Archaeological Studies of the Middle and Late Holocene, Papua New Guinea

Edited by Jim Specht and Val Attenbrow

Australian museum
Nature Culture Discover

Technical Reports of the Australian Museum (2007) No. 20. ISSN 1835-4211 online

Archaeological Studies of the Middle and Late Holocene,
Papua New Guinea
Part VIII

A Preliminary Study into the Lavongai Rectilinear Earth Mounds: an XRD and Phytolith Analysis

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ABSTRACT. This paper reports a pilot study undertaken at the Lavongai rectilinear earth mounds site in New Hanover, New Ireland Province, Papua New Guinea. The objective of the study was to determine whether the mounds were formed as part of a prehistoric agricultural system. X-ray Diffraction and phytolith analyses were used on a series of sediment samples from a test pit excavated into one of the Lavongai mounds. The phytolith results indicate a change from forest species in the lowest samples to grass species in the highest samples and the presence of a variety of plant species recorded in the ethnography of medicinal plants. The XRD results indicate that the sediments throughout the depth of the mound have a similar origin, suggesting that the changes in phytoliths do not represent changes in the source of the sediments. It is proposed that the phytolith results reflect four phases of gardening practices beginning between c. 3000 BP and c. 4000 BP.

LEAVESLEY, MATTHEW G., & ULRIKE TROITZSCH, 2007. Archaeological Studies of the Middle and Late Holocene, Papua New Guinea. Part VIII. A preliminary study into the Lavongai rectilinear earth mounds: an XRD and phytolith analysis. *Technical Reports of the Australian Museum* 20: 245–254 [published online].

The development and spread of agriculture was the single most significant change in prehistoric subsistence and led to unprecedented change in human behaviour. Agriculture was almost certainly a prerequisite to the colonization of Remote Oceania (Spriggs, 1997: 84). The small size and impoverished biota of many Pacific Islands meant that long-term human occupation was not feasible without some form of agriculture (Spriggs, 2002: 87). Bismarck Archipelago agriculture is conventionally thought to have come from Southeast Asia with the Austronesian expansion and the Lapita Cultural Complex (Spriggs, 2000: 300) although it has also been hypothesized that aspects of agriculture developed in the Melanesian region (Yen, 1990).

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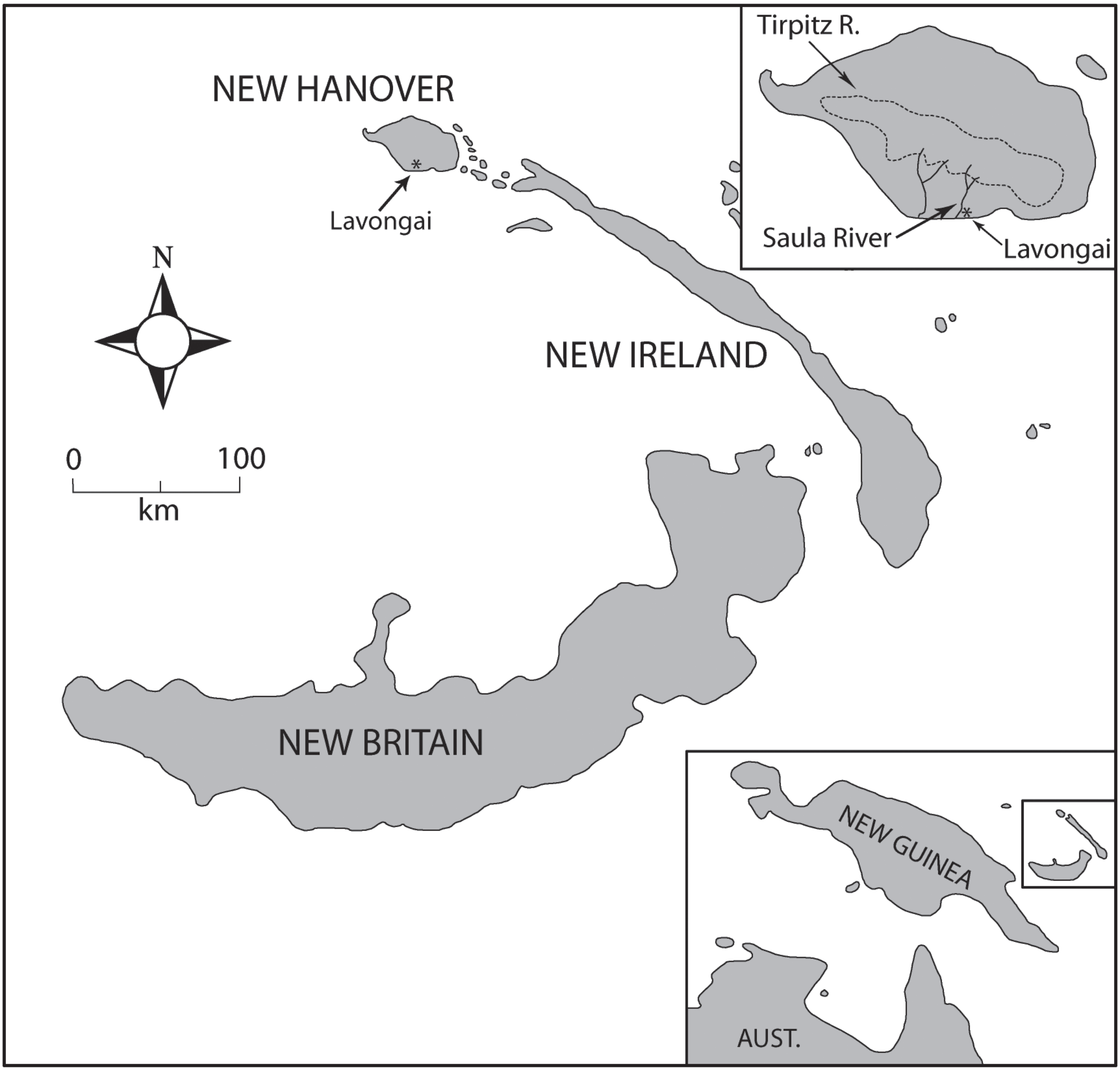

