

# From Field to Museum Studies from Melanesia in Honour of Robin Torrence

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# The Question of Early Lapita Settlements in Remote Oceania and Reliance on Horticulture Revisited: New Evidence from Plant Microfossil Studies at Reef/Santa Cruz, south-east Solomon Islands

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**ABSTRACT.** Since the earliest discoveries of Lapita sites in Remote Oceania there has been ongoing debate about the nature of Pacific island colonisation. In the 1970s, based on the archaeological material from the SE-RF-2 and SE-RF-6 sites on the Reef Islands in the SE Solomons, Roger Green proposed that early Lapita communities there must have relied on horticulture as the mainstay of subsistence. Our analyses of phytoliths and starch in sediments and on pottery has found evidence for burning, food preparation and cooking in conjunction with a suite of wild and domesticated plants indicative of horticulture. Starch and phytoliths from seeded *Australimusa* (syn: *Callimusa*) bananas as well as domesticated *Eumusa* (syn: *Musa*) bananas were recovered, as well as *Colocasia esculenta* (taro) starch, and *Metroxylon* sp. (sago palm) phytoliths. Hence, Green's early hypothesis finds support, but more analyses, together with more precise dating are needed to clarify the time taken to establish sustainable horticulture. The importation of selected plants is confirmed, with potential sources being the Bismarck region or stop-over islands along the way. This was followed by ongoing on-site breeding and/or new introductions from further human migrations into the region and establishment of trade and exchange networks.

## Introduction

After a formative period marking the emergence of the 'Lapita Cultural Complex' in the Bismarck Archipelago ca 3400 cal. BP (Denham *et al.*, 2012: 44; Specht *et al.*, 2014; Sheppard *et al.*, 2015; Sheppard, 2019; cf. Specht and Gosden, 2019: 188, where a much later start date of 3250–3150 cal. BP is considered), there was a rapid demographic expansion into Remote Oceania, reaching the Southeast Solomons, Vanuatu and New Caledonia within a few generations at most, and Fiji, Tonga and Samoa soon after (Bedford *et al.*, 2019: table 1.1; Sheppard *et al.*, 2015). The nature of this migration has long been debated. At one extreme, models advocate a

wave of advance and strand-looping across the region with a reliance on local resources for subsistence (e.g., Groube, 1971; Anderson, 2003; and see Davidson and Leach, 2001; Sheppard, 2019). At the other, leapfrogging scenarios are envisaged, entailing initial long haul voyages from the Bismarcks more-or-less directly across to the Reef/Santa Cruz Islands by groups of migrants carrying a suite of commodities including obsidian, pottery, domestic animals and subsistence plants, intended to facilitate settlement on new islands (Sheppard and Walter, 2006; Walter and Sheppard, 2009; Sheppard, 2011, 2019; Sheppard *et al.*, 2015). Given the bulk of evidence for the presence of exotic cultigens including bananas, taro and yam at sites in Vanuatu, Fiji, Samoa and

**Keywords:** Lapita; SE Solomons; Reef/Santa Cruz; horticulture; phytoliths; starch; banana; taro

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**Table 1.** List of dates with details of the associated ceramic series for the Reef/Santa Cruz sites and Lapita sites of comparable age of initial settlement in Remote Oceania (extracted from Bedford *et al.*, 2019: table 1.1).

code	location name	ceramic series	age cal. BP	references
<b>SE Solomons</b>				
<i>Reef/Santa Cruz</i>				
SE-RF-2	Nenumbo, Te Motu Taibä/ Ngaua, Reef Islands	Middle	3185–2639	Green, 1976; Sheppard <i>et al.</i> , 2015
SE-RF-6	Ngamanie, Lomlom/Ngalo, Reef Islands	Middle	2910–2470	Green, 1976; Green and Jones, 2007
SE-SZ-8	Nanggu, Nendö/Santa Cruz	Middle	2920–2729	Green, 1976; Green <i>et al.</i> , 2008; Sheppard <i>et al.</i> , 2015
<b>Vanuatu</b>				
<i>Malo</i>				
MA 8–20	Batuni-urunga	Middle	3000–2800	Hedrick, n.d.
MA 8–38	Avunatari	Middle	3000–2800	Galipaud, 1998
MA 8–39	Naone	Middle	3000–2800	Hedrick, n.d.
MA 8–40	Atanoasao	Middle	3000–2800	Galipaud, 1998; Bedford and Galipaud, 2010
<i>Efate</i>				
No code	Teouma	Early to Late	3000–2800	Bedford <i>et al.</i> , 2010; Petchey <i>et al.</i> , 2014, 2015
No code	Teouma west	Early	3000–2800	Shing and Willie, 2019
<b>New Caledonia</b>				
<i>North coast</i>				
NKM001	Boirra	Early to Late	3000–2750	Galipaud, 1998
<i>West Coast</i>				
WK0013A	Lapita	Early to Late	3000–2750	Sand, 1998; Sand <i>et al.</i> , 2019
WK0013B	Lapita	Early to Late	3000–2750	Sand, 1998
WBR001	Nessadiou	Early to Late	3000–2750	Sand <i>et al.</i> , 1996
V8	Vavouto	Early to Late	2900–2750	Sand, 2010
<i>South Coast—Île des Pins</i>				
KV003	St Maurice-Vatcha	Early to Late	2950–2700	Sand, 1999

New Caledonia, it is now well-accepted that horticulture was a facet of early Lapita settlement (e.g., Horrocks and Bedford, 2005, 2010; Crowther, 2009a; Horrocks *et al.*, 2009; Horrocks and Nunn, 2007).

