Phytoliths and the Evidence for Banana Cultivation at the Lapita Reber-Rakival Site on Watom Island, Papua New Guinea

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ABSTRACT. Analysis of phytoliths in sediments from Kainapirina (SAC) locality in the Reber-Rakival Lapita site on Watom Island, East New Britain Province, Papua New Guinea, directly confirms and expands on the types of terrestrial plants, both domestic and natural, identified in the cultural and ashfall deposits of c. 400 cal. B.C. to A.D. cal. 650 found at the site. A significant new finding is that evidence for banana cultivation throughout that period can be associated with both former and additional confirmatory evidence for the growing of coconut and *Canarium* nut trees plus a range of new plants. Gardening activity alternating with fallow is also strongly suggested by the types of natural tree cover at the conclusion of that occupation sequence and the garden soils lying just below the primary seventh century A.D. Rabaul volcanic ashfall.

Taken with the hypothesized existence of pig husbandry, which is based on a previous analysis of faunal remains, as well as information about diet derived from the study of stable isotopes and trace elements present in the human bones from the burials, there is a strong case that arboriculture and horticulture formed a major component of the late-Lapita and immediately post-Lapita economy at this site.

In 1965, some 56 years after Father Otto Meyer's early twentieth century investigations and report on the Reber-Rakival Lapita site on Watom Island (Anson, 2000*a*), Jim Specht began the long process of establishing its present-day credentials as an important site among those with Lapita style pottery. Despite the use of modern archaeological excavations and analytical methods (Specht, 1968, 1969), only recently has Reber-Rakival's true value as a late-Lapita site (Green & Anson, 2000*a*) within the widespread Lapita horizon (Kirch, 1997: 203–212) begun to be really appreciated. We offer this paper as a tribute to Specht who first identified the SAC locality of Kainapirina within the

Reber-Rakival site as having highly intact stratigraphy. Its two basal layers, with evidence of cultural occupation, contain a very late style of Western Lapita ceramics; the lowest layer also yielded human remains indicating the location was used as a burial ground during the late-Lapita period.

While Specht's investigations provided information about the ceramic content of these occupation layers, he was unsuccessful in obtaining much additional economic evidence beyond that previously obtained by Meyer, particularly with respect to arboriculture and horticulture. At various localities within the site, both Specht and Meyer found direct evidence for the use of *Canarium, Terminalia*, and coconut (*Cocos nucifera*) in the form of nutshells. More recent excavations at the SAC locality in 1985 by one of the authors (Green) further confirmed the presence of charred coconut shell fragments in both cultural layers (Rod Wallace, pers. comm., 1999) which were subsequently used for AMS dating. In addition, burned pieces of coconut and *Canarium* shells were obtained from a charcoal lens just below the seventh century A.D. Rabaul ashfall at the nearby SDI locality (Anson, 2000*b*: 104; Yen, 1991: 84).

Although direct evidence from plant remains for horticultural activity at SAC remained elusive, some form of cultivation was inferred based on a number of indirect indicators which included the presence of domestic pig and chicken bones (Anson, 2000*a*: 17–18; Specht, 1968: 125–126). One of the strongest indicators from an analysis of the pig bones and their age at death implied a well-developed form of pig husbandry at SAC during the period of Lapita occupation rather than just hunting feral animals. As Smith (2000: 145) notes, "it seems unlikely that pig rearing could be sustained on a small island such as Watom unless food crops were also grown". The 1985 SAC excavations revealed a further five skeletons in addition to the three Specht had found (Green & Anson, 1987: 126). Coupled with the fairly recent developments in the analysis of isotopic and trace element signatures, the human remains provided another way to demonstrate that the diet of the people associated with the SAC Lapita occupation was dominated by a substantial edible terrestrial plant component (Green & Anson, 2000*b*: 49–50; Horwood, 1998; Leach *et al.*, 2000: 158).

Another line of evidence for the inference of horticulture was development of a palaeosol on the late-Lapita occupation layer which was considered to have formed in part as a product of gardening activity. This interpretation was based, firstly, on the loamy texture of the sediment itself and the leaching of shell calcium from it; secondly, the repetitive mixing of the deposit leading to the obvious displacement of bones and artefactual material due to continued human disturbance; and thirdly, the abundance of small broken fragments of bone resulting from mechanical breakdown (Smith, 2000: 141–142). Some disturbance of the terrestrial plant cover inducing a heightened degree of erosion, probably from clearing for gardening on the slopes above the raised limestone cliff at the back of the SDI locality, is also attested in the increased loam content of its successive cultural layers C4 to C1 resting on a sand beach layer (Anson, 2000*b*: 98–99).

All of the above constitute supportive lines of evidence for an arboriculture and horticultural gardening component forming a major basis of the late-Lapita and immediately post-Lapita human diet at the Reber-Rakival site.[1] This is consistent with what is inferred more generally for sites of the Lapita horizon (Kirch, 1997: 203–212). Yet, empiricists among us would require additional direct evidence from plant remains themselves to more firmly establish the claim. If macro-remains could not be retrieved by basic excavation techniques, then an analysis based on plant micro-fossils was the most obvious alternative way of finding direct associations between people, plants and sediments.

Why phytolith analysis? It was the circumstance of one author (Green) hearing the other (Lentfer) reporting on the recovery of plant phytoliths (plant silica cells) from beneath volcanic ashfalls in the Talasea region of West New Britain Province at the Fourth Lapita Workshop Conference in Canberra in June 2000 that led to Green's recognition that the SAC locality offered a splendid context for applying that relatively new technique in this tephra covered region of the Pacific. Moreover, Green knew he had three appropriate sediment samples taken during the 1985 excavations at SAC and on his return to Auckland he quickly ascertained that they indeed contained phytoliths (Rod Wallace, pers. comm.). Here was yet another means for not only further confirming what was already claimed but also directly expanding the range of plants including possible cultivars associated with the SAC locality. He contracted Lentfer to analyse these three sediment samples. The primary aims of this analysis were to determine vegetation communities, disturbance patterns and change associated with Lapita settlement, and search for additional evidence of horticulture.

The SAC locality and sampling location

SAC, at the time of Lapita occupation, was located on a low lying, well-drained sand spit beach adjacent to the sea and bordered by raised limestone cliffs to the west and southwest (Figs. 1, 2 and 3). The beach emerged between 3,500 and 3,300 years ago as a result of a hydro-isostatically controlled lowering of the sea level (Green & Anson, 2000*b*: 39). Three distinct stratigraphic layers were sampled from the south section of Square I-15 in Rectangle III (Figs. 4 and 5). The uppermost of these three layers, B2, represents a zone of primary ashfall 5 to 10 cm thick comprising a plinian pumiceous tephra (Table 1). It was derived from one of the largest eruptions of the Rabaul volcano recorded for the Holocene at between A.D. cal. 650 and 850 (ANU 5338) (Anson, 2000*b*: 102; Nairn *et al.*, 1995). The ash fallout from this catastrophic eruption effectively buried and sealed the underlying ground surface. Subsequently this layer itself was covered by an additional layer of re-deposited ash washed in from the surrounding area. The layers of interest to this analysis lie directly under the layer of tephra. These comprise an upper layer C1, a black sandy loam with an estimated age of 150 cal. B.C. to A.D. cal. 650 (ANU 5330), and a lower layer C2, midden with a grey coralline sand matrix with an age range estimated to be from 400 to 100 cal. B.C.[2] (ANU 5336, Beta 16835; see Green & Anson, 2000*b*: 38–39, 87). Beneath C2 lies a culturally sterile beach sand. Importantly, both C2 and C1 have been identified as late-Lapita occupation layers with shell, fish and pig bones, pottery sherds and stone artefacts. There is evidence for building construction and domestic habitation in the first phase of occupation in C2 (c. 400 to 300 cal. B.C.) which was followed by a period between 300 and 100 cal. B.C. when the site was used for burials. More recently,

Table 1. Summary of sediment characteristics at SAC.

| sample | sediment zone | description | Munsell colour | | pH | Fig. 5 key field descriptions |
			dry	wet		
B2	tephra	Plinian pumiceous tephra	2.5Y 6/2 light brownish grey	2.5Y 3/3 dark olive brown	7.65	ash
C1	palaeosol	sandy loam	7.5YR 2.5/2 very dark brown	10YR 2/2 very dark brown	7.65	black loam
C2	midden	coralline sand	10YR 4/1 dark grey	10YR 2/2 very dark brown	8.09	grey sand midden
	sterile sand	sterile beach sand				coral sand

during the initial development phase of C1, the land use reverted to something associated with domestic activity (between c. 150 cal. B.C. and A.D. cal. 50) which changed later to gardening between A.D. cal. 100 and 650 (Green & Anson, 2000*b*: 84).