Fig. 1. Map of the Bismarck Archipelago (excluding Manus), with New Hanover inset.

Currently there are no well-researched archaeological garden sites within the Bismarck Archipelago against which to test these models. The aim of the present research is to investigate the potential of the Lavongai mound site for indications of long-term gardening practices using phytolith and mineral analyses. A regional survey of the rectilinear earth mounds is reported elsewhere (Leavesley, 2000, 2001). This is the first direct investigation into the antiquity and function of the mounds at the Lavongai site. The results of this pilot study are, by their nature preliminary and therefore the term "gardening" is used in a general sense to represent the systematic manipulation of plants and their environment for food production.

In contrast to the New Guinea Highlands, where plant food production possibly goes back to c. 10,000 BP (Denham *et al*., 2003), elsewhere (apart from Gillieson *et al*., 1985), there has been little exploration of the history of agriculture in the New Guinea lowlands or islands of Near Oceania. Near Oceania has relatively few swamp sites like those of Manton's (Lampert, 1967) and Kuk (Allen, 1970; Golson, 1972, 1976, 1977), or long palynological records (Hope *et al*., 1999), but soil and tool residue studies from Kilu Cave (Loy *et al*., 1992), Balof (Barton & White, 1993) and West New Britain (Kealhofer *et al*., 1999; Lentfer & Green, 2004; Parr *et al*., 2001), provide some evidence for the history of the use of plant foods. Another possible avenue for studying the history of New Guinea lowlands and island agriculture are the earthen mounds found in the Kove area of West New Britain Province (Swadling 1991) and at Lavongai on New Hanover, New Ireland Province (Leavesley, 2000, 2001).

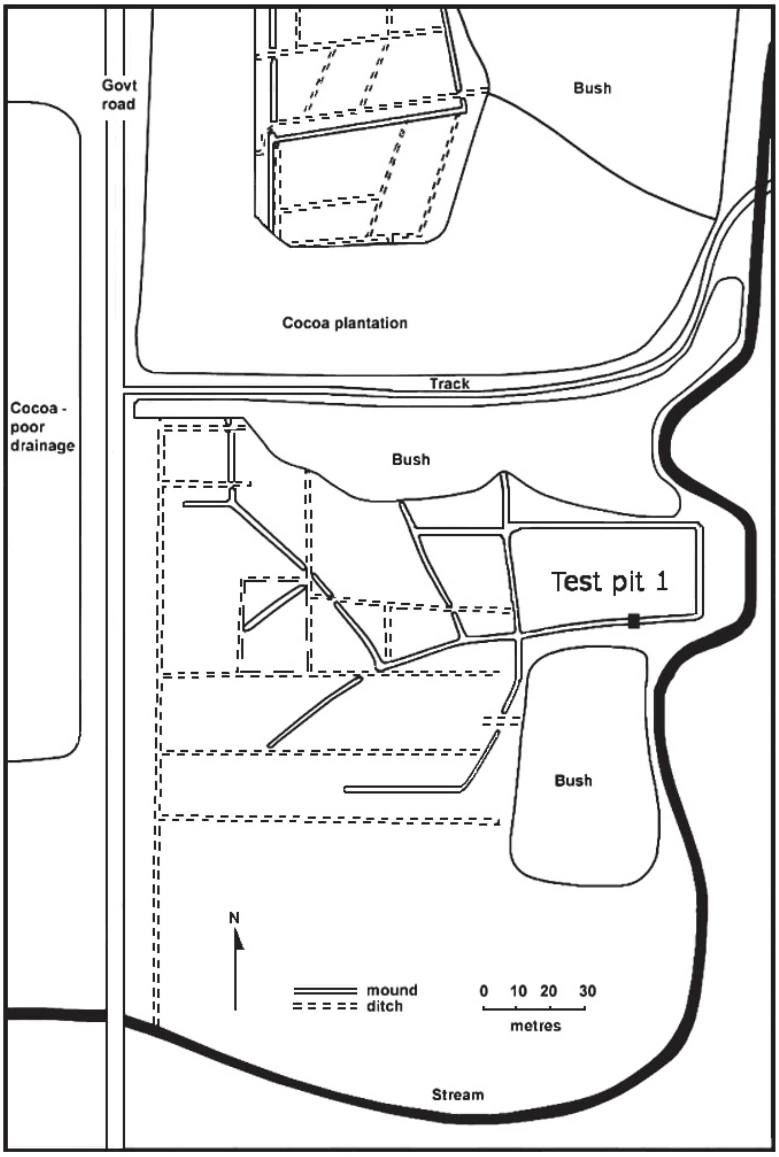

Fig. 2. General plan of the Lavongai mounds and ditches and location of test pit 1.

