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The Archaeobotany of Kuk

Carol Lentfer and Tim Denham

Introduction

The study of plants in archaeology—archaeobotany—is key to discovering how and when people exploited, cultivated and domesticated plants in the past, influenced their dispersal and effected their present-day biogeographic distributions. Archaeobotanical study incorporates a complex of methodologies, often reliant on carefully planned and executed sampling strategies and dependent on good preservation of various plant remains (Pearsall 2000).

Traditionally, the method for studying plant remains in archaeological deposits has been the analysis of macro remains of hardy material such as seeds, wood and nutshell (Textbox 10.1). These can provide direct evidence for human/plant association. However, they are not always available for study, being best preserved in extremely dry and cold environments, as well as in anaerobic conditions such as waterlogged deposits. Generally, macrobotanical remains are poorly preserved in well drained, acidic environments, particularly in the wet tropics, unless they have been burnt and converted to charcoal; even after burning it is usually only the hardy types of material that are preserved. Consequently, macrobotanical remains are limited in what they can tell us about the finer details of changing environments, plant distributions, manipulation and human exploitation because preservation in the wet tropics, when it does occur, is inconsistent, favouring some plants and/or plant parts over others.

It is often the case, therefore, that other analytical techniques are required to complement and enhance the analysis of macroremains or fill the gap in instances where they are not preserved. As well as firmly established pollen/spore and microcharcoal analyses, a host of microscopic techniques have been developed and applied to tropical archaeobotany over the last three decades of the 20th century (see Hather 1994), involving plant fibres, parenchyma and other plant tissues, as well as phytolith, starch and raphide analyses. These techniques enable the identification of a broader array of soft tissues than is usually preserved at archaeological sites, including the microscopic remnants of fruits, roots, rhizomes and tubers. Besides microscopic analysis, a number of chemical, spectrographic and other biomolecular techniques have potential to identify plant residues like resins, proteins, enzymes, lipids and fatty acids preserved on stone tools, pottery and other artefactual material (see Denham, Atchison et al. 2009 for a review). Additionally, techniques have been developed for ancient DNA (aDNA) analysis of plant remains and are presently being developed for identifying plant residues in sediments and on artefacts (Schlumbaum, Tensen and Jaenicke-Despres 2008).

Textbox 10.1 Plant macrofossils: Seeds, fruits and wood

Andrew Fairbairn and Peter Matthews

What are plant macrofossils?

These are relatively large (>0.25 mm) parts or fragments of plant material preserved in sediments that can come from short-lived annual herbs or longer-lived perennials (herbs, shrubs and trees) (Fig. 10.T1.1). Macrofossils can be derived from many different plant parts: seeds, fruits, leaves, stems and roots. They are usually visible to the human eye, but their identification often requires the use of a microscope.

Figure 10.T1.1 Potential macrofossil preservation in three highlands plants.

Source: Drawing by Andrew Fairbairn.

How are macrofossils preserved?

Plant materials can be preserved if they are:

- buried in low-oxygen environments, such as the waterlogged sediments at Kuk;
- partially burnt, charred or carbonised;
- deposited in a constantly dry location, such as inside a cave;
- resistant to decay, e.g. the hard fruit stones of hackberry (*Celtis* spp.).

Waterlogging can preserve most plant parts. Charring favours tougher parts (seeds, wood and fibrous tissues) and can destroy more fragile parts (the soft tissues of fruit and leaves).

What can macrofossils tell us?

Seeds are often starchy food sources and their preservation can provide information about the occurrence and use of food plants. Wood charcoal can tell us what trees were used as firewood or for building houses. Different plants grow in different environments and plant macrofossils can be used to reconstruct the environmental conditions and local flora that existed in the past. Macrofossils are usually deposited close to where the living source plants were growing and can often be identified to the species taxonomic level. They are thus complementary to the evidence provided by microfossils such as pollen and phytoliths, which are more easily dispersed over long distances (in the air or in eroding soils) and which are often more difficult to identify to species level.

How are macrofossils collected?

Some macrofossils can be collected directly by excavation with a trowel or by sieving dry sediments, but most are collected through flotation. The flotation technique is best for charred remains, which are very buoyant. Any organic remains that float can be collected in a sieve after mixing excavated sediment with water (Fig. 10.T1.2).

Figure 10.T1.2 Herman Mandui (left) of the PNG National Museum demonstrates wet sieving in Sandaun (formerly West Sepik) Province, PNG.

Source: Photograph by Andrew Fairbairn.

How are macrofossils studied?

Macrofossils are identified by comparison with known living plants. We compare:

- morphology (shape, size and surface structure), using low-powered microscopy (5–50x magnification); and
- anatomy (the internal tissue structure), using high-powered microscopy (50–5000x magnification).

Seeds can often be identified to species level using morphology. Anatomical study is required to identify fragments of wood or other parts that lack a diagnostic morphology and wood is commonly identified only to family or genus level. Changes in the quantity of macrofossils (counts or weights) over time are used to interpret economic and environmental changes.

Example 1: Prehistory of nut pandanus

Highlands pandanus nuts, including those of the type denoted by the pidgin term *karuka*, such as *P. brosimos* and *P. iwen*, are important foods that are likely to have been used since the time of earliest human presence in the mountainous interior of New Guinea. The oldest charred archaeological nutshells to be radiocarbon dated are from the Ivane Valley in the Papuan highlands and fall between about 36,000 and 34,500 years ago (Fig. 10.T1.3; Fairbairn, Hope and Summerhayes 2006: 379; Summerhayes et al. 2010: 78).

Figure 10.T1.3 Transverse section through a burnt 30,000-year-old *karuka*-type nutshell from Kosipe with vascular bundles (vb) highlighted; inset shows vascular bundle anatomy, a = vascular elements; b = bundle sheath, c = ground tissue. Photographs were taken using a scanning electron microscope.

Source: Photograph by Andrew Fairbairn.

Nutshells found in archaeological sites in the Manim Valley near Mount Hagen (Christensen 1975; Donoghue 1988) show the use of another pandanus species, *P. antaresensis*, from wild or managed stands, from first occupation before around 12,000–10,000 years ago to just after 7000–6000 years ago. After this its use declined, perhaps due to a greater reliance on cultivation (see Chapter 14, section ‘Forest foraging and high-altitude cultivation’).

Example 2: Plants cultivated in the wetlands

At the Kana site, excavators recovered the remains of a single gourd buried in mud, with seeds still associated with pieces of gourd skin (Fig. 10.T1.4; Matthews 2003). These seeds were identified by comparing them with published pictures and herbarium specimens of seeds from other plants in the same family (the cucumber family, Cucurbitaceae). The identification of wax gourd (*Benincasa hispida*) is important because it confirms the presence (and likely cultivation) of a plant that in modern times has had multiple uses as food and as container.

Some very small seeds from Kuk were found only by chance, when sediment samples were processed by Tara Lewis to allow Nick Porch to look for small insect remains (see Textbox 9.2). The seeds are big enough to see by eye (0.5–1 mm approximately), but were not found until a low-magnification microscope was used. They were too small to describe without using the more powerful scanning electron microscope (SEM) (Fig. 10.T1.5). At present, we are not sure what plants these seeds came from. We do know that they come from more than one kind of plant because they have very different shapes. One of the plants may be an aroid, from the Araceae, a family that includes taro (*Colocasia esculenta*), but we are unsure—other plants may produce similar seeds.