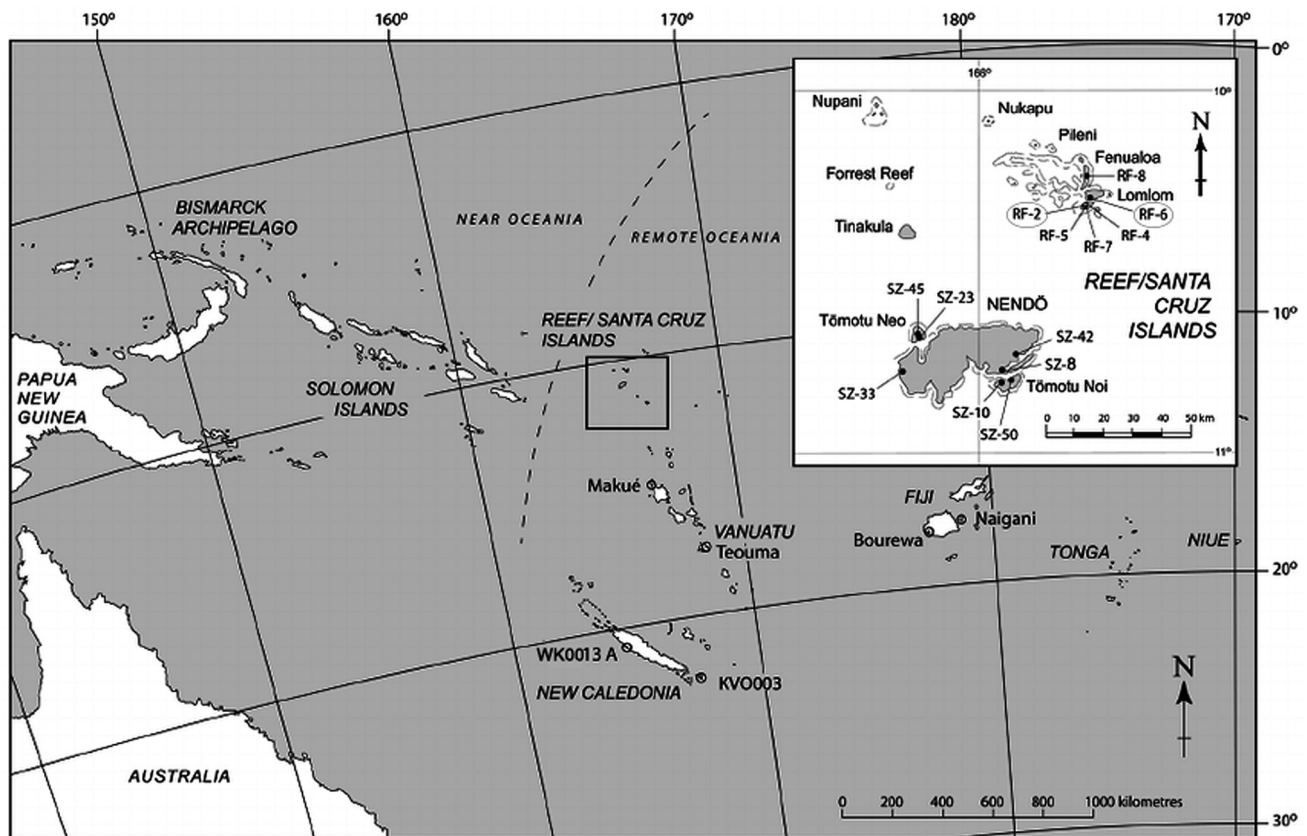
However, the nature of horticultural practice and the extent to which early settlement relied on it compared with natural terrestrial and marine resources is still open to question. As recent isotope studies at Teouma, Vanuatu, have indicated (Kinaston *et al.*, 2014; Lebot and Sam, 2019), this is likely to vary according to local soils and ecology, to availability as well as sustainability of local resources and to time taken to establish sustainable crops. The Nenumbo SE-RF-2 and Ngamanie SE-RF-6 Lapita sites are key localities to further investigate the importance and nature of horticulture in the Lapita settlement of Remote Oceania, especially since revised dating protocols suggest that SE-RF-2 may be one of, if not the earliest Lapita settlement in the region (Table 1; see also Sheppard *et al.*, 2015; Bedford *et al.*, 2019).

### Site locations and background

SE-RF-2 and SE-RF-6 archaeological sites are located on raised coralline islands in the Main Reef Islands in the Te Motu Province of the Solomon Islands. They are among the first set of islands beyond the Near/Remote Oceania boundary, approximately 500 km or an estimated 5 days sailing at 4 knots/hour from San Cristobal (syn: Makira) in the main island group of the Southeast Solomons (Fig. 1 and

see Irwin, 2006: 76, 2008: 21). SE-RF-2 lies on the southeast coast of Ngaua Island (syn: Te Motu Taibä) and at the time of occupation the site would have been adjacent to the beach, fronted by a shallow tidal lagoon. Due to tectonic uplift, it now lies 160 m inland from the present beach and 2.4 m above the average high tide mark (Green, 1976: 248, 1979: 51, 1986: 124). SE-RF-6 is located approximately 3 km to the north of Nenumbo on the southwest coast of Ngalo Island (syn: Lomlom) next to a shallow, mangrove-filled, tidal channel that separates Ngalo Island from Ngangaua Island. They are in close proximity to several other Lapita sites, the most significant being SE-SZ-8 which lies 50 km south on Nendö (Santa Cruz Island) and thought to be slightly younger than or contemporaneous with SE-RF-2 (Fig. 1; Table 1). The sites were initially surveyed and excavated by Roger Green in 1971 and follow-up excavations were undertaken in 1976–1977 (Green, 1979; Green and Cresswell, 1976). Excavations at the sites were conducted after systematic surface collection of artefactual material (Green, 1976: 253; Sheppard and Green, 1991: 90–99; Green and Jones, 2007: 9).

SE-RF-2 has been interpreted as being a small hamlet with two main activity areas within a total estimated area of approximately 2400 m<sup>2</sup>. The excavated area at the time of this study was 153.5 m<sup>2</sup> (Fig. 2; see Sheppard and Green, 2007). The first activity area was located in the middle of the site and was associated with an obvious structure estimated to be 7 × 10 m, as shown by a large rectilinear concentration of sherds that correspond with the layout of post holes, serving perhaps as a dwelling house, a community house or a men's



**Figure 1.** Map showing locations of the SE-RF-2 and SE-RF-6 archaeological sites on the Reef Islands in Remote Oceania. The location of SE-SZ-8 is marked on Santa Cruz Island (Nendö) nearby. Other sites on the Reef/Santa Cruz islands are undated but SE-SZ-23 and SE-SZ-45 also have ceramics from the Middle Lapita period. Sites marked on New Caledonia have ceramics from Early to Late Lapita (see Table 1 and Bedford *et al.*, 2019). Sites in Vanuatu and New Caledonia, are potential sources of propagules for horticulture and arboriculture. Base map from Sheppard *et al.* (2015).

house, possibly with a raised floor at one end (Green and Pawley, 1999: 78–79; Sheppard and Green, 1991: 92–95, 100). The second, a complex of earth ovens and storage pits at the southern end of the site, has been interpreted as a cooking area with a series of open-sided cooking sheds (Sheppard and Green, 1991: 92–95, 100). According to Bayesian analyses of a series of radiocarbon dates on shell and charcoal (Sheppard *et al.*, 2015: table 3; see Green and Jones, 2007: table 3; Sheppard and Green, 2007: 144), the site is thought to have been permanently occupied (Green, 1976: 255) and first settled between 3185 and 2639 cal. BP (95.4% CI) for a period spanning at least 50 years.