The Lavongai site

New Hanover is an island of about 2100 km^2 (ca 60 km by 35 km), located north of New Ireland at 2°31'S 150°2'E in the Bismarck Archipelago of Papua New Guinea. New Hanover receives an average rainfall ranging between 2800 to 3200 mm per annum (Hanson *et al.*, 2001: 246). New Hanover has moderate potential for agricultural expansion on the northern slopes of the Tirpitz Range (Hanson *et al.*, 2001: 251) and low potential elsewhere (Hanson *et al.*, 2001: 253). Contemporary gardening practices are low intensity and focus on sweet potato, with either yam or taro as co-dominant staples, and with one or two plantings before a fallow period of more than 15 years (Hanson *et al.*, 2001: 250; Hide *et al.*, 1996).

Lavongai village is located on the flood plain on the south coast of New Hanover at the mouth of the Saula River (sometimes referred to as the Marsaula River) adjacent to the Catholic Mission. The archaeological potential of the Lavongai site was first recognized by Kirch (Gorecki, 1985) during the Lapita Homeland Project (Allen & Gosden, 1991). Gorecki (1985: 22) recorded that "Kirch's reaction was that it looked like a prehistoric copy of contemporary Futuna taro ponds", and Hide *et al.* (1996: 30–31) later suggested that the rectilinear mounds represent a prehistoric land-use system. Elsewhere, a similar site in the Kove area of West New Britain, Papua New Guinea, has been interpreted as a series of field boundary markers (Swadling, 1991: 551). In the absence of extensive ethnographic records, archaeology provides the best avenue to investigate the prehistoric use of the mound systems of New Hanover.

The site is one of many similar sites found across New Hanover and on at least one of the neighbouring Tigak Islands (Leavesley, 2000, 2001). These sites consist of elongated mounds between 0.5 m to 2–3 m high and 2–3 m wide. The Lavongai mounds intersect and constitute a network or rectilinear pattern across the valley floor (described in detail elsewhere: Leavesley, 2001). The present study is an exercise to determine whether XRD and phytolith analyses of samples from the sediment profiles of the Lavongai site can provide information about past gardening activities at the site.

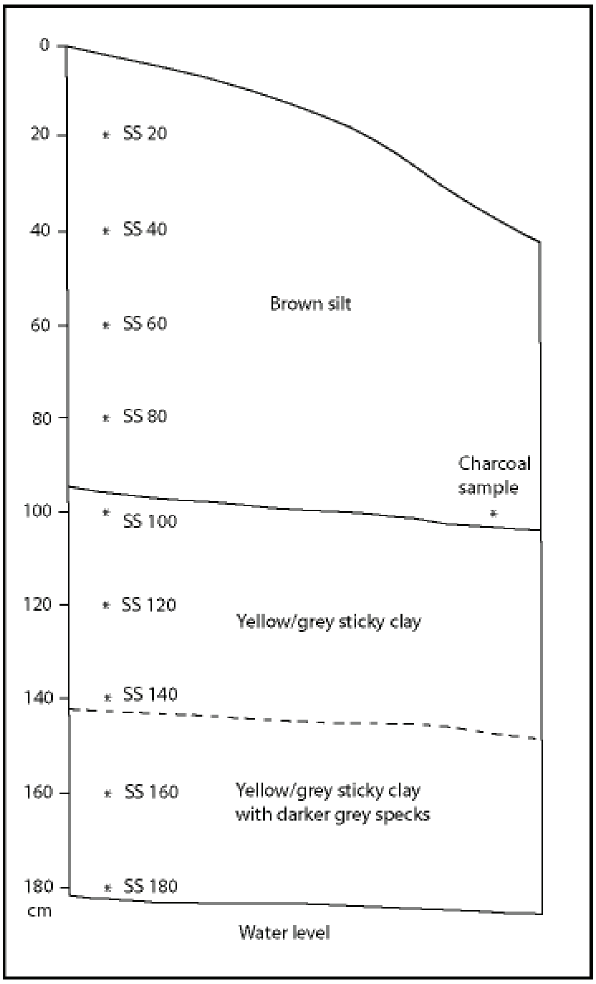

Fig. 3. Lavongai mound test pit 1, west section indicating the locations from which the sediment samples (SS) and charcoal sample were collected.