Background information

Vegetation characteristics and patterns of plant colonization in relation to the sand spit environment at SAC. Studies documenting the vegetation of tropical Pacific Islands (Mueller-Dombois & Fosberg, 1998; Peekel, 1984) indicate that in the Bismarck region strand vegetation typically consists of an herbaceous cover of creeping plants (e.g., *Ipomoea pes-caprae, Canavalia rosea*) as well as grasses and sedges (e.g., *Ischaemum muticum, Lepturus repens, Thuarea involuta, Fimbristylis* spp. and *Cyperus pedunculatus*). The shrub and tree strata are often dominated by *Wollostonia biflora, Scaevola sericea, Hibiscus tiliaceus, Tournefortia argentea, Barringtonia asiatica, Terminalia catappa, Calophyllum inophyllum, Pandanus tectorius* and *Casuarina equisetifolia*. Botanical surveys in the Rabaul region and on islands in West New Britain (Lentfer, 1995; Lentfer & Boyd, 2001) support this description, and verify the predictability of colonization processes and composition of strand vegetation in the region. Furthermore, the Rabaul studies, in particular, reveal the rapid nature of strand colonization even after catastrophic volcanic eruptions, and provide a basis for determining the range of possible environments present on the sand spit at the time of the first Lapita occupation.

Indeed, on the basis of understanding the predictable nature of strand environments, especially colonization and successional processes, there are good grounds for assuming that the beach at SAC was colonized by plants within a reasonably short period of time following its formation— perhaps within a few years after it stabilised. Also, in view of the beach's close proximity to surrounding forests on the bordering cliffs, it is likely that the successional processes were relatively fast, with the introduction of a more complex array of species, predictably present in early secondary tropical vegetation in the region (Lentfer & Boyd, 2001; Thornton, 1996). Therefore, it seems reasonable to assume that at the time of the first Lapita occupation of the locality there was at least some vegetation cover on the sand spit with strand elements similar to that listed above. Furthermore, depending on beach stabilization processes, it is likely that additional early secondary growth and possibly elements of late secondary and primary forest vegetation were present, particularly in sheltered locations. While this cannot be substantiated within the framework of

this analysis, at least some indication of environmental complexity on the recently formed ocean beach environment at approximately the time of first settlement, should be evident from the nature of the phytolith assemblage in the oldest occupation layer, C2.

Sediment characteristics. The characteristics of the three sediment samples vary significantly and are summarized in Table 1. Notably, C2 is more alkaline than the other sediments but is within the range suitable for phytolith preservation. The distinguishing features of the sediments are: the abundance of pumiceous tephra sherds in B2; the siliceous aggregates high in organic matter in C1; and, the presence of shell, coral and sponge spicules in C2.

Sampling and extraction methods

The three sediment samples were collected in 1985 from the SAC excavation pit. They were taken from the south section (Fig. 4), 30 cm from the west section where the stratigraphy was equivalent to that shown in the D-D' transect (Fig. 5). Layer B2, being of no greater thickness than 10 cm at the sampling location was sampled across its entirety avoiding the interface of adjacent layers. Samples from C2 and C1 with greater thickness (20 to 40 cm respectively) were taken from the middle of each layer. Each sample was of c. 10 cm vertical thickness. Five grams of each sediment sample were deflocculated in 5% Calgon solution and sieved through a 300 μm mesh. The fine fractions were used for phytolith analysis. Phytoliths were extracted using a rapid microwave digestion protocol adapted from Parr (2002).

Analytical procedure

Estimation of phytolith and charcoal concentration in sediment samples. Fine sediment fractions (<300 μm) were mounted in benzyl benzoate on microscope slides. The slides were viewed at 400× magnification. All particles were counted in 12 fields randomly selected across each slide. For every field the number of discrete diagnostic phytoliths and charcoal fragments were counted. Charcoal comprised black opaque particles (Piperno & Becker, 1996). Concentrations were measured as the total number of phytolith or charcoal particles per total number of particles and converted to percentage values.

Phytolith classification and counting procedure. Slides were examined under polarized light with an optical microscope. Numbers of all siliceous particles, including

Fig. 2. View of the SAC locality at Reber village 2002. The SAC trench was dug to the right of the church. (Photograph Carol Lentfer).
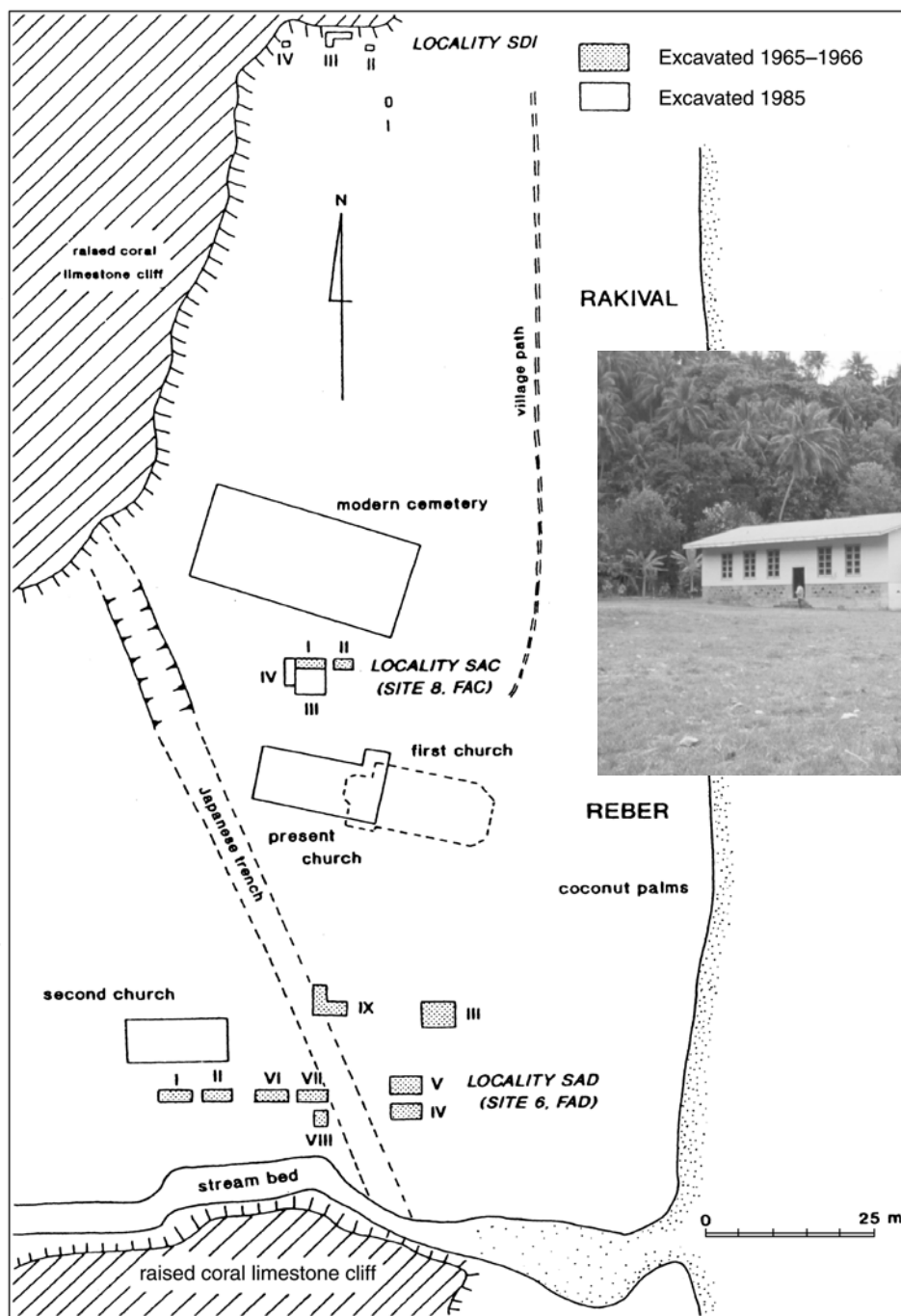
Fig. 1. The Reber-Rakival Lapita site showing localities SAC, SAD and SDI and modern structures (from Green & Anson, 2000*b*: 32). Japanese tench dates to World War II.