The stratigraphy of SE-RF-2 is relatively simple (Fig. 4a) with basal white coralline beach sand (Layer 3) overlain by intact cultural deposits composed of grey charcoal-stained sand (Layer 2, the Lapita occupation layer). Above this is a black garden soil (Layer 1), 25–30 cm thick, principally derived from volcanic ash deposits that most likely originated from the nearby Tinakula volcano between 2400 and 500 BP (Burnett and Fein, 1977; Jones *et al.*, 2007: 99). All layers are alkaline, with pH values of 6.9–7.9 in Layer 1 increasing to 9.5 in Layer 3 (Burnett and Fein, 1977). Based on well-defined sedimentary mineralogy and geochemistry within each of the layers, Green (1986) argued for good stratigraphic integrity. However in its undisturbed context it is thought that the grey sand occupation layer would have been slightly thicker before the original upper 5–8 cm was incorporated into the garden layer. This indicates some upwards disturbance bringing cultural material to the surface. The spatial patterns exhibited by the surface sherd distribution and the subsurface features suggest that little

post-depositional horizontal disturbance of the site's cultural content has occurred (Sheppard and Green, 1991) and it appears that soil-mixing from tree-fall and crab-burrowing would have been minor (Green, 1976: 251; Jones *et al.*, 2007: 99).

The SE-RF-6 site, running parallel to and within view of the sea-water channel, covered a much larger area than SE-RF-2 (Fig. 3). From surface surveys and trowel test-pitting at 10 m intervals, the site was estimated to be approximately 10,800 m<sup>2</sup> (Green, 1979: 51; Green and Jones, 2007: 9; Sheppard and Green, 2007) of which 20 test squares, each 1 × 1 m, within a 100 m<sup>2</sup> portion at the eastern end, were fully excavated. Radiocarbon dates have determined that SE-RF-6 postdates SE-RF-2, perhaps spanning an occupation period of 50 to 100 years beginning sometime in the interval between 2910 and 2470 cal. BP (95.4% CI) (Table 1) (see Green and Jones, 2007; Bedford *et al.*, 2019). Although hearth features were found, no well-defined structures or activity areas were identified within these limited excavations. The stratigraphy of SE-RF-6 is similar to SE-RF-2 (Fig. 4b), having white coralline beach sand and coral limestone in the basal layers, overlain by a grey sand midden layer (Layer 2) and a garden soil derived from Tinakula ashfall (Layer 1) (Green and Jones, 2007).

Cultural material found at both sites include decorated pottery sherds, oven stones, adzes made from local and imported rock, nut-cracking stones, and chert and obsidian cores and retouched flakes (Green, 1976: 259, 1978, 1991; Green *et al.*, 2008). The two sites, especially SE-RF-2, provide important evidence for long distance transport of resources over a distance of more than 2000 km (Green *et*