Figure 10.T1.4 Ancient gourd rind fragments (right) and seeds (left) of wax gourd (*Benincasa hispida*) from the Kana site.

Source: Matthews (2003), reproduced with permission. Photograph by Darren Boyd.

Figure 10.T1.5 Electron micrograph of an aroid-like seed from the 10,000-year-old fill of the Phase 1 palaeochannel, Kundil's Baret, at Kuk (average seed dimension 600 x 300 μm).

Modern taro seeds are typically larger (seed dimension 1000 x 500 μm). The ancient seed illustrated was identified in a sediment sample collected in the field by Tim Denham in 1998.

Source: Image taken on a Cambridge S360 SEM (ANU Microscopy Unit) and is reproduced courtesy of Simon Haberle and Tim Denham.

Table 10.1 Archaeobotanical table listing potential food plants documented from Pleistocene and Holocene contexts at Kuk. Only potential food plants are considered, although other uses may have been as important in the past (cf. Powell 1976a).

Species/Genus ¹	Exploited Form ²	Edible Part(s) ³	Archaeobotanical Evidence ⁴	Earliest Record ⁵
<i>Abelmoschus</i> sp. ⁶	c	l, sh	s	pre-P1
<i>Acalypha</i> sp.	w, t	l	s, p	pre-P1
<i>Castanopsis</i> sp.	w, t	n	w, p?	pre-P1
<i>Cerastium</i> sp.	w	p	s	pre-P1
<i>Coleus</i> sp.	w	l	s	pre-P1
<i>Ficus</i> cf. <i>copiosa</i> ⁶	c, w	f, l	s	pre-P1
<i>Ficus</i> spp.	c, w	l, f	w	pre-P1
<i>Garcinia</i> sp.	w	f, l, b	w	pre-P1
<i>Hydrocotyle</i> sp.	w	l?	s	pre-P1
<i>Lycopodium</i> spp.	w	sh	p	pre-P1
<i>Maesa</i> sp.	w	f	s, w	pre-P1
Musaceae	c, w	f, c	ph, st	pre-P1
<i>Oenanthë javanica</i>	c, w	l, sh	p	pre-P1
<i>Pandanus</i> cf. <i>antaresensis</i>	w	d	p	pre-P1
<i>Pandanus</i> cf. <i>brosimos</i>	c, w	d	p	pre-P1
<i>Pandanus</i> spp.	c, w	d	s, p	pre-P1
<i>Parsonsia</i> sp.	w	n	p	pre-P1
<i>Phragmites karka</i>	w	l, r, sh	ph	pre-P1
<i>Pouzolzia hirta</i>	w	l, st	s	pre-P1
<i>Rubus moluccanus</i>	w	f	s	pre-P1
<i>Rubus rosifolius</i>	w	f	s	pre-P1
cf. <i>Setaria palmifolia</i>	c, w	s	ph	pre-P1
<i>Solanum nigrum</i>	c, w	l, sh	s	pre-P1
<i>Syzygium</i> sp.	w	f	w	pre-P1
<i>Wahlenbergia</i> sp.	w	p	s, p	pre-P1
cf. Zingiberaceae	c, w	r, l, sh	ph	pre-P1
<i>Colocasia esculenta</i>	c	c, l	st	P1
<i>Dioscorea</i> sp.	c	t	st	P1
Elaeocarpaceae	w	n	p	P1
<i>Ipomoea</i> sp.	w	sh	p	P1
Musa section bananas ⁷	c, w	f, c	ph	P1
Ingentimusa section ⁷ bananas	w	f, c?	ph	P1
<i>Phragmites</i> sp.	w	st	ph	P1
<i>Typha</i> sp.	w	st	p	P1
<i>Solanum</i> sp.	c, w	f, l, sh, t	s	pre-P2
<i>Commelina</i> sp. ⁶	c, w	l, sh	s	P2
<i>Drymaria cordata</i> ⁶	w	l?	s	P2
<i>Floscopa</i> sp. ⁶	c, w	l, sh	s	P2
<i>Viola arcuata</i>	w	l	s	P2
<i>Amaranthus</i> sp.	c	l, p	s	P2/P3
<i>Bidens pilosa</i>	w	s	p	P2/P3
<i>Polygonum chinense</i>	w	l	s	P4/P6
<i>Finschia</i> sp.	w	s	s	P5

Species/Genus ¹	Exploited Form ²	Edible Part(s) ³	Archaeobotanical Evidence ⁴	Earliest Record ⁵
<i>Saccharum officinarum</i>	c	st	pa	P5/6
<i>Bambusa</i> sp.	c, w	sh	w	P6
<i>Ipomoea batatas</i> ⁸	c	t	t	P6
<i>Elaeocarpus</i> sp.	w	n	w	P6
prob. <i>Ipomoea batatas</i>	c	t	pa	P6
<i>Polyscias</i> sp.	w	l	w	P6
<i>Oxalis corniculata</i>	w	l, sh	s	post-P6

Source: Updated version of Denham et al. (2003: Table S3) and Denham, Haberle and Lentfer (2004: Table 2).

Notes:

¹ List of edible species at Kuk based on ethnographically documented use of plants in New Guinea (Powell et al. 1975: 15–39; Powell 1976a: 108–112; Powell with Harrison 1982: 57–86; French 1986; M. Bourke 1989 and pers. comm., 2002; Haberle 1995; G. Hope, pers. comm., 2002). Edible species have been reported from other early and mid Holocene archaeological sites in the highlands.

² Exploited form: c = cultivated, w = wild (used as supplementary food), t = transplanted.

³ Edible part(s): b = bark, c = corm, d = drupe, f = fruit, g = gourd, l = leaf, n = nut, p = plant, r = rhizome, s = seed, sh = shoot, st = stem, t = tuber.

⁴ Evidence: p = pollen (by Simon Haberle), pa = parenchyma (by Tara Lewis), ph = phytolith (by Carol Lentfer), s = seed (by Jocelyn Powell and Laurie Lucking), st = starch (by Richard Fullagar, Judith Field and Michael Therin), t = tuber (by Jon Hather), w = wood (by Jocelyn Powell and Laurie Lucking). Only those cases relevant for the earliest recorded occurrence are listed.

⁵ Earliest record are given for Pleistocene contexts (pre-P1), Phase 1 contexts (P1), contexts postdating Phase 1 and predating Phase 2 (pre-P2), Phase 2, 3, 4, 5 and 6 contexts (P2–6), and postdating Phase 6 (post-P6).

⁶ Identification to genus or species level should be considered provisional because it is based on a single seed.

⁷ A review of the sections within the genus *Musa* (Wong et al. 2002), which is not universally accepted (De Langhe et al. 2009), has reclassified the five former sections into three: section *Musa* contains the former *Eumusa* and *Rhodochlamys*; section *Callimusa* contains the former *Callimusa* and *Australimusa*; and section *Ingentimusa* remains the same. Previous identifications of *Callimusa* (formerly *Australimusa*) phytoliths from Phase 2 and 4 contexts at Kuk (Wilson 1985: Table 3) are excluded because they were based on a single phytolith each and no such phytolith morphotypes were documented from Phase 1–3 contexts at Kuk targeted during recent research (Denham et al. 2003: 192).