particles considered to be (*a*) amorphous and/or non-diagnostic, and (*b*) diagnostic phytoliths, were counted in randomly selected fields at 400× magnification. All new morphotypes encountered were described using the terminology proposed by Bowdery *et al.* (2001). Photographs were taken of morphotypes considered to have cultural or environmental significance.

Counting and recording continued until the frequency of new morphotypes encountered approached zero. Following this, the slides were scanned for any new morphotypes not encountered previously. These types were drawn and their presence noted.

During and after the recording procedure morphotypes were compared with phytolith reference samples from plants collected in New Britain and elsewhere in Papua New Guinea (Lentfer, 2003). Where accurate taxonomic identification was possible, phytoliths were assigned to plant family groups, families, genera and species. Where morphotype redundancy (i.e., morphotypes common to several different species and/or genera) was considered to be a confounding factor for accurate identification, comparative taxonomic classifications were given. Other morphotypes, common to several different plant groups, were assigned to growth form categories.
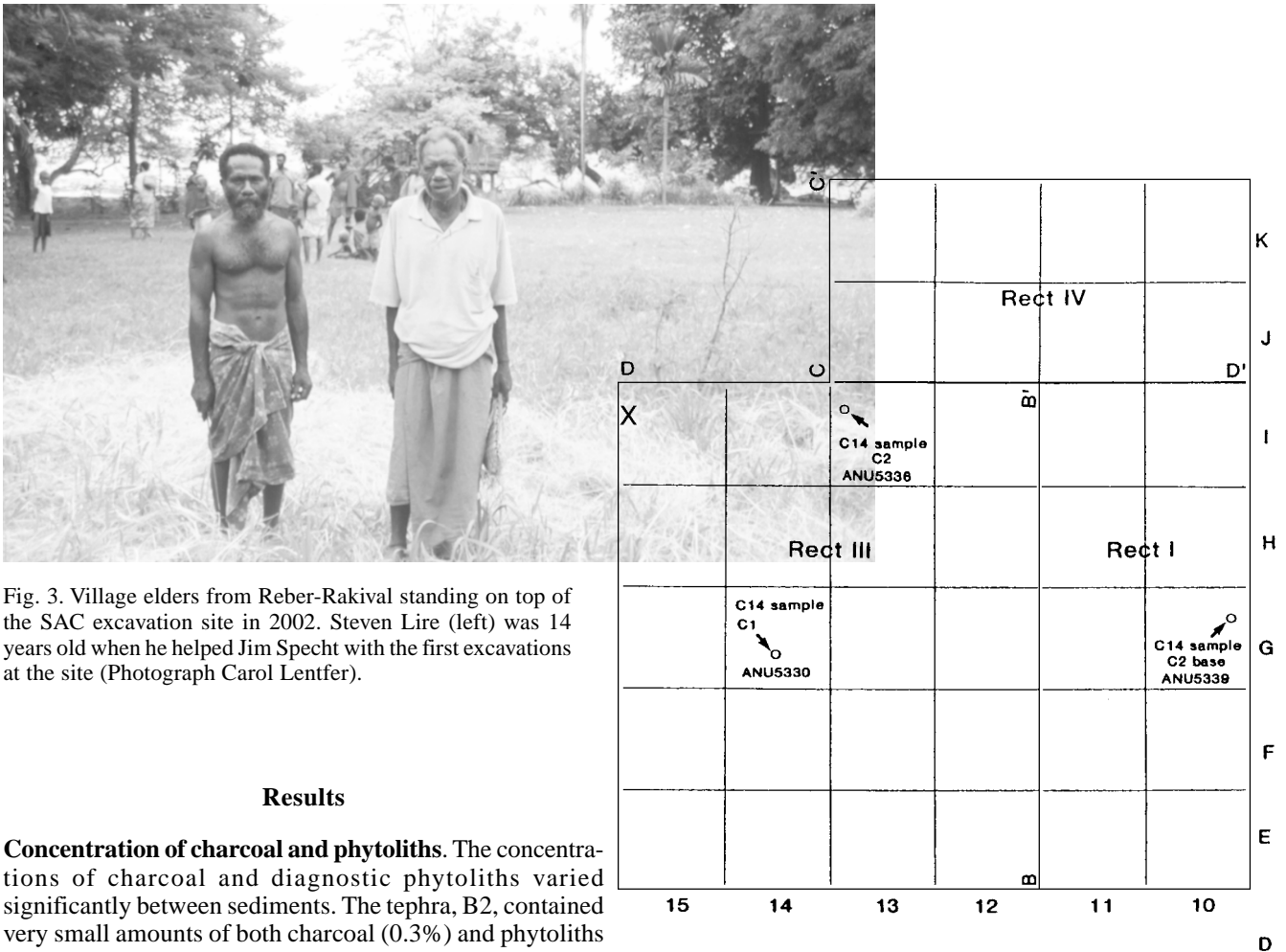
Fig. 3. Village elders from Reber-Rakival standing on top of the SAC excavation site in 2002. Steven Lire (left) was 14 years old when he helped Jim Specht with the first excavations at the site (Photograph Carol Lentfer).

SITE 8—SAC

Rect I—E, F, G, H, I—10 & 11
Rect II—A, B, C—11, 10
Rect III—E, F, G, H, I—12, 13, 14, 15
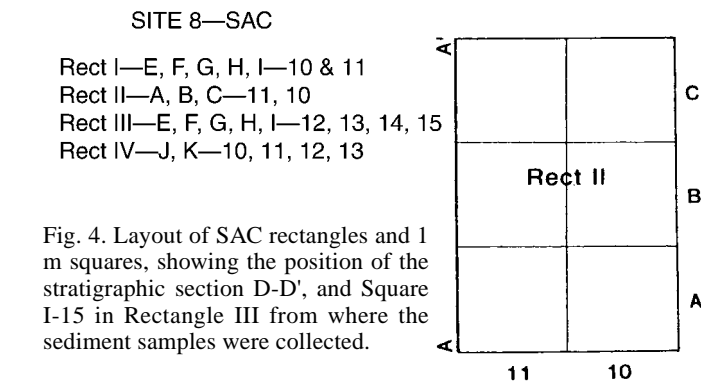Rect IV—J, K—10, 11, 12, 13

Fig. 4. Layout of SAC rectangles and 1 m squares, showing the position of the stratigraphic section D-D', and Square I-15 in Rectangle III from where the sediment samples were collected.

Results

Concentration of charcoal and phytoliths. The concentrations of charcoal and diagnostic phytoliths varied significantly between sediments. The tephra, B2, contained very small amounts of both charcoal (0.3%) and phytoliths (0.8%), contrasting with the palaeosol C1, with 14% charcoal and 7.8% phytoliths. Concentrations in C2 fell between the above with a moderate charcoal content of 4.6% but a much lower value of 1.9% for phytoliths.