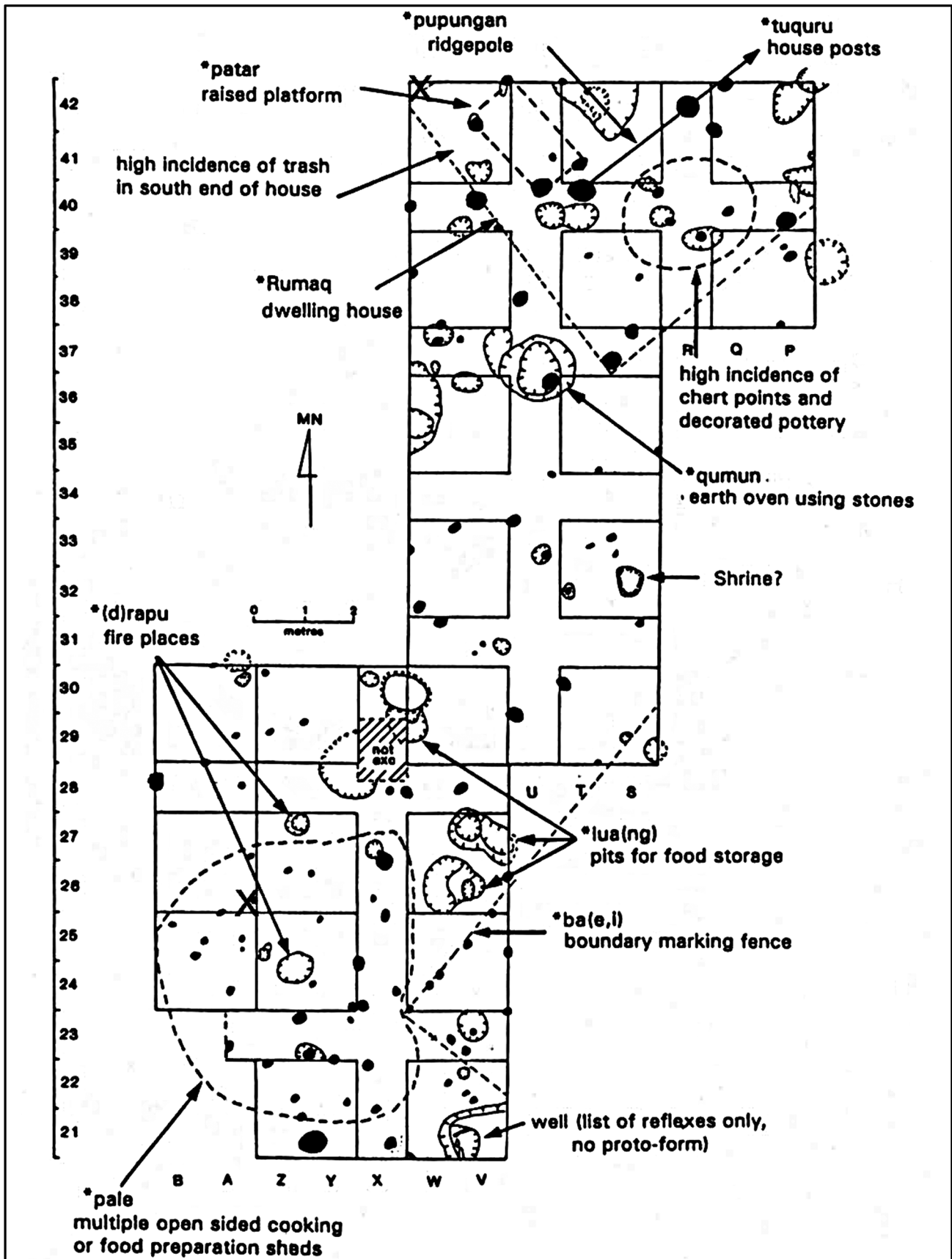
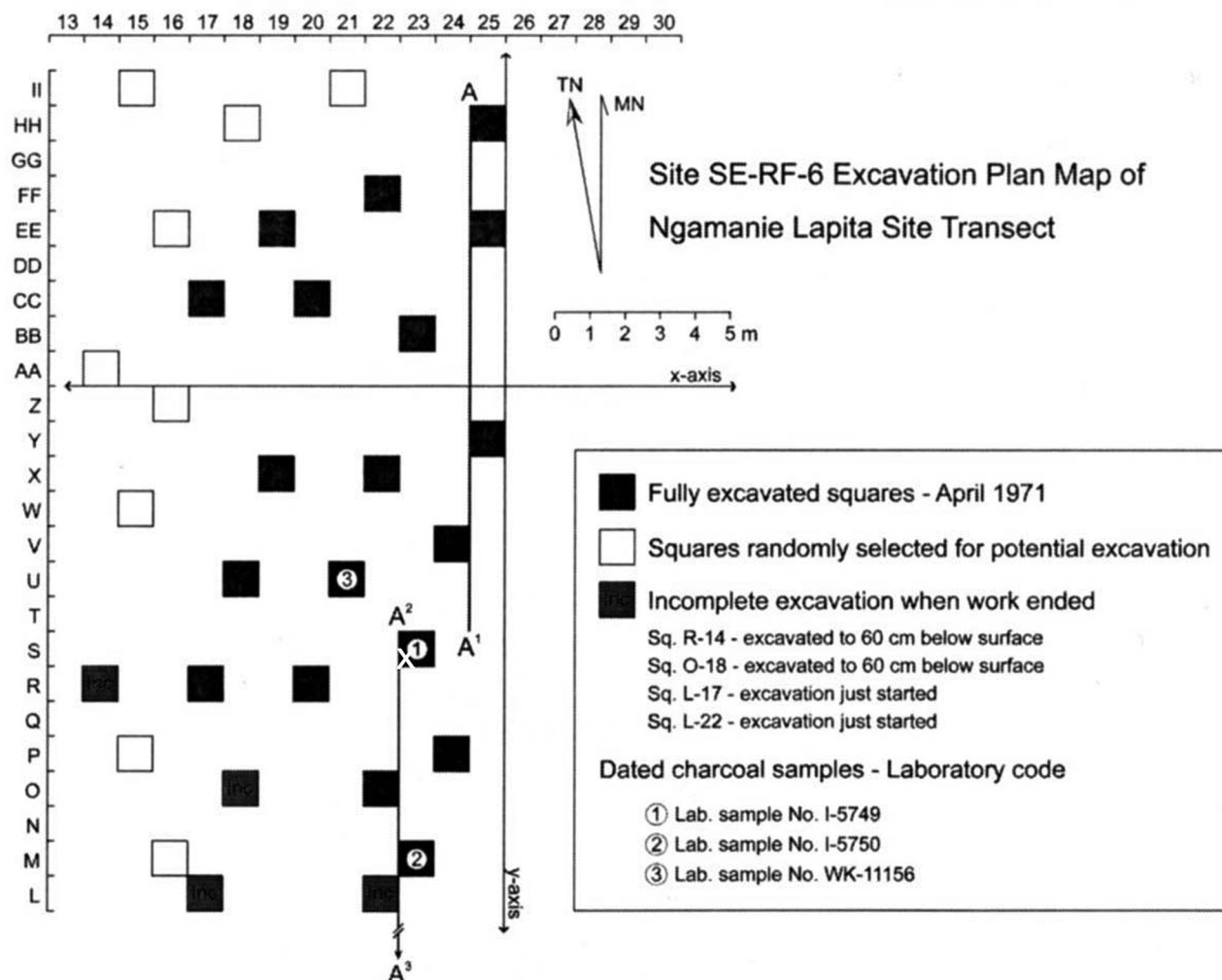


Figure 2. Site plan of SE-RF-2 (extracted from Green and Pawley, 1999). X marks sediment sampling locations.



**Figure 3.** Section of site plan for SE-RF-6 (extracted from Green and Jones, 2007). X marks square S-23 from where the two sediments were collected.

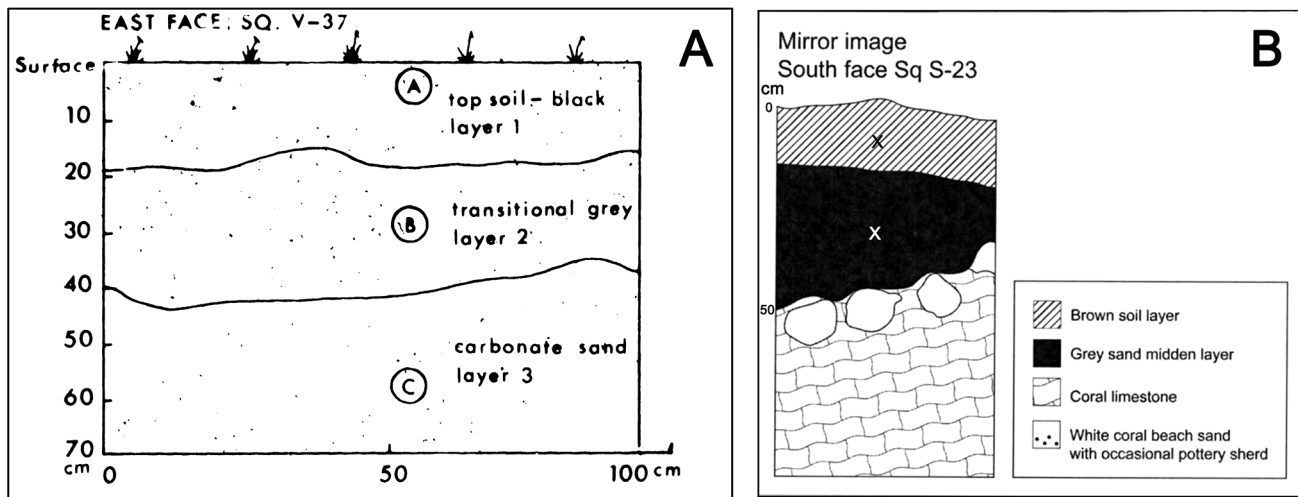
*al.*, 2008: 55). Ceramic styles including decorative motifs are shared with Lapita assemblages from West New Britain in the Bismarck Archipelago (Summerhayes, 2000); chert was imported from the Duff Islands and Ulawa/Malaita (100 km northeast and 350 km east of Santa Cruz respectively) (Sheppard, 1993, 1996; Walter and Sheppard, 2009); and obsidian was sourced from Willaumez Peninsula sources in the Bismarcks, Lou Island in the Admiralties, Fergusson Island in the D'Entrecasteaux Islands at the eastern tip of Papua New Guinea, and the Banks Islands in northern Vanuatu (Green, 1987; Green and Bird, 1989; Walter and Sheppard, 2009; Sheppard *et al.*, 2010: 27, table 5). Together with archaeological evidence from the SE-SZ-8 site on Nendö, where an abundance of obsidian from the same sources was also found along with dentate stamped pottery and motifs most similar to SE-RF-2 (Anson, 1986; Green, 1991; Summerhayes, 2000; Green and Jones, 2007: 7; Green *et al.*, 2008), this suggests that early Lapita colonists maintained close trade and/or exchange and social networks, providing important safety nets for groups as they established themselves in their new settings.