⁸ Provisionally identified as *Dioscorea esculenta* by Jon Hather (pers. comm. to Jack Golson), although reanalysis suggests probably *Ipomoea batatas* (Lewis, Denham and Golson 2016).

Interdisciplinary study at Kuk since the early 1970s has made several significant contributions to archaeobotanical research in Melanesia. A combination of techniques has obtained evidence for the presence of a suite of food plants at Kuk from the Pleistocene to the present (Table 10.1). The focus here is on food plants, although plants were used for a variety of different purposes including medicines, ornamentation, rituals, construction, tools and so on (Powell 1976a).

Archaeobotanical investigations were undertaken on samples collected from archaeological and stratigraphic contexts, with subsequent identification of micro- and macrobotanical remains to genus and species level, where possible. The results of macrobotanical work undertaken in the 1970s were complemented during the 1990s by employing microfossil techniques, primarily phytolith analysis of stratigraphic samples (Textbox 10.2) and starch granule analysis of tool residues (Textbox 10.3) to yield evidence of plants that do not regularly produce pollen or seeds under cultivation, specifically bananas (*Musa* spp.), taro (*Colocasia esculenta*) and yams (*Dioscorea* spp.). The 1970s investigations targeted all archaeological phases and major stratigraphic units at the site, whereas the 1990s investigations targeted early and mid Holocene contexts only.

Textbox 10.2 Analysis of opaline phytoliths at Kuk

Carol Lentfer

Introduction

Opaline silica phytoliths are produced in plants as biogenic silica derived from monosilicic acid deposited in cells and cellular spaces. Similar to other plant microfossils such as pollen, spores, raphides, druses and starch granules, they are deposited as discrete or articulated units in sediments following decomposition of plant tissues. Consequently, they can be used for reconstruction of vegetation at a localised level, providing the means for the reconstruction of on-site vegetation and change according to natural or anthropogenic processes. However, as with all particulate sedimentary inclusions, phytoliths can be subject to translocation through water and wind movement, which results in them ending up in different sedimentary locations such as swamps, lakebeds, seabeds, dunes or glacial deposits. This gives the opportunity for analysis of vegetation at a more regional level, the scale of which is determined by the types of taphonomic processes operative in specific geographical settings.

Phytolith production in plants can be influenced by soil characteristics and other environmental factors, but primarily it is genetically determined. Some plant families such as grasses and sedges have very high phytolith production and others such as aroids (e.g. taro), yams and *Pandanus* spp. are characterised by having very low or nil phytolith production. Furthermore, unlike pollen and spore production, where only one morphotype is produced, a single plant species can produce multiple types of phytoliths, referred to as 'multiplicity'. In some instances, different plant parts such as leaves, stems, flower bracts and fruit produce different diagnostic morphotypes, which can sometimes be useful for determining how plants may have changed or been exploited in the past. However, many plants produce morphotypes that are the same or very similar and difficult to differentiate, especially when phytoliths become disarticulated and occur as discrete particles in phytolith residues. This is referred to as 'redundancy'. Many trees and shrubs in New Guinea are characterised by this feature, sometimes making it very difficult to identify plants to species, genus or family level from the analysis of phytoliths alone (Lentfer 2003b). Nevertheless, given the overall capacity to discriminate between particular plant groups and identify patterns of vegetation change and other important environmental processes, phytolith analysis has proven to be an extremely useful tool for palaeoenvironmental reconstruction in New Guinea (e.g. Lentfer and Green 2004; Lentfer and Torrence 2007).

Phytolith analysis at Kuk

Phytolith analysis was undertaken for various Late Pleistocene and early to mid Holocene contexts at Kuk, including through major stratigraphic units and the fills of palaeochannels, ditches and features associated with Phases 1, 2 and 3. It was thought that phytolith analysis would offer an effective means for palaeoenvironmental reconstruction: identifying past vegetation growing in the swamp and on the surrounding hillsides; tracking environmental change and helping to estimate its extent and identify its cause, whether induced by shifts in climate or by human activity. It would also have the potential to build on previous phytolith studies undertaken at Kuk documenting the presence and introduction of economically important plants (Wilson 1985; Bowdery 1999).

Methodology

Phytoliths were extracted from 40 sediment samples (see Table 10.T2.1), using heavy liquid extraction (Lentfer and Boyd 1998). Phytoliths were mounted in benzyl benzoate and examined using optical microscopy at 400x and 600x magnification. At least 400 phytoliths were recorded per sample. Following initial counts, slides were quick-scanned to record presence of previously unrecorded morphotypes. Morphotypes were assigned to categories representing either plant groups or phytolith groups dependent on diagnostic potential.

Table 10.T2.1 Percentage composition of diagnostic *Musa* and *Ensete* seed phytoliths in phytolith assemblages.

Archaeostratigraphy	Sediment sample no.	Musaceae phytoliths % of total	Diagnostic seed phytoliths/ total Musaceae		
			M	E	I
Black silty clay	1	1.42	12.5	0	0
Black clay	2	0.71	+	+	0
	3	0.83	+	+	0
Phase 3	28	0.51	0	0	0
palaeochannel fills (103)	30	n/c(+)	0	0	0
	32	1.90	0	0	0
Phase 3	58	1.34	0	0	0
palaeochannel fills (107)	59	n/c(+)	0	0	0
	60	3.09	0	0	0
Early Phase 3	52	2.78	0	0	0
ditch fill (353)	53	3.16	0	0	0
Late Phase 2	55	11.49(+)	0	0	0
curvilinear feature fill (504)	56	15.77(+)	9	0	0
Early Phase 2	35	9.38(+)	12.5	0	0
palaeosurface feature fill (3004)	36	4.37(+)	0	0	0
Early Phase 2	37	3.24	0	0	0
palaeosurface feature fill (3009)	38	0.95	20	0	0
'R+W'	4	1.53(+)	0	44.4	0
Grey clay	5	1.12	+	0	0
	6	1.82	16.6	0	0
	7	1.26	0	0	0
	8	0.76	+	0	0
	9	1.53	0	0	0
	10	3.18(+)	10.5	0	0
	11	2.42	0	0	0
	12	9.05(+)	0	0	0
	13	1.57(+)	+	0	0
	14	4.39(+)	0	0	0
	15	0.75	0	0	0
	16	2.11(+)	+	0	0
	17	6.61	4.7	0	0
Phase 1	18	1.80	+	0	0
palaeochannel fill (101b)	19	0.49(+)	66.6	0	+
	20	3.16(+)	0	0	0
Phase 1	25	3.57	0	0	0
palaeosurface feature fill (1401)	26	0.83	0	0	0
Phase 1	21	0.22	0	0	0
palaeochannel fill (101a)	22	3.37(+)	0	0	0
Late Pleistocene peat	23	1.60	0	0	0
	24	0.80	0	0	0

Source: Data collated by Lentfer and Denham.

Notes:

(+) after the Musaceae phytolith percentage (as a percentage of total phytoliths) = presence of articulated Musaceae phytoliths; n/c = no count of disturbed phytolith assemblage/context; M = *Musa* (formerly *Eumusa*) section bananas; E = *Ensete*, I = *Musa ingens*.