The phytolith assemblages. *Categorization of morphotypes and assemblage variation*. Counts on slides varied according to the proportion of diagnostic phytoliths to non-diagnostic phytoliths and amorphous silica (this did not include obvious sherds of tephra). A total of 585 particles were counted for B2, 796 for C1 and 774 for C2. Of these total counts, between 300 to 400 were diagnostic phytoliths. Four amorphous/non-diagnostic groups and 59 separate diagnostic morphotypes were recognized. Following comparison with reference material the diagnostic morphotypes were grouped into 35 categories. Frequencies were then converted to percentage values (Table 2).

Thirty-five diagnostic morphotypes could be assigned to plant family groups, families, genera and species. The remainder consisted of types considered to be redundant. These were assigned to less well-defined groups based on growth form (Table 2). Within these major categories, B2 the tephra, contained the fewest diagnostic morphotypes (19), most were recorded in C1 the palaeosol (33), and 25 were recorded in the oldest cultural layer C2.

Of the diagnostic morphotypes the majority belonged to a suite of trichome bases, trichomes, epidermal and bulliform phytoliths derived mostly from pioneer and early secondary lowland tropical forest species within the Euphorbiaceae, Moraceae and Urticaceae families.

Additionally, morphotypes belonging to tall herbs and palms, including bananas (Musaceae), gingers (Zingiberaceae), cordylines (*Cordyline* sp.), the fish-tail palm (*Caryota* sp.) and other palms (Arecaceae), were present in the assemblages. Grass (Poaceae) and sedge (Cyperaceae) morphotypes were also present albeit at low frequencies. Ten distinct grass morphotypes, including nine bilobate and similar short cell forms and one bulliform were recorded. Most of these were common to a number of grasses including a shade-tolerant forest grass, *Oplismenus compositus*, the pioneer species *Ischaemum muticum*, sugarcanes (*Saccharum* spp.), and a tall-growing grassland species, *Ophiuros tongcalingii*. The lobate/cross form, noted to occur in Job's tears *(Coix lachryma-jobi)*, a native grass
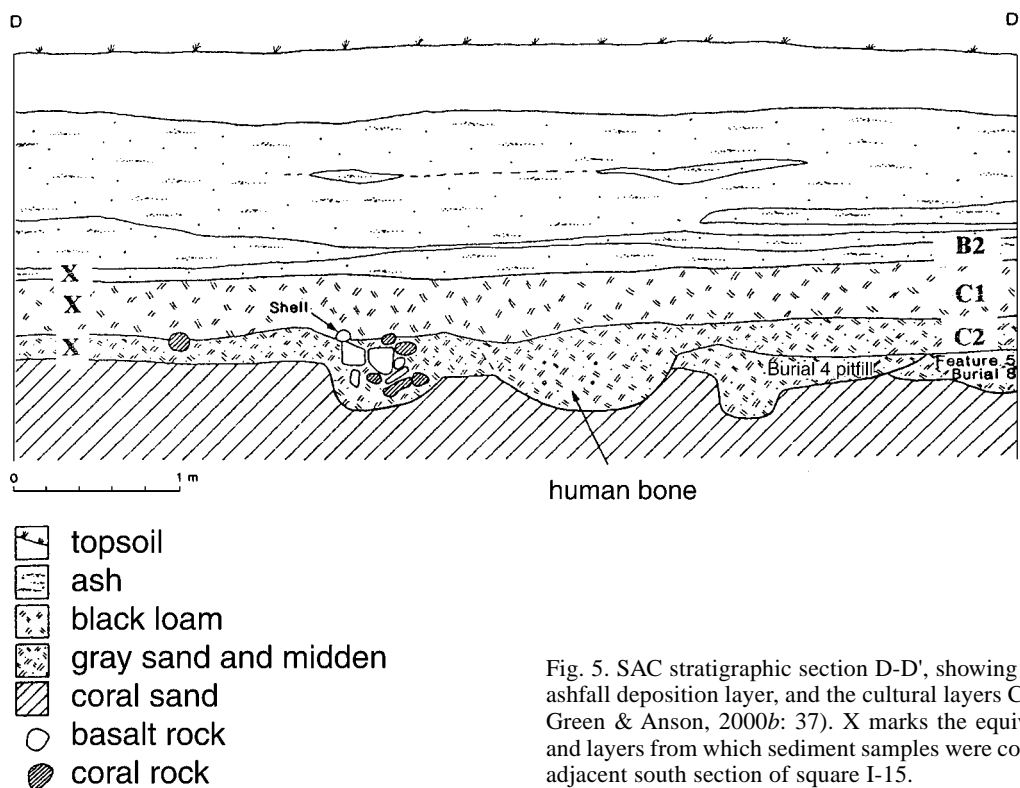
Fig. 5. SAC stratigraphic section D-D', showing the B2 primary ashfall deposition layer, and the cultural layers C1 and C2 (from Green & Anson, 2000*b*: 37). X marks the equivalent locations and layers from which sediment samples were collected from the adjacent south section of square I-15.

in the same tribe as maize, was the only morphotype identified that is possibly species-specific. There was only one morphotype possibly derived from a small sedge (*Cyperus sphacelatus*) commonly found growing in coastal strand environments.

Relative proportions of all morphotypes varied considerably between sediments, with χ^2 tests showing significant differences between B2 and C1, and C1 and C2 assemblages at $\alpha \leq 0.05$. High frequencies of secondary shrub and tree morphotypes occurred in all assemblages; nevertheless the relative proportion of these in the B2 assemblage was much higher than the other assemblages— almost double. Notably, although the C1 and C2 assemblages had similar morphotype presence (see the summary figures at the end of Table 2), there were relatively more vesiculate block and elongate 1 morphotypes in C1 than C2. By contrast, the relative frequency of the tuberculate spheroid 1 morphotype was higher in C2.

Morphotypes of cultural significance. Diagnostic banana (*Musa* spp.) morphotypes were present in all SAC assemblages. Similar relative frequencies were recorded in C1 and C2 assemblages (Table 2). However, only one was recorded in the quick scanning procedure used for the B2 tephra assemblage and thus only its presence was noted. Additionally, a second group was recorded. This consisted of a suite of variable spheroidal morphotypes marked by having troughs with weakly defined rims, as well as small trough apertures in comparison with the body dimensions. These occur in both Zingiberaceae and Musaceae and were given the classification of Zingiberaceae/Musaceae accordingly.

Due to the economic importance of the Musaceae and the relatively low frequency of diagnostic morphotypes recorded in the original assemblage counts, slides were rescanned in continuous transects to record all diagnostic Musaceae phytoliths present. This resulted in a total of 39 and 58 phytoliths being recorded from C1 and C2 samples respectively. Following comparison with modern plant material, this suite of morphotypes was divided into two major groups—seed and leaf/bract morphotypes (Table 3). Thirty-three percent (33%) and 25% of the seed morphotypes in the C1 and C2 assemblages respectively were identified as *Eumusa* (Figs. 6 to 9), while the remaining morphotypes in this group were common to both *Australimusa* and *Eumusa* bananas as well as *Ensete*. Notably, seed morphotypes specific to either *Australimusa* or *Ensete* alone were not recorded.

The leaf/bract morphotypes were more difficult to classify due to the high degree of variation within and between species. However, when compared to reference samples, 13.3% of the leaf/bract morphotypes in the C1 assemblage bore more similarity to the *Eumusa* complex, in particular *Musa acuminata* (Figs. 10, 11), than to either *Australimusa* or *Ensete* species, and 3.3% were more similar to the *Australimusa* species, in particular *M. maclayi*. The remaining morphotypes were less well-defined and were regarded as general types. None of the leaf/bract morphotypes in the C2 assemblage could be assigned to specific *Musa* sections or species, and likewise these were placed in the general categories. Notably, χ^2 tests showed that there was no significant difference between the C1 and C2 Musaceae assemblages at $\alpha = 0.05$.