The excavated midden deposits at the two sites also included a range of tropical shoreline bivalves and gastropods indicating intensive use of lagoons, as well as evidence of on-site shell-working (Green, 1976; Szabó, 2005: 184–197; see also Szabó, 2010: table 3). Other material consisted of inshore marine invertebrates, fish bone, mostly derived from reef and lagoon species, and bones of

turtle, bat, rat, whale, dugong, pig and bird. Bird remains comprised megapode, domestic chicken, a goose-sized bird and other unidentified species (Green, 1976: 255–258; see also Storey *et al.*, 2010). No plant macro-remains apart from *Pandanus* species were recovered from the site (Green, 1976: 258; Szabó, 2005). Nevertheless, the quantity of marine resources used at the site was thought to be limited and 'quite insufficient to constitute more than a minor part of the daily diet of even a small group of people from a settlement inhabited for any length of time' (Green, 1976: 258). Based on the presence of pig bone at the site (and to a lesser degree chicken), Green suggested that subsistence from the time of earliest occupation must have had a heavy reliance on horticulture. More recently, Kirch and Green (2001: 121) went on to claim that:

when Lapita populations expanded into Remote Oceania ... they transported a full roster of oceanic crops, including such staples as taro, yam, bananas and breadfruit. Indeed, the very ability to transfer such systems of horticultural production was arguably an essential aspect of the successful Lapita colonization strategy.

Subsequently, in line with ongoing debates about the nature of Lapita settlement and with the aim of testing this hypothesis with empirical evidence, Green invited the authors to undertake further investigation of the SE-RF-2 and SE-RF-6 sites, using microfossil analyses, primarily phytoliths and starch.



**Figure 4.** (A) Original field drawing by Doug Yen in 1971 of the stratigraphy of square V37, SE-RF-2 with locations of sediment samples used for initial soil analyses by Burnett and Fein (1975). NB stratigraphic drawings were not available for Square W42, from where the sediment samples for our analyses were collected. (B) Stratigraphy of square S-23, SE-RF-6, showing sediment sampling locations (extracted from Green and Jones, 2007).

## Methods

### Pottery

A total of 63 sherds from SE-RF-2 were selected for starch residue analysis. These comprised 36 sherds from the three main activity areas (the occupation structure, the cooking area, and the storage-pit area; a mixture of dentate-stamped, incised, and plain from each), 13 sherds from six partially-reconstructed dentate-stamped vessels, six plain rims, and eight sherds (six plain, one dentate-stamped and one incised) from cooking vessels with charred residues on their interior surfaces. Sherds with well-preserved surfaces, little weathering or edge rounding, and of suitable size and shape were targeted, preferentially from Layer 2 (the *in situ* Lapita occupation layer), which was less affected by modern cultivation activities, though some were also selected from Layer 1. Although the sherds had been lightly washed and handled during post-excavation analysis, several studies have previously demonstrated the potential for recovering use-residues from curated objects (e.g., Piperno *et al.*, 2000; Fullagar *et al.*, 2006).

Residues on the sherds were analysed in a multi-stage process. First, all artefact surfaces (inner, outer, broken edges) were examined directly with high magnification ( $\times 100$ – $1000$ ) reflected light to locate and characterise potential *in situ* residues. Selected samples were also examined via low vacuum scanning electron microscopy (SEM) (JEOL-6460-LV; 155Pa, 15 kV accelerating voltage, 45–55 spot size). For sherds with possible starch residues ( $n = 20$ ), extracts were then removed for more detailed analysis with transmitted light microscopy ( $\times 200$ – $1000$  magnifications). For sherds without charred food crusts, residues were removed with water and pipette from a small spot (c. 1–2 cm diameter), and applied to a clean microscope slide. This process was repeated until a suitable amount of residue was removed. At least one location on the interior and exterior of each sherd was sampled by this method, and for those that had starches on either of these surfaces, the broken edges were also then sampled for comparison. Distribution patterns of starches on each surface were used to evaluate whether the microfossils were associated with vessel use (i.e. located on a used surface but absent from a non-used surface) or post-depositional, including assessing possible

laboratory contaminants. Charred residues were scraped from the potsherds and processed with weak (0.125%) NaOH to break down the carbonised matrix and release entrapped starches (see Crowther, 2009b for full protocol). Prepared slides were examined as water mounts and fully scanned twice; the second time after treatment with IKI stain (to improve the detection of starches) and 5% acetic acid (to dissolve needle-fibre calcite crystals as well as other extraneous carbonates from the sediment and vessel temper) (Crowther, 2009b), both of which were applied *in situ* on the slide. Results before and after IKI and acetic acid treatment were compared. Standard morphometric characteristics were recorded for each starch granule (e.g., Torrence and Barton, 2006; Lentfer, 2009a, 2009b; Crowther, 2018).

### Sediments

Three sediment samples were selected from SE-RF-2 for starch granule and phytolith analyses (Figs 2 and 4a). Samples from Layers 1 (from 0–10 cm depth) and Layer 2 (from 30–40 cm depth) were collected from the northwest corner of square W42 (Green, pers. comm. 2007) and the third from a post-hole located in square A26 in the food preparation area. The post-hole was cut into the underlying sterile sand layer, but was filled with grey sand associated with the Lapita occupation layer (Layer 2). Additionally, two sediment samples collected from Square S-23 at SE-RF-6 were selected for phytolith analysis. These were from Layer 1, the brown loam soil with modern vegetation and gardening, and Layer 2, the grey sand midden horizon at 30 cm depth (referred to in the analytical diagrams and tables as ‘L25’) (Figs 3 and 4b).