+ = values below 0.5%.

Palaeoenvironmental reconstruction

The summary diagram (Fig. 10.T2.1) shows evidence of distinct changes in vegetation, which is linked to periods of burning and erosion in the catchment. In particular, there is a broad pattern of change showing a shift from forest vegetation in the Late Pleistocene to vegetation dominated by grasses (Gramineae) in the mid to late Holocene. Microcharcoal levels (see Denham et al. 2003; Denham, Haberle and Lentfer 2004; and cf. Chapter 9 here) are indicative of forest burning in the Late Pleistocene. The negative correlation between frequencies of platy morphotypes, representing broken epidermal phytoliths derived from non-grass and arboreal vegetation, and Gramineae phytoliths shows that each of these burning episodes was instrumental in opening up the forests sufficiently to promote grass growth.

Figure 10.T2.1 Composite phytolith diagram for samples at Kuk. Percentage values < 1% are marked by black dots.

Sacc. = *Saccharum*, ESC = epidermal short cell, Pooideae grasses are C3 grasses, Imp. = *Imperata*, Them. = *Themeda*, Set. = *Setaria*, ELC = epidermal long cell. Note the sudden peak in Musaceae phytoliths starting in Phase 2 palaeosurface feature fills after a period of intensive burning. The presence of *Musa* (formerly *Eumusa*) section bananas was confirmed during this period. Chronology and stratigraphy after Denham et al. (2003: Fig. 3) and Haberle et al. (2012).

Source: Drawing by Carol Lentfer.

At the beginning of the Holocene, within the period of grey clay deposition, this becomes more obvious, with a major peak in microcharcoal directly followed by an increase in grass phytolith frequencies. This is indicative of burning within the swamp catchment causing forest clearance, erosion and the deposition of grey clay in the swamp. Following clearance, there is a sharp increase in palms and gingers, signalling a period of regrowth, possibly associated with garden fallow. Towards the end of grey clay deposition, a slight increase in burning prompted a sharp decline in palms and gingers and another sharp rise in grasses.

At the beginning of Phase 2, grass phytoliths continued to dominate. The low frequencies of early regrowth elements such as gingers and palms in the phytolith assemblage indicates a shift in land management practice leading to higher and more sustained levels of disturbance of natural forest vegetation in the swamp and its catchment.

Evidence for plant cultivation

Phytolith morphotypes from a number of cultivated plant groups were recorded in the assemblages. Included are morphotypes that occur in palms, gingers and edible grasses such as *Setaria palmifolia* and two *Saccharum* species, *S. officinarum* (sugarcane) (Fig. 10.T2.2), and *S. edule* (edible *pitpit*). The high frequencies of palms and gingers in the grey clay deposit signal periods of regrowth possibly associated with garden fallow. The distribution of grass morphotypes in the phytolith record, however, offers no clear evidence for cultivation of either *Saccharum* or *Setaria*. As pointed out in the second paragraph of this textbox, *Pandanus* spp., *Colocasia* taro and yam have low phytolith production and no diagnostic phytoliths, so their presence is not reflected in the phytolith record.

Figure 10.T2.2 Leaf phytoliths from *Saccharum officinarum* (sugarcane, modern reference: WNB1020) and fossil phytoliths found in the fill of the late Phase 2 curvilinear feature 504 (sample 55).

A. Epidermal short cell from WNB1020. B. Epidermal short cell recovered from microfossil assemblage. C. Articulated trichomes of *S. officinarum*. D. Disarticulated trichomes from microfossil assemblage.

Source: Photograph by Carol Lentfer.

The most significant evidence for plants being cultivated at Kuk prior to the mid Holocene comes from the presence of Musaceae phytoliths in the palaeosurface feature fills of Phase 2 and the ditch fills and palaeochannels of Phase 3 (see Fig. 10.T2.1). Notably, *Musa* and *Ensete* phytoliths were identified in these assemblages from diagnostic seed phytoliths (Table 10.T2.1; Fig. 10.T2.3), though there were no diagnostic seed phytoliths of bananas of the *Callimusa* section, which includes the former *Australimusa* section (see Table 10.1, note 7). Morphotypes derived from leaves were more abundant in the assemblages than seed morphotypes (Fig. 10.T2.3 H and I), but work on reliably differentiating banana species and cultivars using leaf morphotypes is still in progress (Ball et al. 2006; Lentfer 2009).

Rather than being cultivated, it is possible that bananas and *Ensete* were regrowth elements. However, substantial increases in Musaceae phytoliths first occur in association with a major burning episode and reductions in frequencies of panicoid grasses and reeds (*Phragmites* sp.). Furthermore, it is interesting that the morphotypes of ginger/palm phytoliths, which we should expect to find in association with those of wild bananas in regrowth vegetation following disturbance, are virtually absent from the assemblages where the Musaceae phytoliths peak. This is suggestive of deliberate clearance, possibly linked to the preparation of land for gardening. Furthermore, the relatively high frequencies of Musaceae phytoliths in the fossil assemblages of Phases 2 and 3 especially, in comparison with low frequencies of other regrowth elements such as palms and gingers, point more towards bananas being cultivated than merely a component of wild regrowth vegetation. It is also significant that spikes in banana phytolith frequencies occur in stratigraphic units with posthole, ditch and mound features.

Additionally, as discussed in the main text, wild *Musa* (formerly *Eumusa*) section bananas and *Ensete* are predominantly lowland species. Therefore, their appearance at Kuk indicates either a warmer than at present period in the early to mid Holocene or their introduction by humans perhaps as cultivars. If the latter was the case, the presence of *Musa* section bananas in the assemblage in Phase 1 would imply that they were introduced to the region by about 10,000 years ago and prior to this it is likely that the only banana species growing there was the giant wild species, *Musa ingens*. The presence of *Musa* section bananas in the grey clay layer shows that they were quite common in the region during the early Holocene and possibly cultivated on the slopes surrounding the swamp. If this was so, the sustained presence of seeded bananas above the Phase 3 horizon (see Table 10.T2.1), dated roughly to around 2500 years ago (see Chapter 14, section 'Soil tillage as an innovation'), would provide tangible evidence that the domestication of edible bananas, leading to sterility and loss of viable seeds, has been a long, drawn-out complex of processes, involving interbreeding of wild and partly domesticated populations over several thousands of years. As indicated by the occasional presence of seeded cultivated diploid bananas in some regions of Papua New Guinea today (Lentfer 2009), similar processes are ongoing and would have been crucial in the development of the diverse range of diploid, triploid and polyploid cultivars that are now grown throughout the world (see Perrier et al. 2011).

Conclusion

Samples at Kuk yielded rich and well preserved phytolith assemblages from the Late Pleistocene to mid Holocene that provides us with a better understanding of past vegetation and the forces driving palaeoenvironmental change at Kuk. The assemblage, together with the microcharcoal record, shows forest clearance and cycles of regrowth signifying land management by the use of fire since the beginning of the Holocene. Phytolith morphotypes found in a number of economically important plants are present in the assemblage. Musaceae morphotypes, in particular, provide strong support for the early cultivation of bananas. This has been a major contributing factor in the Kuk site playing a key role in the recognition of agricultural origins and developments in the New Guinea region.