Other morphotypes in the sediment assemblages with possible cultural significance include those derived from palms, gingers, the cordylines, Job's tears, possibly the sugarcanes and figs (*Ficus* cf. *copiosa*), and additionally some of the large granulate blocks possibly derived from *Canarium,* since these types are abundant in the wood of

Table 2. Concentrations of charcoal and phytoliths and percentage composition of phytolith morphotypes extracted from SAC sediments.

	sediment zone B2 tephra %	C1 loam %	C2 midden %
charcoal	0.3	14.0	4.6
phytoliths	0.8	7.8	1.85
NON-DIAGNOSTIC PHYTOLITHS			
aggregate/granulate	54.8	80.1	67.9
sherd/vesiculate	13.5	1.7	14.1
plate/psilate	31.6	18.2	18.0
spheroid <10µm	27.3	17.1	31.7
DIAGNOSTIC MORPHOTYPES			
SHRUBS/TREES			
Euphorbiaceae/Moraceae/Urticaceae			
prism/facetate	10.7	3.4	2.9
spheroid/prism complex	5.2	2.4	0.4
spheroid/vesiculate	53.4	26.9	26.1
block/perforate	0.0	0.7	1.1
block/vesiculate	2.9	6.3	0.7
Urticaceae			
point/verrucate .... cf. *Dendrocnide cordata*	5.8	0.2	1.8
short point/echinate	0.3	0.0	0.0
Euphorbiaceae			
point/psilate .... cf. *Macaranga* sp.	0.0	P	0.0
Moraceae			
long point/echinate .... *Ficus* cf. *copiosa*	0.0	0.2	0.4
block/echinate .... *Ficus* cf. *copiosa*	0.0	1.9	6.4
TALL HERBS/PALMS			
Zingiberaceae/Arecaceae			
spheroid 1/tuberculate	2.9	4.6	14.3
spheroid/psilate	0.3	1.9	2.5
spheroid/echinate <10µm	4.5	8.4	10.0
PALMS			
Arecaceae			
spheroid/echinate 10–25µm .... cf. *Calamus* sp./*Cocos nucifera*	1.3	3.4	4.6
spheroid 2/tuberculate .... *Caryota rumphiana*	0.0	0.0	P
Liliaceae			
spheroid 3/tuberculate .... *Cordyline* sp.	0.0	P	0.0
Musaceae/Zingiberaceae			
spheroid/trough ...... cf. *Musa* spp./*Hornstedtia* spp./*Tapeinochilos* spp.	0.0	1.9	2.5
Musaceae			
block/tuberculate/trough ....*Musa* spp.	P	3.6	4.3
GRASSES			
Poaceae			
bilobe 2 .... cf. *Oplismenus compositus/Ischaemum muticum*	0.0	0.5	0.0
bilobe 5 .... cf. *Oplismenus compositus*	0.0	P	0.0
bilobe 3 .... cf. *Oplismenus* sp./*Saccharum* spp.	P	0.5	0.0
bilobe 6 .... cf. *Oplismenus* sp./*Saccharum* spp.	0.0	0.2	0.4
prism 1 .... cf. *Oplismenus* sp./*Saccharum* spp.	P	P	0.0
bilobe 4 ....cf. *Saccharum* spp./*Ischaemum muticum*	0.0	P	0.0
bilobe 1 .... cf. *Ophiuros tongcalingii*	0.3	0.2	0.0
prism 2 .... cf. *Ophiuros tongcalingii/Ischaemum muticum*	P	P	0.4
lobate/cross ....*Croix lachryma-jobi*	0.0	0.0	P
bulliform 1/psilate	0.0	1.2	1.1
SEDGES			
plate/ruminate/trough .... *Cyperus* cf. *sphacelatus*	0.0	P	P
TREES/SHRUBS/HERBS			
elongates 1	9.7	24.5	9.6
block/granulate >25µm	0.0	1.0	2.5
bulliform 2/psilate/tuberculate	1.6	0.7	0.7
grass/herbs/trees/shrubs			
block/psilate/tuberculate <25µm	0.0	1.4	2.5
long Point/psilate	0.0	0.5	0.0
point/granulate	P	P	0.0
elongates 2	1.0	3.4	5.0
SUMMARY			
shrubs/trees	78.3	42.1	39.6
trees/shrubs/herbs	11.3	26.2	12.9
tall herbs/palms	9.1	23.8	38.2
grass/herbs/trees	1.0	5.3	7.5
grass	0.3	2.6	1.8
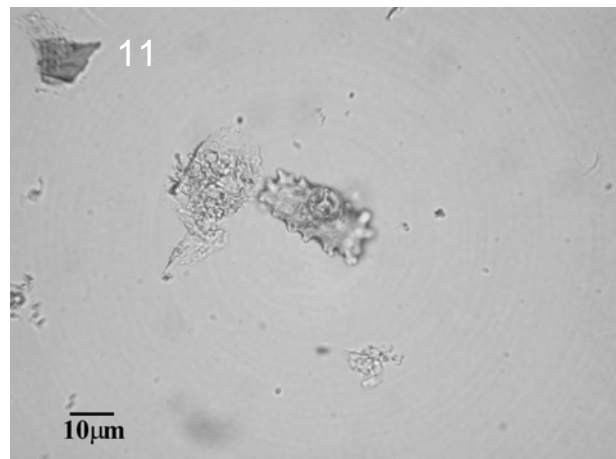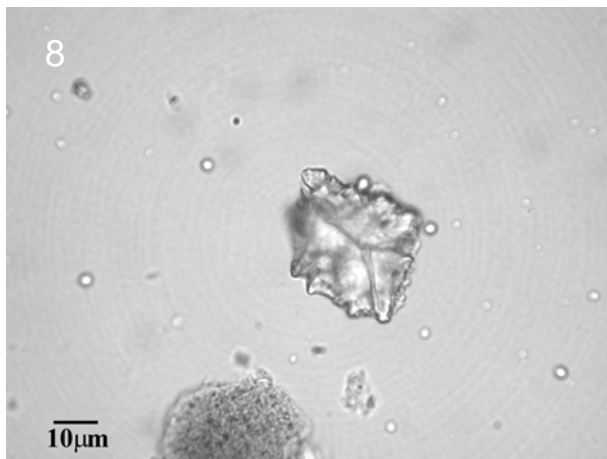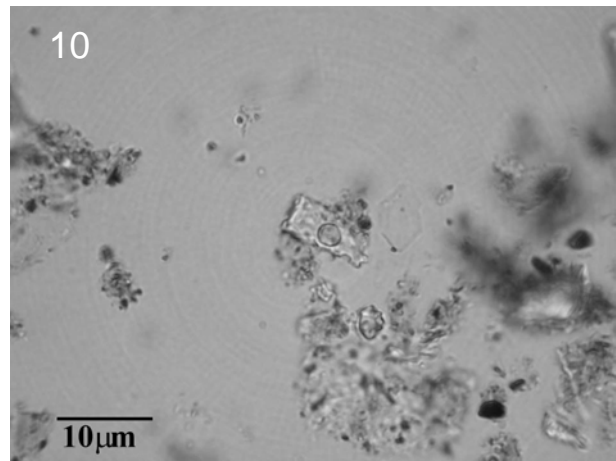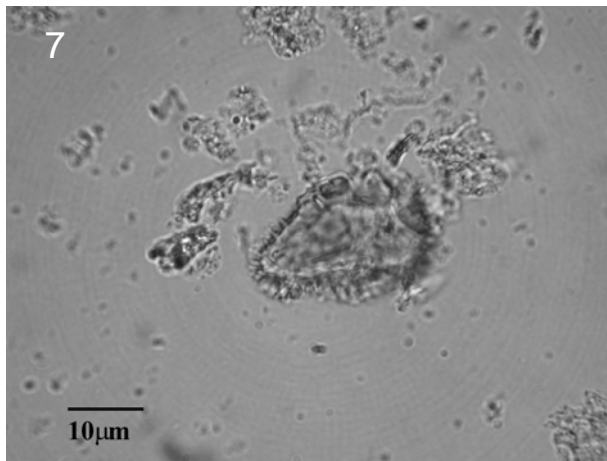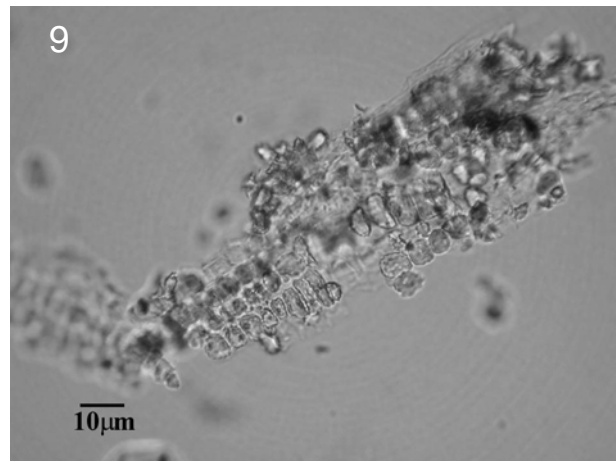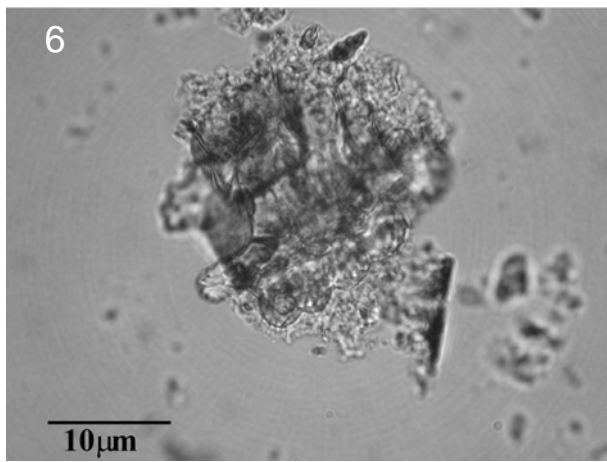
Figs. 6–11. (*6*) Sheet phytoliths from the midden sediment C2. The same articulated morphotypes are found in the seeds of *Musa acuminata banksii,* see Fig. 9. (*7*) Phytolith from C2. This morphotype is also found in seeds of wild *Eumusa* bananas. (*8*) Phytolith morphotype found in the palaeosol sample C1. The central ridge is a diagnostic feature of *Eumusa* seed phytoliths. (*9*) Sheet of seed phytoliths from *Musa acuminata banksii*. The plant material was obtained from the Queensland Herbarium, accession no. QH067962. (*10*) Phytolith from C1. This morphotype is commonly found in leaves of cultivars derived from *Musa acuminata*. (*11*) Leaf phytoliths from cultivated *Eumusa* banana from West New Britain, accession no. SCU WNB1024.