Little is currently known of the construction of New Hanover's rectilinear mounds. The mode of construction has important implications for the mound stratigraphy and therefore, the interpretation of the sediments. In the absence of large-scale excavation or ethnography, two possible construction scenarios are considered "most likely". The first construction scenario reflects an initial, relatively rapid, construction phase with limited post-construction maintenance. The sediment was removed by digging, from immediately adjacent to the mounds and piled up to form the mounds with a series of parallel ditches running along either or both sides of the mounds. The second scenario reflects relatively longer-term initial construction followed by regular maintenance. The sediment was raked from across a broad area between the mounds. The ground surface between the mounds remained relatively even with no explicit ditches resulting from the removal of the earth on to the mounds. The first scenario is considered less likely because there is no conspicuous evidence of ditches running systematically parallel to the mounds. The only ditches reported from the site have been interpreted as relatively recent drainage trenches (Gorecki, 1985: 22; Leavesley, 2001: 204–206). The second scenario is considered more likely because it is more consistent with the landscape. Within this framework sediment samples taken from the mounds can be interpreted as primarily representing the biota derived from the ground between the mounds, as well as vegetation that grew on top of the mounds during the intervals between mound maintenance.

Lavongai rectilinear earth mound stratigraphy. In 1999 a 2 by 1 m test pit was excavated in one of the mounds at Lavongai (Leavesley, 2001: fig. 2). The southern section of the test pit was parallel with the apex of the mound, which here is about 70 cm high (Leavesley, 2001: 206–208). The test pit was excavated to the water level, 183 cm below the apex of the mound. During excavation three stratigraphic layers were identified (Fig. 3). The top, layer 1 (0–95 cm), consists of brown silt; layer 2 (95–142 cm) is yellow/grey sticky clay and the third layer (142–183 cm) is yellow/grey sticky clay with darker grey inclusions. No pH values are currently available.

Ten samples were collected from the test pit (9 sediment and 1 charcoal). Nine samples were utilized for phytolith and mineralogical analyses and are referred to here as "SS" followed by a number reflecting the depth in the sediment profile at which the individual samples were collected (e.g., SS100 = sediment sample from 100 cm below the apex of the mound). The sediment samples were collected at 20 cm intervals down the western wall of the test pit (Fig. 3). The tenth sample was charcoal, of unidentified wood, collected at 95–100 cm below the ground surface from the northern end of the west face of the test pit. The charcoal was dated by AMS to 2040±60 BP (Wk-9033) and the result calibrates to 2037–1949 cal. BP (2 sigma range) using CALIB Rev. 5.0.1 (Stuiver & Reimer, 1993).

The stratigraphic relationship between the charcoal sample and the sediment samples is unclear for two reasons. First the test pit is located on the Saula River flood plain in alluvial deposits. Charcoal and sediment react differently in water because sediment is heavier than charcoal. Therefore, the charcoal and sediment cannot necessarily be assumed to have been deposited as a result of precisely the same depositional processes. Secondly, as described above, the nature of the mound construction is, as yet, unknown. If the mounds were constructed by the "digging" method, as described above in the first scenario, it might be expected that some aspects of the stratigraphy were inverted. Stratigraphic inversion can occur when each successively deeper load of sediment is placed systematically on top of the spoil heap. The result is that the topsoil from the hole is on the bottom of the spoil heap and the sediment from the bottom of the hole is on the top of the spoil heap. Alternatively, if the mounds were constructed by the "raking" method, or the entire site was regularly overlaid with sediment (perhaps by periodic flooding) and were effectively annually reconstructed with the new alluvium, then the mound stratigraphy may reflect conventional processes of superposition. The source of the new alluvium might be the result of increased erosion caused by vegetation clearance upriver (perhaps associated with increasing human populations) within the river catchment area such as has been described elsewhere in the Pacific region (Kirch & Hunt, 1997; Spriggs, 1982).

Methods

Each sediment sample was divided for X-ray diffraction analysis (XRD) and phytolith identification to investigate the possible presence of evidence for past gardening activities in the mound sediments.

X-ray diffraction analysis. X-ray diffraction analysis characterizes sediment according to mineralogy both quantitatively and qualitatively, and was applied to the sediment samples to explore three propositions:

1. Different types of minerals, or unusual ones, found at different levels of the sediment column may reflect a change in sediment source.
2. Changes in the ratio of common minerals (e.g., quartz versus clay minerals) may indicate a change in sediment source, or a change in depositional environment.
3. If no significant changes are found throughout the sediment column, then a change in sediment source or depositional environment is unlikely.

The method of X-ray diffraction (e.g., Moore & Reynolds, 1997) investigates the mineralogical content of a sample, based on the principle that each mineral has a unique and characteristic way of diffracting X-rays. When a powdered mineral is exposed to an aligned, monochromatic X-ray beam, the crystal lattice of the mineral will "split" (diffract) the beam into a set of X-rays that exit the sample at defined angles from the incoming beam. This set of outgoing X-rays is measured, and used as a "fingerprint" to identify the mineral. When a sediment sample is investigated, minerals present in the powdered sample produce specific sets of X-rays, and can thus be identified. The intensities of the peaks assigned to each mineral can be used to estimate the abundances of the minerals in the sediment, based on the Rietveld method (Young, 1993).