Figure 10.T2.3 Photographs illustrating discrimination of contemporary and prehistoric *Musa* spp. phytoliths.

A. Articulated phytoliths from seed of *Musa acuminata* ssp. *banksii*, showing the distinct dorsal ridging of *Musa* (formerly *Eumusa*) section seed phytoliths (modern reference: QH067962). B. Articulated phytoliths from seed of *Musa peekelii*, with the distinctive tabular dorsal surfaces found in *Callimusa* section seed phytoliths, which were not present in the Kuk assemblages (modern reference: LH82751). C. Seed phytolith from *Musa ingens* (modern reference sample). D. Dorsal and lateral views of *Ensete glaucum* seed phytoliths (modern reference: QH356652). E. Fossil *Musa* section seed phytolith with distinct dorsal ridging, found in the phytolith assemblage from near the top of grey clay (sample 5). F. Faceted phytolith morphotype found in the phytolith assemblage from the upper fill (101b) of the Phase 1 palaeochannel (sample 19), which is similar to the seed morphotype of *Musa ingens*, although its surface is more heavily textured. G. Lateral view of *Ensete* seed morphotype found in a Phase 2 feature fill and the black clay sediment above (samples 3 and 4). H. Articulated chain of *Musa* leaf phytoliths from within the grey clay formation between Phase 1 and Phase 2 (sample 10). I. Fossil leaf phytolith of *Musa* sp. from the upper fill of the Phase 1 palaeochannel (sample 19). J. Fossil *Musa* section seed phytolith from the upper fill of the Phase 1 palaeochannel (sample 19).

Source: Photographs by Carol Lentfer.

Textbox 10.3 Tool usewear and residues

Richard Fullagar

The study of how ancient tools were used is as old as archaeology. Over the last 50 years, new techniques have been developed to identify diagnostic wear patterns and organic/inorganic traces that can be related to how stone artefacts were used in the past. The concept of function refers to a range of specific aspects of implement use that usually requires an understanding of design, motion or mode of use (e.g. sawing, scraping), holding, hafting, properties of worked materials (e.g. wood, bone, grass), stages of manufacture and edge reduction and the type of stone (such as obsidian, chert and basalt). The techniques of usewear and residue studies are thus grounded in material sciences like biology. Some wear patterns are highly distinctive, like the polished surface on stone sago pounders (Fig. 10.T3.1). However, experiments are vital to evaluate variables like edge angle and scarring type and to test interpretations of residue forms (cf. Barton 2007).

Figure 10.T3.1 Above: Use-polish on an ethnographic sago pounder from PNG collected by Ross Bowden, La Trobe University, Melbourne (Fullagar 1989: Plate 10.10). Below: Sago starch grains from the same artefact. Metallographic microscope, scale divisions are 0.0068mm (Fullagar 1989: Plate 10.11).

Source: Photographs by Richard Fullagar, reproduced with permission.

Tool-use experiments are particularly important for usewear studies because different kinds of stone, like obsidian and basalt, will sustain usewear according to differences in hardness and mineralogical composition. Tool-use experiments are particularly important in the study of residues on tool edges because tiny traces, like feather particles or plant fibres, might not be part of processing or manufacturing particular things, but instead be related to hafting, decoration or storage (e.g. as in a knife sheath). It is vital to integrate the results of usewear and residue analyses with broader information regarding stone tool technology and other data from the archaeological site.

Residue studies require specific comparative reference collections for identifying the diagnostic particle shapes of pollen grains, starch granules and phytoliths. Starch from stone tool surfaces has shown the presence and use of *Colocasia* taro and a yam in the highlands during the early Holocene (Figs 10.T3.2 and 10.T3.3 here; Denham et al. 2003; Fullagar et al. 2006). Earlier use of tubers in Island Melanesia is indicated by starch grains on stone artefacts dating to over 28,000 years ago from Buka (Loy, Spriggs and Wickler 1992).

Microscopy and lighting conditions are critical for observing particular forms of usewear. In the usewear studies reported (see Chapter 20), metallographic microscopes, with vertical incident light, and stereomicroscopes, with a point source of oblique incident light, were used to observe stone tool surfaces and edges. The former provides high magnification (well over 200x) but has a flat image, with little depth of focus, which is useful for examining smooth or polished surfaces. The latter provides images of surface features like striations and scarred or beveled edges in clear relief.

Figure 10.T3.2 Above: Retouched flake (K/76/29B) collected from beneath the grey clay fill of a basin-like Phase 1 feature (c. 10,000 cal. BP) at Kuk (Chapter 20). Scale bar is 10 mm. Below: Starch grains of taro (*Colocasia esculenta*) from the working edge of the retouched flake (left: transmitted light; right: cross-polarised light).

Source: Photographs by Richard Fullagar.

Residues are observed under reflected light microscopes, but tiny particles, organic structures and fibres are best viewed on mounted glass slides through transmitted light. Diagnostic shapes of phytoliths and starch grains found on artefacts and in sediments provide some of the earliest definitive evidence of plant food exploitation and cultivation of tropical crop plants, such as banana and yam (Lentfer, Therin and Torrence 2002; see Textbox 10.2).

In Melanesia, microscopic studies have identified the use of flaked stone tools for a range of distinct tasks other than plant food processing. For example, woodworking in the Jimi River Valley is indicated by a distinctive polish on retouched blade-like flakes (Fullagar 1989), while the usewear on stone drill bits indicates the drilling of shell for making fishhooks at Motupore Island, near Port Moresby (Allen, Holdaway and Fullagar 1997). Evidence for butchering, bone working and skin working is less commonly found (but see Kononenko 2008).

Figure 10.T3.3 Above: Grinding stone (pestle, K/75/S178) recovered from the Phase 1 palaeochannel base of channel 101 (Kundil's Baret) dating to about 10,000 cal. BP. Below: Large starch grain of a yam (*Dioscorea* sp.) from the residue extraction (left: transmitted light; right: cross-polarised light).

Source: Photographs by Richard Fullagar.

Food plants are presumed to have been continuously present in the upper Wahgi region after their earliest record at Kuk. Table 10.2 lists archaeobotanical finds at other sites in the upper Wahgi: gourds at Warrawau (the Manton site), as well as the middle Wahgi site of Kana; and pandanus at four Manim Valley sites (Donoghue 1988). Of the three other sites listed Yuku (bamboo and, problematically, sugarcane) is just north of the upper Wahgi in the upper Yuat; Aibura (bamboo) is at the upper reaches of the Lamari River in Eastern Highlands Province near Kainantu; and the Ivane Valley (pandanus) is in the Papuan highlands to the southeast.

Table 10.2 Macrobotanical remains of food plants reported at other archaeological sites in the highlands.