this genus. Of these, the cordyline morphotype in the C1 assemblage, and the fish-tail palm and one of the ginger morphotypes (*Tapeinochilos* sp.) in the C2 assemblage, were positively identified to the generic level. Most of the palm morphotypes, however, were more difficult to differentiate, having similar forms to spheroids, not only found in other palms, but also in a number of gingers. This suite of ginger/palm confounders includes the tuberculate spheroid morphotype, most common in the C2 assemblage, and the larger psilate and small echinate spheroids most common in both C1 and C2 assemblages. Likewise, the larger echinate spheroids with higher relative frequencies in C1

Table 3. Number and percentage frequencies of Musaceae phytolith morphotypes in C1 and C2 assemblages at SAC.

phytolith morphotypes	category	sediment zone			
		number of phytoliths		% frequency	
		C1 loam	C2 midden	C1 loam	C2 midden
seed forms					
block/tuberculate	Eumusa	3	3	33.3	10.7
block/trough 1	Eumusa	0	4	0.0	14.3
block/trough 2	General	6	21	66.7	75.0
leaf/bract forms					
tabular/trough/orn 1	Eumusa	4	0	13.3	0.0
tabular/trough/orn 2	Australimusa	1	0	3.3	0.0
tabular/trough/orn 3	General	15	14	50.0	46.7
spheroid	General	10	16	33.3	53.3

and C2 could not be assigned to a single palm species, being common to rattans (*Calamus* spp.) and the coconut (*Cocos nucifera*). Additionally, the echinate trichomes and blocks assigned to *Ficus* cf. *copiosa* are possibly doubtful given the small numbers present in the assemblages and the large variation of those morphotypes in the numerous fig species that occur in the region. Likewise, the large granulate blocks, common in the wood of *Canarium* species, have a broad distribution in many plant groups making taxonomic classification difficult. Finally, from the grass morphotypes it is highly probable that the lobate/cross form found in C2 was derived from Job's tears. However the status of the *Saccharum*-like morphotypes is less certain since these are not confined to cultivated species of sugarcanes (*Saccharum officinarum* and *S. edule*), also being present in *S. robustum* and *S. spontaneum* (pioneer grasses in the same genus), *Oplismenus compositus, Ischaemum muticum*, and possibly a suite of other grasses.

Discussion

The charcoal and phytolith concentrations, as well as the morphotype distribution in the phytolith assemblages from the three SAC sediments, were clearly differentiated. Layer C2, marking the earliest phase of settlement, had relatively low concentrations of phytoliths and some evidence of burning. The vegetation represented by the morphotypes comprised mostly arboreal vegetation as well as tall herbs and palms. Phytolith input from similar vegetation increased substantially in the following phase, C1, and there was a significant increase in levels of burning. The final phase in the sedimentary sequence marked by B2 was notable in having very low concentrations of both phytoliths and charcoal. The vegetation represented by the morphotypes in this layer also changed, and was largely dominated by trees. Thus, within this analysis, the patterns of change observed in the charcoal and phytolith record concur with changes in the archaeological record and provide strong support for taphonomical integrity. How the observed changes reflect the nature of the plant environment, patterns of human activity and land use specific to the SAC locality is discussed below.

General trends and vegetation change

Layer C2. The assemblage in layer C2, representing the earliest occupation phase, has a high relative frequency of morphotypes derived from secondary forest species comprising the Euphorbiaceae/Moraceae/Urticaceae complex, relatively low frequencies of grasses and sedges and an absence of peas and composites. This assemblage implies that either: (*a*) plants represented by the phytolith morphotypes were brought into the site specifically for building house structures and domestic purposes (this is considered to be unlikely since most of the morphotypes are leaf, not wood derivatives); (*b*) the strand vegetation in the vicinity of the SAC site had developed considerably beyond the pioneer strand forest stage at the time of occupation—this is also possibly indicated by the ginger/palm complex, the ginger component in particular; or (*c*) the beach vegetation was still undeveloped and phytoliths were derived from leaf litter and sediment washed into the site from the surrounding escarpment, possibly as a result of disturbance there. It is notable that the assemblage composition of C1 and C2 were significantly different. Therefore, there is no evidence for contamination of the C2 assemblage resulting from downwashing of phytoliths from C1.

The very low concentration of phytoliths in the sediment is significant, possibly due to SAC being situated on a mainly open sandy beach with minimal leaf litter, or rapid deposition of sediment relative to plant microfossil input. This accords with points (*a*) and (*c*) above. It is notable, however, that ethnographic and palaeoenvironmental studies have recorded low phytolith densities in swept village environments in both coastal and forested areas in other parts of New Britain (Boyd *et al*., 1998; Parr *et al*., 2001). Therefore, as there is good archaeological evidence for an initial phase of building activity indicating domestic habitation in this phase (Green & Anson, 2000*b*), ground sweeping to remove excessive litter from around habitation areas could also be a contributing factor here.