Both bulk samples and their separated clay fractions were analysed by Troitzsch with a SIEMENS D501 Bragg-Brentano diffractometer equipped with a graphite monochromator and scintillation detector, using CuKα radiation. Bulk samples were ground by hand in an agate mortar with acetone, dried at 40°C, and filled into side-packed sample holders, aiming for random orientation of the crystallites. These were then analysed over a scan range of 2° to 70° 2-theta, at a step width of 0.02° and a scan speed of 1° per minute. The results were interpreted using the SIEMENS software package Diffrac*plus* Eva (2000). Amorphous content was not analysed. Clay fractions were separated from the rest of the sample by gravitational settling, and processed according to the method as described in Moore & Reynolds (1997). Samples with strongly preferred orientation were prepared by filtration method and treated as follows: (*a*) Mg saturation, (*b*) ethylene glycol saturation, (*c*) heating to 350°C, (*d*) heating to 550°C. After every step, an XRD pattern was taken, between 2 and 42/32/28/28° 2-theta, with the same step width and scan speed as for bulks.

Phytolith analysis. The phytolith study was undertaken by D. Bowdery to look for evidence for possible changes in vegetation on or around the mounds. Phytolith (plant biogenic silica microfossil) analysis was employed to determine phytolith morphologies present in the nine sediment samples and their possible identification to plant taxa. Changes in phytolith presence/absence or relative frequencies are treated as reflecting variation in vegetation cover arising from a range of natural or humanly induced environmental impacts. To provide a control sample for the natural background, without human influence, a sample (SS180) was taken from what was considered to be the ground surface below the base of the mound, just above the water table.

To extract phytoliths from the sediment samples, after removal of clay and organic material, a heavy liquid flotation method was used with Sodium Polytungstate at <2.3 sg as the heavy liquid (Bowdery, 1998). Phytoliths recovered were mounted in Eukitt® between glass, and scanned under an Olympus BH2 light microscope. Complete scans were made of all slides, and the presence of phytoliths and other microfossils was recorded. The phytoliths were classified into 143 broad morphological groups representing tree, shrub, herb and grass species.

To provide a wet/dry index for the mound from phytoliths, specific, large-celled morphologies from hydrophilic plants were targeted. This provided a qualitative rather than a quantitative result, depending on number of different morphologies recorded in each sample rather than abundance. The wet/dry index ranges from 1 to 9, with 1 the wettest and 9 the driest (Table 1).

Table 1. Lavongai: number of phytolith morphological groups present and wet/dry index (wet = 1 and dry = 9).

sample	stratigraphic layer	morphological types, n = 143 presence	%	wet/dry index
SS20	1	88	62	6
SS40	1	106	74	1
SS60	1	113	79.7	2
SS80	1	87	60.8	5
SS100	2	61	42.7	4
SS120	2	32	22.4	8
SS140	2	21	15.4	7
SS160	3	18	14.0	9
SS180	3	130	82.5	3

Results

X-ray diffraction analyses. All samples are composed predominantly of quartz, kaolinite and smectite, with or without vermiculite. Most samples contain traces of feldspar (plagioclase and K-feldspar) and hematite. A trace of illite is present in one sample, anhydrite in another. All of these minerals are common primary phases or their secondary weathering products that one would expect to find in alluvial sediments and soils downstream of island arc volcanic rocks. The absolute abundances of the different minerals in the samples were not determined. However, the almost identical peak intensities across the samples indicate that the relative abundances of the minerals in Table 2 must be very similar in all samples.

The only major mineralogical variation in the samples from top to bottom of the profile is the amount of vermiculite, as shown in Figure 4 by the presence/absence of the main vermiculite peak in the ethylene glycol scans. This fluctuation in the amount of vermiculite can have several causes. For example, it could be due to different source material that was deposited in a changing sedimentary environment, such as changing stream direction, or deposition of layers of volcanic ash of different composition. Alternatively, the absence of vermiculite in some of the samples could indicate that these sediments were exposed to weathering for longer, causing the vermiculite to weather to smectite (Langmuir, 1997). This would not require a change in source material but in sedimentation rate, or a long break before new material was heaped on top of the mounds. A third possible explanation is a change in climate (Barshad, 1966) but this is considered less likely given the relatively short period of time in question.

All of the above potential causes for mineralogical changes through the profile have to be viewed in the light of the fact that the mounds do not necessarily represent a natural sedimentary sequence, but are probably humanly built up from the surrounding soil. This action by itself may alter the mineralogy of an existing soil simply by changing the soil structure, affecting properties such as drainage and aeration.