Plant	Site	Approx. antiquity (years ago) ⁴	Laboratory code	References
Bamboo				
<i>Bambusa</i> sp.	Yuku	11,600–10,600	ANU-358	Bulmer 1975: 31
<i>Bambusa</i> sp.	Aibura	after 4450–3900	GaK-623	White 1972: 57, 61
Gourds				
<i>Lagenaria siceraria</i> or <i>Benincasa hispida</i>	Warrawau (Manton)	5900–5050	ANU-288 and 2086	Powell 1970b: 144–145; Golson 2002: 70–71; Denham 2003b: 170; 2007a: 88
<i>Benincasa hispida</i>	Kana	2950–2000	ANU-9487	Matthews 2003; Muke and Mandui 2003: 184
Pandanus^{1,2}				
<i>Pandanus</i> spp.	Ivane Valley	36,300–34,600	Wk-17261	Fairbairn et al. 2006: 379; Summerhayes et al. 2010: Table S1
<i>Pandanus</i> spp. (wild)	Etpiti	after 2350–2000	ANU-1323	Christensen 1975: Table 1; Donoghue 1988: 85–88
	Kamapuk	from 2750–2350	ANU-1326	Donoghue 1988: 78–80
	Tugeri	after 2700–2350	ANU-1321	Donoghue 1988: 88–90
<i>Pandanus antaresensis</i>	Kamapuk	after 2750–2350	ANU-1326	Donoghue 1988: 81
	Manim 2	from before 11,800–10,300 to just after 7000–6350	ANU-1375 ANU-1373	Christensen 1975: 31; Donoghue 1988: 71–73
<i>Pandanus brosimos</i>	Tugeri	after 1700–1400	ANU-1322	Donoghue 1988: 88–90
<i>Pandanus iwen</i>	Etpiti	after 2350–2000	ANU-1323	Donoghue 1988: 85
	Kamapuk	after 2750–2350	ANU-1326	Donoghue 1988: 78
<i>Pandanus julianettii</i>	Etpiti	after 1350–1050	ANU-1324	Donoghue 1988: 85
	Kamapuk	modern?	stratigraphic inference	Donoghue 1988: 81
	Tugeri	after 1700–1400	ANU-1322	Donoghue 1988: 88
Sugarcane				
<i>Saccharum officinarum</i> ³	Yuku	5650–4550	GX-3111B	Bulmer 1975: 31

Source: Data collated by Lentfer and Denham.

Notes:

¹ Abundant archaeobotanical material besides pandanus was collected from the Manim Valley sites and is subject to ongoing investigation. Seeds collected as part of palaeoecological studies at wetlands in the highlands are excluded here because of their uncertain associations with humans.

² *Pandanus conoideus*, identified at Yuku and formerly referred to as *Pandanus* spp. (Bulmer 1975: 31), was subsequently claimed as approximately 14,000 years old (Bulmer 2005: 392–393). Recent redating by Denham (2016) of pandanus material recovered during the original Yuku excavations has yielded modern radiocarbon dates and it should be considered likely that all *P. conoideus* at Yuku is modern. Consequently, these finds are excluded from consideration here.

³ The identification of *Saccharum officinarum* at Yuku is uncertain (Yen 1998: 168) and given problems of dating at the site, both botanical identification and age are problematic (Denham 2016).

⁴ The radiocarbon calibrations are derived as follows: for Yuku and Aibura from Sutton et al. (2009: Table S1, supplementary information); for Warrawau inferred from chrono-stratigraphic interpretations of the site (references in table); for Kana and the Ivane Valley derived from the listed publications; and for the Manim Valley sites using Calib 6.0.0 (Stuiver and Reimer 1993) and IntCal04 calibration curve (Reimer et al. 2004). Only the highest probability distributions at two standard deviations are given. Calibrated date ranges below 10,000 years are rounded to the nearest 50 years and those above 10,000 years are rounded to the nearest 100 years.

Suite of techniques: Suite of food plants

Through the combined application of a suite of macrobotanical and microbotanical techniques, it was possible to identify in the archaeological and stratigraphic records a suite of plants that could have been used for food during various periods in the past (Table 10.1). The suite of food plants recovered from the archaeological record at Kuk, comprising starch-rich staples and supplements, vegetables and food-bearing trees, is similar to that harvested wild and cultivated in gardens across the Wahgi Valley today (Powell et al. 1975; Powell 1976a; Denham 2016). Many food plants were present from the Pleistocene, although several highly significant examples first appear in the early, mid and late Holocene. Analyses have provided evidence for the use and cultivation of some plants, but most techniques indicate no more than the presence of specific plants. The availability of a wide range of edible plants opens up the possibility for broad-spectrum subsistence systems persisting up to the early Holocene (Powell 1982a: 211).

Starch-rich staples and supplements

The most significant new archaeobotanical evidence is for the use of taro (*Colocasia esculenta*) and a yam (*Dioscorea* sp.) and the presence of *Musa* spp. from the early Holocene (Phase 1). These plants provide energy-rich sources of food and could have functioned as staples in the Wahgi Valley because they provide aseasonal, high-caloric resources in parts of New Guinea today (e.g. Powell 1976a; Gagné 1982a: 236; Dwyer and Minnegal 1991; Yen 1991a, 1995).

Starch granules of taro and yam were recovered from the used edges of stone tools dating from the early and mid Holocene (Fullagar et al. 2006, 2008; see Chapter 20 here). These finds, together with the appearance of other plant residues on stone tools, are indicative of plant processing, most probably prior to consumption. The presence of these two starch-rich plants is significant, because taro and some yam species are indigenous to and were domesticated in the New Guinea region (Lebot 1999; see Chapter 3 here). There is earlier evidence that starch-rich tuberous plants were being exploited in lowland sites of Island Melanesia (Loy, Spriggs and Wickler 1992; Barton and White 1993).

High frequencies of Musaceae phytoliths, including types of seed morphotypes specific to the *Musa* (formerly *Eumusa*) section, recur throughout the Holocene (Denham et al. 2003; Lentfer 2003a). Importantly, the high frequencies of banana phytoliths in some Phase 2 contexts (dating from 7000–6400 years ago) are suggestive of deliberate planting in multi-cropped plots within a grassed landscape managed by fire (Textbox 10.2). In New Guinea generally, bananas and possibly *Ensete* could have been exploited for their fruit, flowers, leaves and/or for their seeds and the edible corm at the base of the pseudostem during the early Holocene or earlier (Michael Bourke, pers. comm., 2002; Lentfer 2003b).

Banana, yam and taro starch sources could have been supplemented by edible *pitpit* (*Setaria palmifolia*), which may have been present in the vicinity during the Pleistocene (see Table 10.1), and potentially sugarcane (*Saccharum officinarum*), although mid Holocene claims for the latter at Yuku are unlikely (Bulmer 1975: 31; cf. Yen 1998: 168). Both these grasses have starch-rich pith. *Saccharum officinarum* could also have been a staple as reported ethnohistorically for the highlands (Daniels and Daniels 1993). Gingers (cf. Zingiberaceae) could have been exploited for their starch from the early Holocene, even though they are only minor contributors to diet in the highlands today.

In addition to these known starch sources, wild tubers are eaten in the highlands today, particularly during famine conditions (Watson 1964b; Waddell 1973; Powell et al. 1975: 15–32). Wild forms of *Colocasia* taro (swamp), *Dioscorea* yams (forest), *Pueraria* sp. (forest) and yam-like tubers (possibly *Dioscorea* but unknown species of the forest) grow in highland valleys

today and are used for food (Michael Bourke, pers. comm., 2002; Powell et al. 1975: 21, 24–25, 36; Yen 1991b: 77, 81). Other wild varieties of the same species are known but never eaten or have poorly developed tubers or corms (Powell et al. 1975: 21, 24–25). Although many of these plants are generally associated with dryland forests, they may have grown, or been grown, at Kuk during drier periods and could have been significant sources of starch in the past. At present, the taxonomy, ecology, nutritional value and human exploitation of these wild plants are poorly understood and consequently they may have limited archaeobotanical visibility.