Layer C1. The dramatic increases in concentrations of phytoliths and charcoal in layer C1 (Table 2) mark a substantial change in land use at the SAC locality and possibly on the surrounding escarpment. Certainly, if ground sweeping was responsible for low concentrations of phytoliths in the first phase of occupation, there is very little

evidence for this type of activity in the second phase wherein concentrations quadrupled. Rather, having considerably higher microfossil and charcoal concentrations and thus comparatively more grass and Musaceae morphotypes than C2,[3] there is strong evidence for gardening activity in C1. Additional support for this is given by the large component of morphotypes derived from secondary forest tree species and understorey gingers that commonly invade abandoned gardens (Lentfer, 1995; Mueller-Dombois & Fosberg, 1998; Paijmans, 1976). The likely presence of the shade tolerant grass *Oplismenus compositus* indicates that either: (*a*) the garden clearing was relatively small, certainly not of a scale large enough to encourage the prolific growth of sun tolerant grasses (Boyd *et al.*, 1998); (*b*) bananas were planted in sufficient numbers to create shade over the ground cover; or finally, (*c*) the garden was planted under a canopy, possibly of coconuts. For any of the above, considering the high relative abundance of regrowth elements, it is likely that the garden environment was held in a state of flux throughout the entire occupation phase, alternating between fallow regeneration and cultivation.

Layer B2. After the ashfall, concentrations of charcoal and phytoliths again fell to extremely low levels. Since this layer was culturally sterile, it is of interest to consider the origin of the phytoliths present. Were they derived from leaves and wood and incorporated into the ash during and after the fall as the buried plant material decayed, or were they washed down into the primary tephra from the secondary ash burying it? Certainly, further investigation of phytolith distribution patterns throughout the primary and secondary ash deposits is necessary before this can be truly resolved. However, having said this, there is a degree of support from the B2 assemblage for in-situ derivation of phytoliths. For instance, the morphotypes mostly comprised secondary forest elements similar to the C1 layer, which accords with the expected bush fallow vegetation growing in an abandoned garden. Compared with the C1 assemblage, there was a higher relative frequency of Urticaceous morphotypes and a significant decline in frequencies of tall herbs and grasses. While the latter may have resulted from differential destruction of plants during the ashfall, whereby more flexible grasses and herbs were flattened and not incorporated into the ash layer, as much as below it, there is still strong evidence from the Urticaceous element showing the B2 assemblage to be representative of a successional environment with transitional forest elements typical of early secondary and late secondary vegetation (Mueller-Dombois & Fosberg, 1998). Therefore, this implies that before the ashfall the vegetation was comparatively well developed, most likely following a lengthy period of garden abandonment immediately prior to the Rabaul eruption and the resultant ashfall. This has also been suggested by Smith (2000) following an analysis of the weathering patterns of pig bones.

Evidence of banana cultivation. The most outstanding outcome of this analysis is the presence of Musaceae morphotypes in the assemblages. This constitutes the first direct evidence of bananas in association with Lapita settlement in the Bismarck Archipelago. Importantly, it raises questions about whether these were derived from cultivated bananas or wild bananas growing naturally in the SAC environment.

Watom Island is within the natural geographical range of *Ensete* and *Australimusa* and *Eumusa* wild bananas (Argent, 1976; De Langhe & De Maret, 1999; Simmonds, 1962), although a recent survey by Lentfer in August 2002 found no evidence for wild plants from either section growing on the island itself. Two wild *Australimusa* species (*Musa peekelii* and *M. maclayi*[4]) presently grow in close proximity to Watom Island. Both species occur on New Ireland and *M. peekelii* has been recorded growing wild on the Gazelle Peninsula (Argent, 1976; Daniells *et al.*, 2001; Peekel, 1984; Qld. Herb. records, unpubl.). Their fruits are filled with hard seeds encased in yellow flesh (Stover & Simmonds, 1987). The male flower buds and pseudostems can be eaten (Arnaud & Horry, 1997) as well as the sweet yellow flesh of the fruit (Lentfer, pers. obs., 2002).

As well as the two *Australimusa* species noted above, *Ensete glaucum* and three wild species of *Eumusa* (*Musa acuminata banksii, M. schizocarpa* and *M. balbisiana*) occur in the general Papua New Guinea region. It is important to note, however, that various banana collecting missions (Argent, 1976; Sharrock, 1988; Simmonds, 1956) recorded only *M. balbisiana* and *Ensete glaucum* from East New Britain. *Musa schizocarpa* seems to be confined to the New Guinea mainland and has not been recorded from New Britain. *Musa acuminata banksii* has been found in West New Britain. Sharrock (1988) made a point of noting that *M. acuminata banksii* was not found in New Britain. However, a specimen was recently collected by Lentfer in the Talasea region in West New Britain.

It is of interest to this study, questioning the origins of the SAC bananas, that the endemic status of *Musa balbisiana* in the New Guinea region has not been resolved (Argent, 1976; De Langhe & De Maret, 1999). Possibly it was introduced to Papua New Guinea from regions further west (e.g., the Philippines) as a primitive diploid with a BB genotype and reverted to the wild non-parthenocarpic plant. The indigenous status of *Musa acuminata banksii*, however, is well recognized. It has a wide distribution ranging possibly from as far west as the Philippines to Papua New Guinea, Australia and Samoa (Argent, 1976). Its genome is present in banana cultivars, including diploid, triploid and polyploid varieties (De Langhe & De Maret, 1999; Lebot, 1999). Notably, it is thought to have been the source of banana phytoliths found in the Kuk assemblages from the New Guinea highlands, where current evidence suggests that there was early banana cultivation beginning c. 6,950 years ago and possibly earlier at c. 10,000 years ago (Denham *et al.*, 2003; Wilson, 1985). Importantly, genetic evidence shows that at some stage, possibly prior to the Austronesian expansion into the Pacific region, *M. acuminata banksii* was crossed with *Musa balbisiana*, creating two important groups of AAB triploids, the plantains growing in Africa and India, and the *Maia-maoli/popoulu'* bananas growing in Polynesia (De Langhe & De Maret, 1999).

From current banana distributions and their genetic relationships, therefore, there are several possible sources of the SAC banana phytoliths, both natural and cultivated. In view of the present geographic distribution of wild bananas and close proximity of two wild species of *Australimusa* bananas to Watom, it would be expected that these would be represented in the phytolith assemblages. However, this is not the case. Although many of the morphotypes recorded in the SAC samples are common to

Australimusa and *Eumusa* bananas, as well as other members of the Musaceae family including *Ensete*, there is substantial evidence from the frequency of *Eumusa* seed types in the assemblages for a strong presence of *Eumusa* rather than *Australimusa* bananas, the most likely candidates being *M. acuminata banksii* and *M. balbisiana* or cultivars from both or either one of them. While the analysis cannot preclude *Australimusa*, it is notable that there were no *Australimusa* seed phytoliths recorded in the assemblages, although banana seeds more so than leaves are prolific phytolith producers. Furthermore, it is unlikely that *Ensete* was growing in the vicinity of SAC since none of its distinctive and abundantly produced seed phytoliths were recorded in the assemblages. All this constitutes strong support for anthropogenic introduction of bananas to Watom Island.

Several important implications for horticulture come from linking the results of this analysis with complementary lines of evidence. For instance, the extreme diversity of non-seeded, parthenocarpic banana cultivars the strong evidence of early banana cultivation at Kuk in the highlands of Papua New Guinea is indicative of the longevity of banana domestication and cultivation in the southeast Asian, New Guinean and Oceanic regions. This, coupled with the phytolith evidence, provides good grounds for inferring that bananas were being cultivated at SAC during the time of late-Lapita occupation.

Presently, the question of how the Lapita people acquired the practice of banana cultivation can only be surmised. Given the Kuk evidence for early banana cultivation on mainland New Guinea, it is possible that the original inhabitants who had occupied the Bismarck region for c. 30,000 years prior to Lapita occupation (Allen *et al.*, 1988, 1989; Wickler & Spriggs, 1988) had begun the process of domestication of bananas there. The Lapita peoples may have adopted banana cultivation from them when they settled in the region. Alternatively, if indeed the Lapita culture originated from the Southeast Asian region, the Austronesians could have brought bananas with them, and possibly at some stage used newly encountered cultivars in conjunction with their own, thereby merging two streams of domestication. While both models are equally plausible, the latter integration model, though more complex than the former, finds support not only from studies documenting geographical distribution and morphotaxonomy of bananas but also from a growing body of evidence arising from genetic and linguistic research (Arnaud & Horry, 1997; Daniells *et al.*, 2001; De Langhe & De Maret, 1999; Lebot, 1999; Ross, 1996: 184–185). This integration scenario is canvassed in more detail by Green (2000: 377–378).