Starch granules were extracted from 5 g sub-samples of the SE-RF-2 sediments using heavy-liquid flotation with sodium polytungstate ( $\text{Na}_6(\text{H}_2\text{W}_{12}\text{O}_{40})$ ) (SPT) (Therin and Lentfer, 2006). They were first treated with weak (6%) hydrogen peroxide for 30 minutes to remove organics, sieved at 300  $\mu\text{m}$  to remove large sand grains, and deflocculated with warm (35°C) 5% sodium hexametaphosphate ( $\text{NaPO}_3$ )<sub>6</sub>. All sediment extracts were dried and suspended in 500  $\mu\text{l}$  of water from which 50  $\mu\text{l}$  samples were removed per slide, which were examined as water mounts both before and after IKI staining (as above).

Phytoliths were extracted from 5 g sediment sub-samples

using heavy liquid flotation with sodium polytungstate (Lentfer and Boyd 1998). Residues were mounted onto microscope slides in benzyl benzoate, examined with transmitted light microscopy ( $\times 400$ – $600$  magnification). A minimum of 100 phytoliths were counted for each sample after which slides were fully scanned and presence of previously unrecorded morphotypes were noted.

### Microfossil recording and identification

Starch and phytolith morphotypes were photographed and compared with modern comparative reference material and published descriptions (e.g., Loy *et al.*, 1992; Lentfer, 2003, 2009a, 2009b, 2009c; Fullagar *et al.*, 2006), and classified accordingly. To differentiate Musaceae seed phytoliths from leaf phytoliths, and further, to differentiate between Musaceae sections (*Eumusa* syn: *Musa* and *Australimusa* syn: *Callimusa*) and species, maximum dimensions of craters and body length were measured for all Musaceae morphotypes with craters. Body length/crater width ratios were calculated and compared with morphotypes from the modern comparative Musaceae collection (see Wilson, 1985; Ball *et al.*, 2006; Lentfer, 2009c, Vrydaghs *et al.*, 2009). Tukey HSD and B tests for homogeneity were also undertaken. Charcoal particles and burnt phytoliths were also recorded (see Lentfer *et al.*, 2010).

## Results

### Starch Analysis

Twenty of the 63 sherds were observed under reflected light as having possible starch residues. Of these, 11 sherds were confirmed by transmitted light analysis as having starch: five plain sherds, one incised and five dentate-stamped. A total of 55 starch granules were recovered, most of which were from the interior (no. granules = 28) and exterior ( $n = 23$ ) of the sherds rather than the broken edges ( $n = 4$ ) (see Table 2). Although the degree of confidence is reduced by the small number of granules ( $< 3$ ) recovered in any single sherd extract, this overall pattern is compelling and suggests that the residues in the majority of cases originate from vessel use, most likely for food preparation, storage, cooking or serving. Twenty-one of the recovered granules were morphologically 'native' (visibly undamaged), three had minor mechanical damage (e.g., cracked, split, torn or partial loss of birefringence; referred to as 'Type 1' damage in Table 2), 15 had more extensive mechanical damage resulting in complete loss of birefringence ('Type 2' damage), two were gelatinised (modified by cooking, i.e. heat and moisture), and 14 were amorphous and appeared as solubilised or dispersed deposits that stained with IKI but otherwise had no discrete form. IKI staining proved critical for detecting small and damaged starches during the analysis. No gelatinised granules or amorphous deposits were detected prior to staining. Nor were the majority of starch granules less than about  $5 \mu\text{m}$  in size, which nonetheless comprised over one quarter (30.4%) of the entire morphologically-classifiable starch assemblage. These granules were otherwise difficult to detect owing to their small size and typically low birefringence. Many larger, damaged granules that had weak or no birefringence were also revealed by the stain.

In addition to the 55 starches extracted from sherd residues, 51 granules were recorded in the extracts analysed from the three SE-RF-2 sediments. Most of these were native or displayed only minor damage such as small surface pits or cracks. A single, slightly swollen granule with weak

birefringence at its periphery was recovered from Layer 2 (Table 2).

The pottery and sediment starch assemblage (excluding those granules with extensive morphological alterations) was classified into 18 morphotypes (Table 3). Of these, four could be assigned to specific plant taxa with a high degree of confidence. Type 1a1 ( $n = 8$ ) (Fig. 5a–c), found on four sherds (163/P2, 165/P1, 166/23 and 166/P5) and in the post-hole grey sand feature, was identified as *Colocasia esculenta* (taro) (Fig. 5d). This morphotype displayed a combination of attributes typical of storage starch granules from the corn including small size  $\leq 8 \mu\text{m}$  (most were  $3$ – $6 \mu\text{m}$ ), round (spherical) to sub-round (sub-spherical) shape and the presence of multiple flat to slightly concave facets. The facets have slightly rounded edges when viewed with long working-distance lenses, but appear sharper when examined using an oil immersion objective that enabled their differentiation from transitory starch granules of similar size that are found in the photosynthetic tissues of many plants (Fullagar *et al.*, 2006: 598). Types 2a2 ( $n = 1$ ), 6a ( $n = 6$ ) and 6b ( $n = 5$ ) (Figs 6a and 7), found only in the SE-RF-2 sediment samples, were identified as being derived from Musaceae (see Figs 6b and 8); 6a and 6b were present in all three samples and 2a2 exclusively in the grey sand of the post-hole feature (more specific descriptions and identification of these starch granules is given in a later section of this paper). Within the limits of the reference material available for comparison, and at the present stage of morphometric analysis of that material, the other 14 morphotypes could not be assigned to any specific plant taxa. However, given the range of starch granule morphotypes present in the extracted assemblages, it is very likely that several plants and plant products were represented and probably on the menu, in particular those present in the pottery residues: types 1, 1a2, 1a3, 1c, 7, 9a, 10 and 10a2. Nevertheless, until starch granules are identified, the derivation of morphotypes from edible plants cannot be assumed.

The presence of the Type 1a1 morphotype is the most significant finding from the sherd analysis, pointing to the likelihood of taro being processed and cooked on site. The morphotype occurred exclusively on either the interior or exterior surfaces of four sherds (163/P2, plain; 165/P1, plain; 166/P5, plain; 166/23, dentate stamped), and was absent from their broken edges (which would reflect post-depositional contaminants). It is probably not by coincidence that they were recovered from the purported cooking sheds and food preparation area (specifically, excavation squares ZY26-27 and WV26-27). It is very likely that 166/23 and 166/P5, with charred interior surfaces, came from pots used for cooking. The other two sherds, which were associated with pit features in the purported food preparation area, were probably from vessels used for preparation of taro and/or storage. Similarly, the occurrence of gelatinised and damaged granules on the interior and exterior surfaces of other sherds found in the two areas suggests similar types of vessel usage (Table 2).