In conclusion, several starch-rich plants were potential food sources for people in the highlands at various times from the beginning of the Holocene. Most significantly, the remains of three starch-rich plants, *Musa* bananas, *Colocasia* taro and a *Dioscorea* yam, which have featured prominently in the development of Melanesian and Pacific agriculture, were first present at Kuk in the early Holocene and were associated with the earliest evidence of plant manipulation along the wetland margin.

Vegetables

At an early stage of the Kuk Project, Jocelyn Powell began a programme of macrofossil analysis, using seeds recovered by flotation from sediment samples taken from stratigraphic columns and ditch fills (Powell 1982b). The aim was to obtain more information on the presence of food plants and gardening systems at the site than was provided by pollen analysis. The field and laboratory work was conducted by Powell and Laurie Lucking in 1974–76.

The results showed that many indigenous vegetables were present at Kuk in the early to mid Holocene or earlier (Table 10.1). Many of these plants are highly nutritious, although not major sources of calories. Several are cultivated in gardens today, including *Amaranthus* sp., *Commelina* sp., *Floscopa scandens*, *Oenanthë javanica* and *Solanum* spp. (Powell 1970a: 200; 1981: 296; 1982b: 31–32; Powell et al. 1975: 15–32), whereas others are harvested from wild sources or as garden weeds, e.g. *Cerastium* sp., *Drymaria cordata*, *Hydrocotyle javanica*, *Oxalis corniculata*, *Rubus rosifolius* and *Viola* sp. Although it is possible that these resources were all natural colonisers of the wetland margin at Kuk and other wetlands in the upper Wahgi Valley (Powell 1970b), their distributions may have been enhanced by clearance using fire and by the cultivation of plots. The similarity of the suite of vegetables and starchy staples available in the past at Kuk to contemporary garden assemblages in the area suggest intentional behaviour, i.e. management or deliberate planting in gardens (after Powell 1982b: 31).

Nut- and fruit-bearing trees

Two of the most important nut-bearing trees in the highlands, *Pandanus* spp. and *Castanopsis* sp., were present in the Kuk catchment from the Pleistocene (Table 10.1). Wood from an additional nut-bearing tree, *Elaeocarpus*, was present in Phase 6 contexts at Kuk, and was probably there at an earlier date. *Castanopsis* sp. pollen decreased markedly in the Holocene from Pleistocene levels, largely as a result of forest disturbance (Denham, Haberle and Lentfer 2004: 848).

Pollen records from Kuk (Denham et al. 2003; Denham, Haberle and Lentfer 2004: 845–848) show that *Pandanus* spp. were present in low frequencies in the Pleistocene and at the beginning of the Holocene (Phase 1). During grey clay deposition (approximately between 10,000 and 7000 years ago) the frequency of pandanus pollen increased dramatically. Two kinds of wild nut *Pandanus* were present at Kuk in the Late Pleistocene, *P. cf. antaresensis* and *P. cf. brosimos*, belonging to two distinct groupings in terms of pollen morphology, the *antaresensis*-type being spiky (echinate) and the *brosimos*-type being smooth (psilate) (Haberle 1995: 200–206).

Pandanus brosimos has a mean usual altitudinal range of 2400–3100 m and *P. julianettii*, referred to as the cultivated form of *P. brosimos* (cf. Haberle 1995: 207), has a mean altitudinal range of 1800–2600 m. *Pandanus antaresensis* has a mean altitudinal range of 1000–2350 m (Table 4.4).

Pandans of the *brosimos/julianettii* complex have been previously characterised as a highly seasonal resource. Indeed, some authors have claimed that human presence in the highlands during the Pleistocene was based on hunting and the seasonal harvesting of nuts (White, Crook and Ruxton 1970: 168–169; Bulmer 1977: 69; Golson 1991b: 86–88; Fairbairn, Hope and Summerhayes 2006: 379). However, seasonality and hence reliability of production in these species have been shown to vary geographically with climate across the highlands (Bourke et al. 2004: 39–40, 154, 191; cf. Donoghue 1988: 50). Consequently, people must have relied upon a much more broad-based diet in those parts of the highlands where nut pandanus produced aseasonally (Denham 2007c).

According to Hyndman (1984: 296), writing of the Wopkaimin of the Star Mountains, *Pandanus antaresensis* produces continuously throughout the year, which would compensate for the difficulty of getting at the nuts inside the hard fused drupes (Haberle 1995: 197). The species is unimportant as a food source throughout the highlands today (Haberle 1995: 197), although a range of other uses has been documented (Hyndman 1984: 296–298; Majnep and Bulmer 2007: 313–314, 330–332, 362). The abundance of carbonised drupe fragments of *P. antaresensis* in Late Pleistocene and early Holocene contexts at Manim 2, a rockshelter off the upper Wahgi Valley (Christensen 1975; Donoghue 1988), suggests that the species may have been a more important food source in the past. The period of relatively intensive exploitation of *P. antaresensis* at Manim 2, from before 11,800–10,300 BP to just after 7000–6350 BP, broadly corresponds to the deposition of grey clay at Kuk (see Fig. 6.10, note C and D) and a peak in the frequency of pandanus pollen (see Chapter 9, section ‘The early Holocene’ and Fig. 9.4). Haberle (pers. comm., 2008) states that the pandanus pollen at Kuk is overwhelmingly of *antaresensis*-type, which is also the case for a *Syzygium* swamp forest dating to about 8000 years ago at Kelela Swamp in the Baliem Valley (Haberle 1995: 207).

Pandanus of the *brosimos/julianettii* complex and *Castanopsis* are producers of abundant highly nutritious nuts that are still, or were until recently, targeted by highlands populations (Bourke 1996: 49–50 and Bulmer 1964, respectively). For *P. antaresensis*, which is not an important food source, there is no comparable information regarding productivity and food value (Robin Hide, pers. comm., 2008). Bulmer has remarked that the kernels of *antaresensis* nuts ‘require considerable effort to extract, for a rather small return’ (Majnep and Bulmer 2007: 314; cf. Hyndman 1984: 296). Several other fruit- and nut-bearing species were present at Kuk during the Pleistocene and Holocene (Table 10.1). Although of minor importance in contemporary diets, these fruit- and nut-bearing trees, together with edible forbs, ferns, shrubs, vines and fungi in the understorey, could have been highly significant contributors to diet in the past (after Powell 1982a: 210–211).

Archaeological associations

The presence in prehistoric contexts of plants that are today exploited for food does not mean they were necessarily used for food in the past. The presence of food plants in prehistoric contexts that are today associated with agriculture is not necessarily a sign of agriculture in the past. Even today, in simple numerical terms, most kinds of food plant are wild varieties (Powell 1976: Table 3.1). There is currently insufficient archaeobotanical resolution to determine whether most prehistoric plants were wild or domesticated varieties, although there is evidence for the use of plants that

were subsequently domesticated. More detailed corroboratory information on the use of plants is needed from occupation sites in the highlands, such as the archaeobotanical collection from Manim 2 (Christensen 1975).