Certainly, given both the spatial and temporal context of SAC on Watom Island, it is likely that the late-Lapita settlers arrived on the newly formed sand spit with domesticates as part of their "cultural baggage"; the simultaneous presence of bananas and pigs in particular, gives credence to this. Furthermore, from the range of evidence presented here, it appears that banana cultivation occurred at SAC during the first period of occupation, possibly as small-scale, house-garden horticulture, and intensified during the second period.[5] Currently, given the evidence, there is no reason to assume that cultivation was limited to only one banana species or variety, and indeed, crop diversity would be expected given the likelihood of cultivation and prolonged agricultural activity. There is strong evidence from the phytolith analysis for presence of *Eumusa* but there is also some indication for *Australimusa* presence. Moreover, the presence of *Eumusa* seed phytoliths in the assemblages (Table 3) is significant, showing that sterility and parthenocarpy were not fully developed, and banana domestication processes were still *in operandum*.

Although no discernible difference between C2 and C1 banana phytolith assemblages could be detected, there is the possibility that ongoing trade may have influenced domestication and crop development processes on Watom and in the broader region. Indeed, the possible presence of *M. maclayi* in C1 may be linked with this type of activity. (*M. maclayi* is not found on Watom Island or the Gazelle Peninsula, though *M. maclayi maclayi* var. *erecta* grows on Bougainville in the Solomon Islands and *M. maclayi maclayi* var. *namatanai* grows in New Ireland.) Furthermore, since obsidian sourcing data confirms trade networks from the Talasea region in West New Britain and the Admiralty Islands, trade may have accounted for the introduction of new horticultural commodities from those regions. Certainly, the presence of *Canarium harveyi*, tentatively identified from the nearby SDI locality by Yen (1991: 84), is consistent with this.

Other cultivation. Evidence for other cultivars from the phytolith assemblages remains tentative. The cordylines, sugarcanes, Job's tears, *Ficus copiosa, Canarium*, coconut, betel nut (*Areca catechu*), the fish-tail palm and several types of gingers are known useful plants and may well have been cultivated. However, due to multiplicity and redundancy of phytoliths in plants, positive identification without rigorous size/shape analysis was possible only for the cordyline, the fish-tail palm, only one of the gingers, *Tapeinochilos* sp., and possibly Job's tears.

The grass Job's tears grows naturally in the region, mostly favouring swampy environments. Therefore, the areas bordering the stream to the south of the SAC locality would have provided a suitable natural growing environment for this grass. Alternatively, since it often occurs away from its favoured environments in association with gardening (Lentfer, 1995; Peekel, 1984) and the large shiny-grey seeds are edible and also used for beads, its cultivation on the dry sandy spit in the C2 occupation phase is plausible. Likewise cordyline species and several ginger species occur naturally in the region but, unlike Job's tears, this group of plants (the gingers in particular) commonly invade old gardens; hence, their cultivation cannot be assumed from the available data. Furthermore, although the natural distribution of the fish-tail palm is less well known (it is possibly endemic to Asia), it is too premature to assume anything other than a natural distribution (Yen, 1990). Of the remaining plants, coconut palms and *Canarium* nut trees are the most likely to have been cultivated at SAC, but since the *Canarium*-like morphotypes occur in multiple plants and since coconuts have a phytolith morphotype similar to gingers and other palms, this assertion is based primarily on the complementary evidence from macro-remains found at SAC and also a short distance away at SDI and SAD. Finally, from the phytolith analysis alone, the evidence for sugarcane cultivation is inherently weak. However, the possibility should not be dismissed, for again an integration scenario at the time of the spread of Lapita can be sketched involving both New Guinea and Southeast Asia (Green, 2000: 377).

Moreover, some circumstantial evidence from SAC, possibly supportive of sugarcane cultivation, comes from isotope studies. The mean daily consumption of C4 plants (commonly represented by tropical grasses) was calculated to be 2.7% from isotope analysis of human bones (Leach *et al.*, 2000). *Saccharum officinarum* and *S. edule* are C4 plants and a proportion of the bilobate morphotypes recorded in the assemblages could indeed have been derived from one of these species, having been cultivated for both pig food and human consumption. A less likely possibility is that *Saccharum robustum*, a pioneer weed species often invading abandoned gardens, could have been consumed by pigs and possibly contributed to the C4 component of the human diet.

There may have been additional crops planted in the SAC gardens as evidenced by the high estimations of C3 plants in the human diet (Leach *et al.*, 2000). However, two of the most important root crop complexes in Melanesia, Micronesia and Oceania, the taros and yams, being high in starch, but non-phytolith producers, would be invisible in the phytolith record. Starch analysis has been recognized as complementary to phytolith analysis (Fullagar *et al.*, 1998; Lentfer *et al.*, 2002; Piperno & Holst, 1998; Therin *et al.*, 1999) and would be necessary to determine the presence of such crops at SAC. Examination of the sediments for starch grains would be useful, as obsidian tool residue studies have proven unrewarding (Green & Anson, 2000*b*: 65).

Conclusion

The SAC locality at the Reber-Rakival site on Watom Island has yielded a wide range of archaeological evidence for settlement and changing land use patterns by its late-Lapita inhabitants. This phytolith analysis complements the broad range of analyses previously applied to the site and has produced data that is supportive of former archaeological interpretations.

Evidence of banana cultivation constitutes the most significant outcome of this analysis, being the first direct evidence for its association with Lapita settlement in the Bismarck Archipelago. Diagnostic phytoliths from banana seeds indicate a strong presence of *Eumusa* banana species in the assemblages, whereas the evidence for *Australimusa* is much weaker. Given this evidence, together with genetic, morphotaxonomic and linguistic evidence, as well as the present geographical distribution of bananas, it is very likely that the first Lapita settlers at the SAC locality arrived with *Eumusa* bananas as part of their cultural baggage having inherited the horticultural "know-how" from generations of predecessors living in the Bismarck region and/or Southeast Asia. Further to this, the presence of seeds implies that development of domesticates was still *in operandum* in the region possibly implicating newly encountered banana species and varieties in ongoing domestication processes.

While further investigations are recommended to refine analyses for more definitive reconstruction of the SAC subsistence economy, the phytolith analysis presented here, in tandem with a range of previous analyses documenting evidence for pig husbandry and a variable human diet with high estimations of C3 and C4 plants, gives strong support for the late-Lapita economy having a well-developed agricultural base. In particular, the presence of bananas and pigs in the initial stage of occupation at SAC implies that the first Lapita settlers arrived with plant cultivars. It appears that pig husbandry and horticultural activities more or less continued, apparently successfully, for several hundred years until finally the Reber-Rakival site was abandoned when the area was buried under a substantial ashfall after the Rabaul volcano erupted.

Notes

1   A transitional style of pottery referred to as "post-Lapita" is found at the SDI locality in layers C2 and C1 (Anson, 2000*b*).

2   A newly calculated ΔR value makes shell dates at SAC c. 200 years younger than shown here (new dates and recalibration of older ones are to be published in a forthcoming paper by Roger Green and Fiona Petchey).

3   Although banana phytoliths have similar relative frequencies in C1 and C2, the concentration of phytoliths is more than four times higher in C1 than in C2. The absolute frequency of banana phytoliths in the C1 sediment is greater than in C2, and it would be expected that bananas were also more numerous in the area at the time of C1 deposition.

4   Genetic and morphotaxonomic evidence indicates that the early domestication of *M. maclayi*, possibly in the Solomon Islands where *M. maclayi maclayi* var. *erecta* is endemic, led to the development of the Fe'i banana cultivar, now grown in Papua New Guinea and the wider Pacific region (De Langhe & De Maret, 1999).

5   See Note 3 above.

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