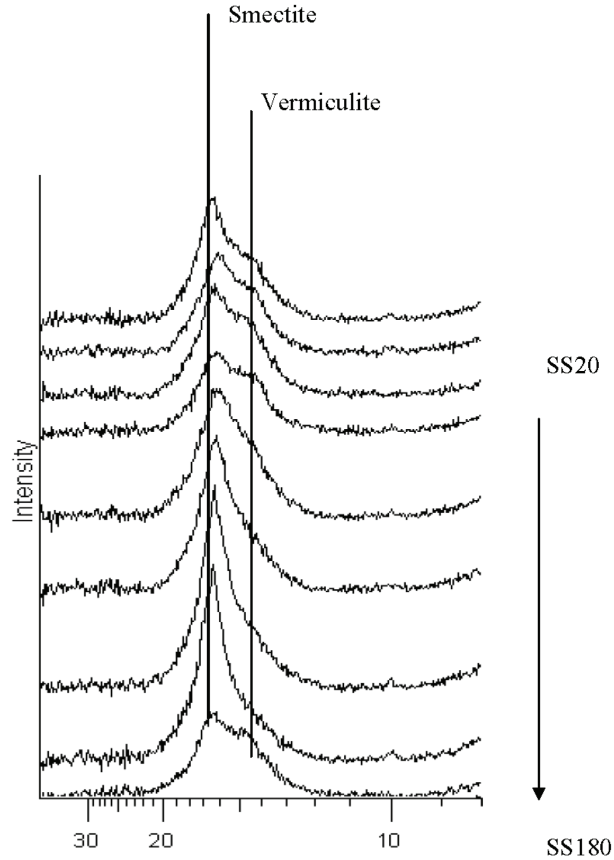

Fig. 4. Extracts from the X-ray diffraction patterns of samples SS20 to SS180, showing the [001] reflections of smectite and vermiculite after saturation with ethylene glycol. The intensity unit is arbitrary. The term "d-spacing" (measured in Ångstrom) refers to the distance between sets of parallel planes of atoms in the crystal structure, which is characteristic for every mineral and can be used as a fingerprinting method for their identification. The 001 peak discussed here refers to the distance between planes running parallel to the crystallographic a and b axes in the crystal structure of the clays.

Table 2. Summarizes the mineralogical content of the samples based on both bulk and clay scans. Mineral content of the samples (columns are quartz, kaolinite, smectite, vermiculite, plagioclase, K-feldspar, hematite, illite, anhydrite). + = major phase, tr = trace.

sample	qtz	kaol	smec	verm	plag	ksp	hem	ill	anh
SS20	+	+	+	+	—	—	tr	tr	—
SS40	+	+	+	+	tr	tr	tr	—	—
SS60	+	+	+	+	tr	—	tr	—	—
SS80	+	+	+	+	tr	—	tr	—	—
SS100	+	+	+	+	tr	—	tr	—	—
SS120	+	+	+	tr	tr	—	tr	—	tr
SS140	+	+	+	—	tr	tr	tr	—	—
SS160	+	+	+	—	tr	—	—	—	—
SS180	+	+	+	+	tr	tr	tr	—	—

The XRD results suggest that the sediment within the profile most likely originated from one source. Any changes that might be identified in the vegetation are therefore highly likely to reflect changes in conditions local to the Saula River drainage basin rather than changes in the origin of the sediment.

Phytolith analysis. Tentative identifications of phytoliths to plant family or species were made from a very small reference collection obtained from Indonesian, Malaysian and Thai plant material and the phytolith literature. Regrowth plants were identified, in particular the grasses *Phragmites* and *Ischaemum*. Zingiberaceae appear for the first time at SS100. Cyperaceae appears for the first time at SS180 and above SS100. Also, *Cordyline* sp. (Liliaceae) and a species of palm were noted in all samples except SS160 and SS140, and increased in quantity of species after SS100 (Tables 1, 3 and 4).

Four main points emerge from the phytolith analysis:

1 The highest diversity of phytolith morphological types was recorded in the lowest, 180 cm, control sample.
2 There is a marked decrease in morphological types of phytoliths between SS180 and SS160. Samples SS160 to SS120 have so few phytoliths that they are considered to be barren. The numbers of phytoliths of grasses (high silica producers) are very low and the grasses present represent a dry habitat preference.
3 Phytolith morphological types show a gradual expansion of diversity and quantity from SS100 to SS40.
4 SS20 shows a decrease in diversity and size of phytolith morphological types, and these indicate a drier period. This change cannot be attributed to displacement of vegetation by low silica producing plants.

In general terms, the phytolith sequence changes through time from “normal” to “barren” to increasing diversity, and then a reduction of diversity in the most recent period.

Discussion

The objective of the study was to determine whether the Lavongai rectilinear mounds were formed as part of a prehistoric gardening system. The archaeological evidence relating to prehistoric gardening at Lavongai is discussed in terms of site formation, chronology and function.

Site formation. In the best case scenario, a large scale excavation would trace the stratigraphy across the site in order to demonstrate the relationships between different layers in order to investigate the presence and impact of natural, cultural and post-depositional processes on the Lavongai sediment profile. However, in the absence of detailed datasets we propose a hypothesis based on the preliminary evidence presented above that can be tested with future research.

