist in climate reconstructions for the early second millennium AD, because of problems of accurately dating lake sediments (a major source of palaeoclimate evidence in the region) and of extracting a climate change signal from sediments that are likely to have been affected by human activity; the general scarcity of evidence; and the complexity of, e.g., rainfall patterns in the region. Thus, ostracode data are said to represent relatively low Lake Tanganyika levels cal. AD 1050–1250 (Alin and Cohen, 2003), although the data are limited and chronologically poorly constrained. Furthermore, Stager *et al.* (2003) claim that Lake Victoria water levels were relatively low from *c.* AD 830–1340, while Russell *et al.* (2003b) maintain that Lake Edward levels were low *c.* AD 1100. Lake Naivasha levels may also have been lower (Verschuren *et al.*, 2000), although the evidence is equivocal because of the occurrence of reversed ^{14}C ages. In contrast, evidence of a prolonged period of increased aridity during the early part of the second millennium AD is absent from cores of sediment from alpine lakes on Mount Kenya (Barker *et al.*, 2001), and not apparent in records of Nile River discharge minima that Nicholson and Yin (2001: 393) maintain largely reflect Lake Victoria levels, and therefore rainfall in the Lake Victoria catchment (Nicholson, 1996, 1998). Instead, Nile River discharge minima indicate climatically relatively dry conditions AD 940–1040, followed by a period of enhanced precipitation.

Recovery of forest around Munsa is dated from *c.* AD 1780. Relatively recent forest recovery is recorded about the same time in mid-altitude parts of western Uganda at Kabata Swamp (post-dating cal. AD 1510) (Taylor *et al.*, 1999, 2000) and around Lake Kasenda and nearby Lake Wandakara (*c.* AD 1700–1750) (Ssemmanda *et al.*, 2005). The onset of forest recovery appears to have occurred during or shortly following a period of prolonged drought conditions from the late AD 1500s through to the late AD 1700s that has been recorded in many parts of central and eastern Africa (Nicholson, 1996, 1998; Robertshaw and Taylor, 2000; Taylor *et al.*, 2000; Verschuren *et al.*, 2000; Thompson *et al.*, 2002; Alin and Cohen, 2003; Robertshaw *et al.*, 2004). Forest recovery appears also to coincide with the abandonment of the Munsa earthworks (Robertshaw, 1997; Robertshaw and Taylor, 2000) and a more widespread regional shift in settlement patterns towards dispersed homesteads (Robertshaw, 1994). An oral tradition recorded in the 1950s recounts that disgruntled peasants murdered the ruler of Munsa prior to abandonment of the site (Lanning, 1959), and it is tempting to see this tradition as a metaphor for a widespread shift from agriculture to pastoralism, at least by the nobility.

The presence of phytoliths from bananas and maize suggests that some agricultural activity continued in the catchment for Munsa II, post-forest recovery. By late in the eighteenth century, much of western Uganda had been politically united into the kingdom of Bunyoro, whose peripatetic rulers managed to hold together a state comprising a pastoral nobility and an agricultural peasantry. Agriculture, however, reasserted its importance in the twentieth century AD following the decimation of the cattle herds at the hands of warfare, disease and misguided colonial veterinary practices. Moreover, the cultivation of crops from the Americas, notably cassava and sweet potatoes, became increasingly important during the last century as a mechanism to cope with famine (Robertshaw *et al.*, 2004).

Conclusions

Sediment-based palaeoenvironmental data from a papyrus swamp at Munsa archaeological site, in conjunction with the available archaeological and palaeoclimatic evidence, indicate that:

(1) the area was largely forested prior to *c.* AD 1100, although some food crops may have been grown, presumably in small forest gaps and on forest margins;

(2) deforestation commenced during the early part of the second millennium AD, in association with increased burning of vegetation and concurrent with archaeological evidence for occupation of Munsa by a substantial human population;

(3) the period *c.* AD 1100 to *c.* AD 1780 is characterized by evidence for increased densities of herbivores, presumably cattle. Climatic conditions during the period are not resolved to a satisfactory level, although one and possibly at least two major periods of moisture stress seem likely on the basis of the available palaeoclimatic evidence;

(4) forest recovery from *c.* AD 1780 concurs with archaeological evidence for the abandonment of the site and other major settlements in Uganda. The widespread abandonment of settlements may have been in part caused by a period of prolonged drought that is widely recorded in the region for the *c.* 200 years up to the late AD 1700s;

(5) possible evidence for the early presence of members of the Musaceae, notably *Musa*, merits further investigation. Recent discoveries of *Musa* phytoliths in West Africa, and archaeological evidence of early African cultivars in India as well as of early extra-African domesticates in Africa, are good reasons for further examination of possible evidence from Munsa for the cultivation of bananas > cal. 3220 BC. Confirmation of this finding will require improved knowledge of the variability of Musaceae phytolith morphotypes, as well as improved chronological control for the early part of the sedimentary record at Munsa.

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