Most food plants in archaeobotanical assemblages at Kuk occur in low frequencies and are not correlated to archaeological phases. The low frequencies suggest low numbers, wild plants and possibly adventitious colonisation of disturbed habitats. However, given the phenology, reproductive habits, infrequent flowering at altitude and harvesting prior to flowering of these plants under cultivation, their limited archaeobotanical signal is not entirely surprising (after Powell 1970a: 199). Overall, food plants have similarly low frequencies in seed assemblages from samples collected in undoubtedly agricultural contexts, i.e. Phase 4, 5 and 6 ditch fills and stratigraphy, which also had better preservation and generally larger assemblages of most taxa. The lack of correlation between food plant frequencies and archaeological phases in general suggests that the archaeological evidence reflects only a part of broader, continuous land-management practices. The wetland archaeological evidence has been buried and preserved, whereas that on dryland slopes within the catchment has been eroded.

Importantly, high frequencies of *Musa* spp., *Pandanus* spp. and Zingiberaceae phytoliths in early to mid Holocene contexts are suggestive of deliberate management. The presence of *Musa* section phytoliths, in particular, is significant, because two species of that section, *Musa acuminata* and *Musa balbisiana*, are central to the early domestication of *Musa* bananas and the subsequent development of hybrids and sterile triploids (Yen 1998; De Langhe and de Maret 1999; Lebot 1999).

Previous to the Kuk studies in the 1990s, it was thought that bananas of *Musa* (formerly *Eumusa*) section, as distinct from those of the former *Australimusa* section, were an Austronesian introduction to the region (Simmonds 1962; cf. Wilson 1985; see Table 10.1 note 7). However, recent biomolecular and genetic studies have shown that the wild subspecies of *M. acuminata* indigenous to New Guinea, *M. acuminata* ssp. *banksii*, is an early and significant contributor to the A genome of *Musa* section banana cultivars (De Langhe and de Maret 1999; Lebot 1999; Careel et al. 2002; Perrier et al. 2009, 2011). The genetic and biogeographic evidence, together with the high numbers of diploid *Musa* spp. still cultivated there, indicate the New Guinea region as a centre for the early domestication of *Musa* section bananas (Lebot 1999; Perrier et al. 2009, 2011; see Chapter 3 here). The presence of *Musa* spp. at Kuk in the early Holocene is therefore not necessarily a product of human agency, although wild populations of *M. acuminata* ssp. *banksii* and its close relative, *M. schizocarpa*, presently occur at much lower altitudes. In view of the current biogeographical and archaeobotanical evidence, the presence of *Musa acuminata* morphotypes at Kuk suggests natural dispersal into the highlands and/or intentional translocation of bananas from the lowlands by humans following climatic amelioration at the beginning of the Holocene. Irrespective of how they got there, cultivation of bananas at about 7000–6400 years ago at Kuk, including those of *Musa* section, corroborates and provides a minimum time depth for the domestication of bananas in New Guinea.

Given the estimated timing of the introduction of *Musa* bananas (with New Guinea-type A genome) into Africa by 2500 years ago (Mindzie et al. 2001) and perhaps as early as 5200 years ago (Lejju, Robertshaw and Taylor 2006), it is likely that banana domestication processes were underway before they were introduced there. Such processes would have involved the deliberate selection of desirable traits, ultimately leading to the development of parthenocarpy, hybridisation and seed sterility as seen in the fully domesticated banana varieties grown throughout the world today. Domestication of starch-rich food crops, including bananas, may have been initiated in the New Guinea region during the early Holocene or even earlier. *Colocasia* taro and a *Dioscorea* yam were present in the highlands and were being exploited by at least 10,000

years ago (see Textbox 10.3). Like *Musa* bananas, both taro and yam are generally considered to be lowland plants (Yen 1995: 835) and introduced to the highlands. Their presence in the early Holocene at Kuk therefore gives additional support for human translocation, deliberate planting and incipient domestication of starch-rich food crops.

Conclusion

The archaeobotanical records at Kuk and other sites, taken together with the chronology of agriculture in the highlands, enable some general trends in plant exploitation to be elicited. Some minor starch-rich staples, most vegetables and some nut-bearing trees in Pleistocene contexts are still cultivated and gathered from wild resources in the Kuk vicinity today. The Pleistocene antiquity of these plants at Kuk suggests that they were exploited, gradually brought under cultivation and in some cases domesticated from wild sources in the highlands.

For some of the major starch staples, particularly *Colocasia* taro, *Musa* bananas and *Dioscorea* yams, the history of plant use may be more complex. The earliest records of these three plants at Kuk coincide during the early Holocene, following post–Last Glacial Maximum climatic amelioration. These three plant groups are thought by some to be native to the lowlands of New Guinea, to have been domesticated there first and to have been brought into the highlands by agricultural populations who moved upward as climates ameliorated at the beginning of the Holocene (Hope and Golson 1995; Yen 1995; Golson 2007: 115–117). The archaeobotanical evidence appears to support this scenario. Detailed microfossil research has not been undertaken on sufficient Pleistocene samples to determine if any of the plants in question occurred in the highlands before the Holocene, although Bourke (Table 4.1) would argue the opposite on grounds of their altitudinal limits at the present time.¹ Even if these plants did diffuse to the highlands during the early Holocene, it is still not clear if people brought them as part of agricultural practices or as part of another form of plant exploitation (Denham and Barton 2006). Furthermore, it is quite possible that these three plants all dispersed naturally to the highlands from the lowlands as climates ameliorated.

In summary, from the early Holocene, most of the important plants of traditional highlands agriculture, including several starch-rich staples, were present in the upper Wahgi Valley. By taking the archaeobotanical finds in conjunction with other lines of evidence—primarily archaeological, palaeoecological and stratigraphic—specific landuses can be inferred during periods of wetland manipulation. During archaeological Phase 1 at Kuk, it is unclear whether people were engaged in agriculture (see Chapter 11, section ‘Agriculture at 10,000 years ago?’), although they were certainly practising a form of plant exploitation that included, among other things, digging, the likely tending of plants and the processing of tuberous plants. However, by at least 7000–6400 years ago (early Phase 2; see Chapter 12), people had begun to undertake mounded cultivation on the wetland margin, which is likely to have consisted of the intercropping of plants with different edaphic requirements. Subsequent periods of wetland cultivation (Phases 3–6; see Chapters 13–16) required the digging of ditches for drainage and to delimit plots, with cultivation on the intervening drained surfaces.

1 Horrocks, Bulmer and Gardner (2008: 300, cf. 293–294) say that starch evidence from Yuku rockshelter at 1280 m on the northern fall of the Sepik-Wahgi Divide suggests processing of the lesser yam, *Dioscorea esculenta*, possibly from before 14,000 years ago. The starch grain identifications were made on the basis of Horrocks, Grant-Mackie and Matisoo-Smith (2007). However, whatever the status of the identifications, the dating at Yuku is problematical and much of the stratigraphy is likely disturbed: see Table 10.1, notes 2 and 3 here; Denham (2016).

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