The XRD results support the proposition that the sediment throughout the profile originated from a single geological source area. The geographic setting of the site, on an alluvial coastal plain, suggests that the sediment was originally deposited by periodic flooding. The only depressions across the site are relatively recent drainage ditches or current watercourses (Leavesley, 2001: 206). This is consistent with the “raking” method of mound construction and maintenance, which may have occurred between flood events. The most significant implication of this method of mound construction is that the stratigraphy is likely to be consistent with conventional processes of superposition.

The limited size of the excavation provided few stratigraphic indicators of the initial vegetation clearance at the site. However, the phytolith data suggests a major non-conformity between SS180 and SS160. While relatively few plant species were identified in the phytolith results, Table 1 lists a large number of morphological types reflecting two aspects of site formation, namely species diversity and phytolith taphonomy. First, the quantity of morphological types has a direct relationship to the quantity of plant species. Secondly, the quantity of types may also be the product of post-depositional fragmentation of the phytoliths into

Table 3. Phytolith botanical identifications; p = present.

	SS20	SS40	SS60	SS80	SS100	SS120	SS140	SS160	SS180
Anarcardiaceae *Spondias* sp	—	—	—	p	—	—	—	—	p
Cucurbitaceae *Luffa* sp	—	—	p	—	—	—	—	—	—
Cyperaceae	p	—	p	—	—	—	—	—	p
Euphorbiaceae *Macaranga* sp	—	—	—	—	p	—	—	—	—
Liliaceae *Cordyline* sp	p	p	p	p	p	p	—	—	p
Maranthaceae *Donax* sp	—	—	p	p	—	p	p	p	p
Poaceae *Ischaemum* sp	—	—	p	—	—	—	—	—	—
Poaceae *Phragmites* sp	—	—	p	p	p	—	—	—	—
Zingiberaceae	p	—	p	p	p	—	—	—	—
total per sediment sample	3	1	7	5	4	2	1	1	4

Table 4. Phytolith morphological types per sediment sample (SS). p = present.

		SS20	SS40	SS60	SS80	SS100	SS120	SS140	SS160	SS180
	echinate (palms)	5	4	5	3	3	2	1	—	4
	psilate (palms & others)	2	1	1	2	2	1	1	1	3
	other sperical/oval	4	4	5	5	2	5	1	1	2
	perforated (2)	1	2	1	—	—	—	—	—	—
tree/shrub/herb	interlocking	1	1	3	4	3	1	—	—	3
	amorphous	—	—	—	p	p	p	p	p	p
	anticlinal	—	p	—	p	p	—	—	p	p
	crescent	—	p	—	—	p	—	—	—	p
	ornamented rectangle	p	p	p	p	p	—	—	—	p
	sheet	—	—	p	—	—	—	—	—	—
	tracheid	p	p	p	p	p	—	—	—	p
	trichome	10	9	19	10	13	5	3	1	21
	Cyperaceae	p	—	p	p	p	—	—	—	p
	short	2	3	3	3	3	1	3	1	3
tree/shrub/grass	medium	3	3	3	2	2	1	2	2	3
(rectangles)	long	2	2	2	1	1	—	—	—	3
	square	p	p	p	p	p	—	—	p	p
	others	3	3	3	4	3	3	1	1	2
	B 1	1	5	4	2	—	—	—	—	2
	B 2	12	4	4	4	—	—	—	—	8
	B 3	—	8	1	2	1	—	—	—	5
	B 4	6	11	12	14	4	2	—	—	17
	B 5	—	2	5	2	—	1	—	—	5
Poaceae	B 6	5	5	4	3	2	—	—	1	14
(bilobes)	B 7	3	3	4	4	—	—	—	—	1
	B 8	2	4		1	1	—	—	—	2
	B 9	—	1	1	1	—	—	—	—	—
	B 10	4	1	2	—	—	1	—	—	3
	angular	3	2	3	2	2	1	1	2	3
	ornamental rectangle	6	3	5	2	1	1	—	—	4
	arc/triangle	9	20	18	10	11	6	7	5	15
		88	106	113	87	61	32	21	18	130
	diatoms (4 spp)	1	2	2	1	2	2	1	—	—
	sponge spicules	—	p	—	p	—	—	—	—	—
starch	quantity	129	50	>500	59	188	191	112	129	128
	size range <μ	40	20	25	25	25	30	30	20	30

unidentified segments. Although the direct implications of these factors have not yet been fully assessed for this data set, assuming that the quantity of morphological types broadly correlates with the quantity of plant species, it is expected that a tropical rainforest will have a greater species diversity than a food garden. The number of morphological types in SS180 is much greater than in any other sediment sample (Tables 1 and 4), and is about seven times greater than in SS160. If forest clearance equates with a reduction in species diversity, then it can be hypothesized that forest clearance began between SS180 and SS160.