It is notable that within the constraints of this analysis and the small amount of starch recovered, there were no discernible relationships between pot decoration and usage. This needs further investigation but it should be kept in mind that one of the primary factors contributing to the low starch yield in the sherd analysis may be the poor survival of starch in a cooking environment where granules are exposed to heat and hot water in particular. Experiments undertaken by Crowther (2009a) showed that taro starch does not remain very cohesive or sac-like when fully gelatinised from cooking and, therefore, may not have been detected or differentiated from small, amorphous deposits in the sample residues analysed. Gelatinised granules are also more susceptible



**Table 2.** Records of starch granule morphotypes on pottery sherds and in sediments from SE-RF-2, and comments relating to pottery use. For indeterminate starch morphotypes (indet.): *T1* = Type 1 damage, *T2* = Type 2 damage, *g* = gelatinisation, *n* = native, *a* = amorphous. For sample location: *I* = interior of sherd, *E* = exterior of sherd, *BE* = broken edge of sherd, *ch* = charred residue.

pottery sherds	sample location															indeterminate	comments				
		1	1a1	1a2	1a3	1b	1c	2	2a1	2a2	6a	6b	7	9a	10			10a1	10a2	10b1	10b2
135/39?	I(ch)	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 <sup>T1</sup>	Use indeterminate.
	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2 <sup>a</sup>	
	BE	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1 <sup>n</sup>	
16/21	I	—	—	—	2	—	—	—	—	—	—	—	1	—	1	—	—	—	—	1 <sup>g</sup> ,1 <sup>a</sup>	Gelatinised starch and four native granules on interior. No starch from broken edge. Probable cooking or serving.
	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
	BE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
16/P1	I	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 <sup>n</sup> ,1 <sup>a</sup>	Use indeterminate.
	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 <sup>a</sup>	
	BE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
163/115	I	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5 <sup>T2</sup> ,1 <sup>a</sup>	Five damaged granules on interior and single Type 1a3 granule on exterior. No starch from broken edge. Possible food storage or preparation
	E	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
	BE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
163/P2	I	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2 <sup>T2</sup> ,1 <sup>a</sup>	Single cf. <i>C. esculenta</i> granule on exterior. Possible storage or preparation of <i>C. esculenta</i> .
	E	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2 <sup>T2</sup>	
	BE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
163/27	I	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 <sup>T2</sup>	Use indeterminate.
	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 <sup>T2</sup> ,1 <sup>a</sup>	
	BE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
165/P1	I	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Two cf. <i>C. esculenta</i> granules on interior. Possible storage or preparation of <i>C. esculenta</i> .
	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 <sup>a</sup>	
	BE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 <sup>T2</sup>	
166/23	I(ch)	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Three cf. <i>C. esculenta</i> granules on exterior. Charred residue on interior. Possible cooking of <i>C. esculenta</i> .
	E	1	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 <sup>T1</sup> ,1 <sup>T2</sup>	
	BE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
166/P1	I(ch)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 <sup>T2</sup> ,2 <sup>a</sup>	Use indeterminate.
	E	—	—	—	—	—	—	—	—	—	—	—	2	—	—	1	—	—	—	—	
	BE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 <sup>T2</sup>	
166/P5	I(ch)	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Single cf. <i>C. esculenta</i> granule from interior charred residue. Possible cooking of <i>C. esculenta</i>
	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3 <sup>a</sup>	

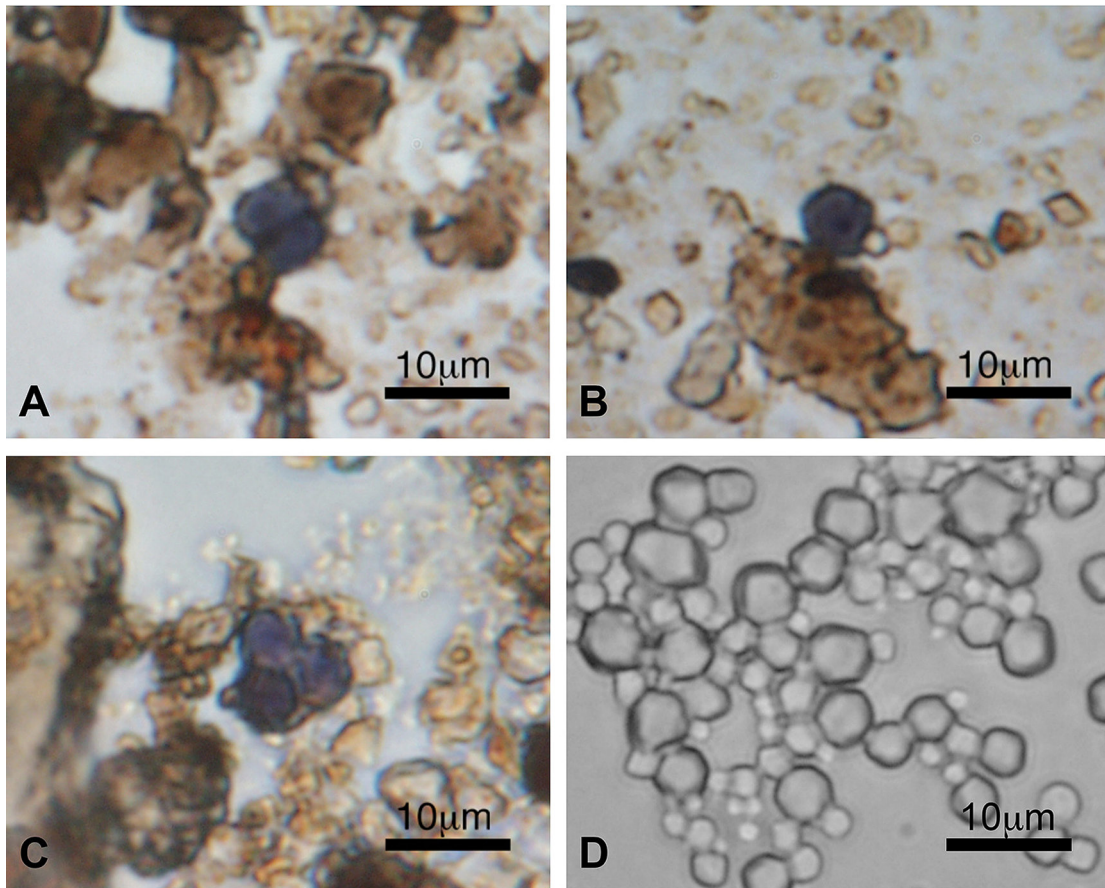
to enzymatic digestion and will degrade preferentially in archaeological residues (Barton and Matthews, 2006). If pottery vessels at the site were used primarily for cooking, it is probably not surprising that starch survival overall was poor and no gelatinised taro starch granules were observed. It is also notable that no calcium oxalate raphides were present in the sample residues, despite their recovery in other Pacific island contexts in association with aroid starches (e.g., Horrocks and Barber, 2005; Horrocks and Bedford, 2005; Horrocks and Weisler, 2006). This suggests that on-site conditions may not have been conducive to their long-term preservation at SE-RF-2. Large quantities of needle-fibre calcite crystals were present on the sherds. Morphologically they are similar to calcium oxalate raphides, but can be distinguished from them because they are soluble in weak acetic acid (Crowther, 2009b).