The phytolith results also provide indirect evidence of the first mound construction at the site. Leavesley (2001) suggested that the rectilinear mounds were designed to increase the quantity of water within the network of rectilinear mounds. The wet/dry index from SS100 to SS40 inclusive indicates a dramatic increase in taxa with relatively greater tolerance to wet sediments (Table 1). In particular, *Cordyline* sp. (Liliaceae) and palm species (particularly Echinate palms) were present in increasing quantities above SS120 (as does Cyperaceae occurring in SS60 and SS20), indicating increased water availability. Therefore, it is hypothesized that the rectilinear mound construction began stratigraphically between SS120 and SS100.

Chronology. The single AMS 14C determination (2037–1949 cal. BP: Wk 9033) is interpreted here as a general indicator rather than a definitive statement of age for two reasons. First, it is not corroborated by a sequence of determinations. Secondly, the lack of knowledge of the site formation processes means that the association between the charcoal sample and the sediment samples is not clear. The available evidence, however, allows two hypotheses for testing by future research.

The first hypothesis concerns the approximate age of forest clearance at the site. The phytolith results suggest that this occurred between SS180 and SS160. Extrapolating from Wk 9033 and assuming a constant rate of sediment accumulation, forest clearance might be hypothesized to have occurred between c. 3000 BP to c. 4000 BP.

The second hypothesis concerns the initial construction of the mounds. Assuming that they were formed by the raking method of construction, sample Wk 9033 from 95 cm below the mound surface may indicate that mound construction, which began between SS120 and SS100, dates to c. 2000 cal. BP.

Mound function. Leavesley (2001) hypothesized that the function of the New Hanover rectilinear mounds was to increase the relative quantity of water in the sediments in order to improve the productivity of plants preferring waterlogged soils. This is consistent with the evidence presented here in three ways. First, the reduction of plant species, reflected in the phytolith morphological types between SS180 and SS160, is consistent with forest clearance activities. Secondly, a change to grasses has been interpreted elsewhere as evidence for forest clearing (Parr *et al*., 2001: 132). For the Lavongai mound, there is a shift to grasses contemporary with or following soon after the construction of the rectilinear earth mounds. In particular, the grasses *Phragmites* and *Ischaemum* sp. were identified in SS60 and above. *Ischaemum* spp. are commonly associated with garden re-growth and *Phragmites* spp. are wetland taxa. Thirdly, the phytolith results reflect the presence of *Macaranga* sp. (SS100) and particularly Zingiberaceae (SS100, SS80, SS60 and SS20). These plants are described in the ethnographic literature as having medicinal uses. The fruit of *Macaranga aleuritoides* "are chewed to relieve abdominal pain and various *Macaranga* sp. are used to cure diarrhoea, constipation and stomach complaints elsewhere in the region" (Holdsworth *et al*., 1982: 105). Species of Zingiberaceae, such as the rhizome of *Zingiber officinale*, "…is chewed and the juice rubbed on the head to treat migraine…or swallowed to alleviate vomiting" (Holdsworth *et al*., 1982: 108).

The evidence for site formation, chronology and function provide the basis of a 4-phase model for the development of the site. Phase 4 is reflected by SS180 and indicates the end of forest coverage at the site. Phase 3 began with forest clearance at c. 3000 BP to c. 4000 BP. Phase 2 began at c. 2000 cal. BP with the construction of the mounds and was associated with an increase in wetland taxa. Phase 1, the most recent period represented by SS20, is characterized by a return to dryland species and is most likely associated with the drainage ditches at the site.

The data are consistent with and extend the previous interpretations of the site. First, the four-phase model is consistent with Kirch's interpretation of the mounds as reflecting pondfield gardening (Gorecki, 1985). Second, in addition to the mounds acting as retaining walls of a pondfield system, they might also have delineated the "ownership" of specific gardens (Swadling, 1991), although this cannot be tested with the current data.

Conclusion

The evidence derived from XRD and phytolith analyses on the Lavongai sediment samples indicate that valuable information reflecting aspects of the development of Island Melanesia gardening can be obtained from rectilinear earth mounds. The evidence informs aspects of site formation, chronology and function, which, in turn, form the basis of a four-phase model of activities at the site. The model reflects the initial forest clearance, mound construction and, most recently, drainage of the area. This pilot project indicates that rectilinear earth mounds sites contain good archaeological potential and the model provides the basis for future research into the development of agriculture in New Hanover and Near Oceania.

ACKNOWLEDGMENTS. The 1999 fieldwork was undertaken by MGL who was affiliated with the Papua New Guinea National Museum and Art Gallery, Port Moresby. While on Lavongai, MGL was assisted by John Aini, the late Milla Aini, Jack, Hagar, Agnes Boskuru (Lavongai village), Herman Mandui (PNG National Museum) and Glenn Summerhayes (University of Otago). The Centre for Archaeological Research (CAR), at The Australian National University awarded the radiocarbon determination to MGL. Doreen Bowdery undertook the phytolith analysis funded by a CAR New Initiatives Grant to MGL, and the XRD analysis was funded by the Claude C. Albritton Award to MGL from the American Geological Society. Also thanks to Jim Specht and Caroline Read for useful feedback. Finally, thanks to the two reviewers who provided extremely useful comments. Any errors, of course, are ours.

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Associate Editor: Dr Val J. Attenbrow.