### Phytolith Analysis

The results of the phytolith analysis for SE-RF-2 and SE-RF-6 sediments are presented in Table 4. The assemblages were dominated by epidermal morphotypes (listed as ‘other (indet.)’) that have low diagnostic value but are characteristic of a complex of vegetation types including dicotyledonous trees, shrubs and scramblers. Diagnostic morphotypes were present but in relatively low numbers. These represented panicoid grasses and bamboo, palms including morphotypes characteristic of *Metroxylon*, *Cocos*, *Calamus* and *Licuala* species, small to medium, echinate to nodular, globular morphotypes found in several species of palms, ginger and Marantaceae, as well as morphotypes from Musaceae, Euphorbiaceae, Burseraceae, Malvaceae, Dilleniaceae, Rhizophoraceae, Fabaceae and Solanaceae. Burnt phytoliths and charcoal were also present.

**Table 3.** Description and counts of archaeological starch morphotypes present on sherds and sediments from the SE-RF-2 Lapita site.

starch type	count	shape(s)	hilum	vacuoles	fissures	lamellae	max. size range (µm)	comment
1	9	round (not sub-classified)	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	
1a1	8	round, sub-round and sub-elliptical with multiple facets, some with irregular margins	centric	absent	absent	absent	2.5–8	cf. <i>Colocasia esculenta</i>
1a2	2	round, sub-round and sub-elliptical, often with multiple facets and/or irregular margins	centric	absent	absent	absent	10–11	
1a3	3	round, elliptical, sub-round/polygonal with up to six facets, bell with two facets	centric	absent	absent	absent	6–9	Surfaces and margins very smooth.
1b	1	round	centric	absent	fine and shallow V- or Y-shaped 'crack'	absent	14–19	
1c	3	round, sub-round, sub-elliptical	centric	absent	absent	rare; indistinct where present	18–35	Surfaces and margins generally very smooth; cross arms perpendicular and often diffuse (not sharp) at the periphery.
2	3	elliptical (not sub-classified)	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	
2a1	1	elliptical	centric	absent	absent	absent	12–21	elongate cross-point
2a2	1	elliptical/oblong, almost elongate; surface appears wrinkled, but may be an effect of the fissure	centric	absent	longitudinal with wrinkled edges	absent	24	Margin irregular and surface slightly rough cf. Musaceae: <i>Musa acuminata</i> , <i>Musa AAA</i>
6a	6	sub-elongate to elongate irregular-ovate with acute hilum end, generally obtuse, rounded distal end and enlarged middle; one granule has distinctive protrusion from hilum end	highly eccentric	absent	absent	present but generally weak; most distinct toward distal end	40–55	cf. Musaceae: <i>Musa cultivar AAA</i> , <i>Musa acuminata</i> × <i>schizocarpa</i>
6b	7	elongate to very elongate elliptical, occasionally slightly curved	highly eccentric	absent	absent	generally present but weak; most distinct toward distal end	39–53	cf. Musaceae: <i>Musa cultivar AAA</i> , <i>Musa acuminata</i> × <i>schizocarpa</i>
7	1	irregular (not sub-classified)	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	
9a	2	bell with single, round-edged facet	centric	absent	absent	absent	13–37	
10	3	polygonal (not sub-classified)	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	
10a1	6	polygonal (multi-faceted) with six or seven sharp-edged (angular), slightly concave facets	centric, rarely slightly eccentric	absent	straight (transverse) or Y-shaped, usually deep	absent	11–24	
10a2	11	polygonal (multi-faceted) or sub-round with three to six flat or convex facets,	centric or slightly eccentric	absent	straight (transverse), V-, Y-, or X-shaped, fissure, usually deep	absent	10–27	
10b1	4	polygonal (multi-faceted) or sub-round with three to six flat or convex facets, generally round-edged	centric or slightly eccentric	small cavity	absent	absent	10–24	
10b2	2	polygonal (multi-faceted) with five or six round-edged flat or convex facets	centric or slightly eccentric	large open cavity	absent	absent	13–21	Large cavity may be the result of damage rather than a feature of the native granule

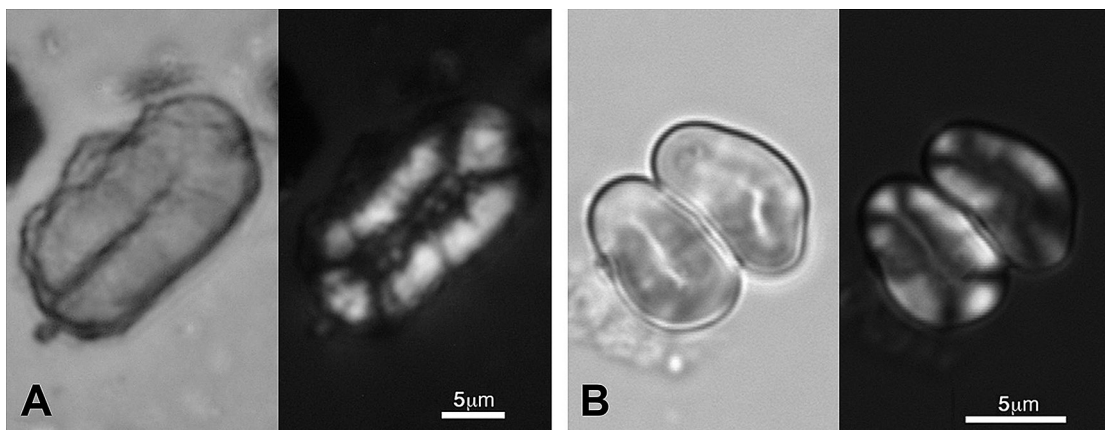


**Figure 5.** (A–C) Examples of Type 1a starch granules (stained purple with IKI) from SE-RF-2 Lapita sherds and (D) modern *Colocasia esculenta* starch for comparison. (A) Cluster of two granules from RF2/165/P1. (B) Isolated granule from RF2/166/P5. (C) Cluster of three granules from RF2/166/23.

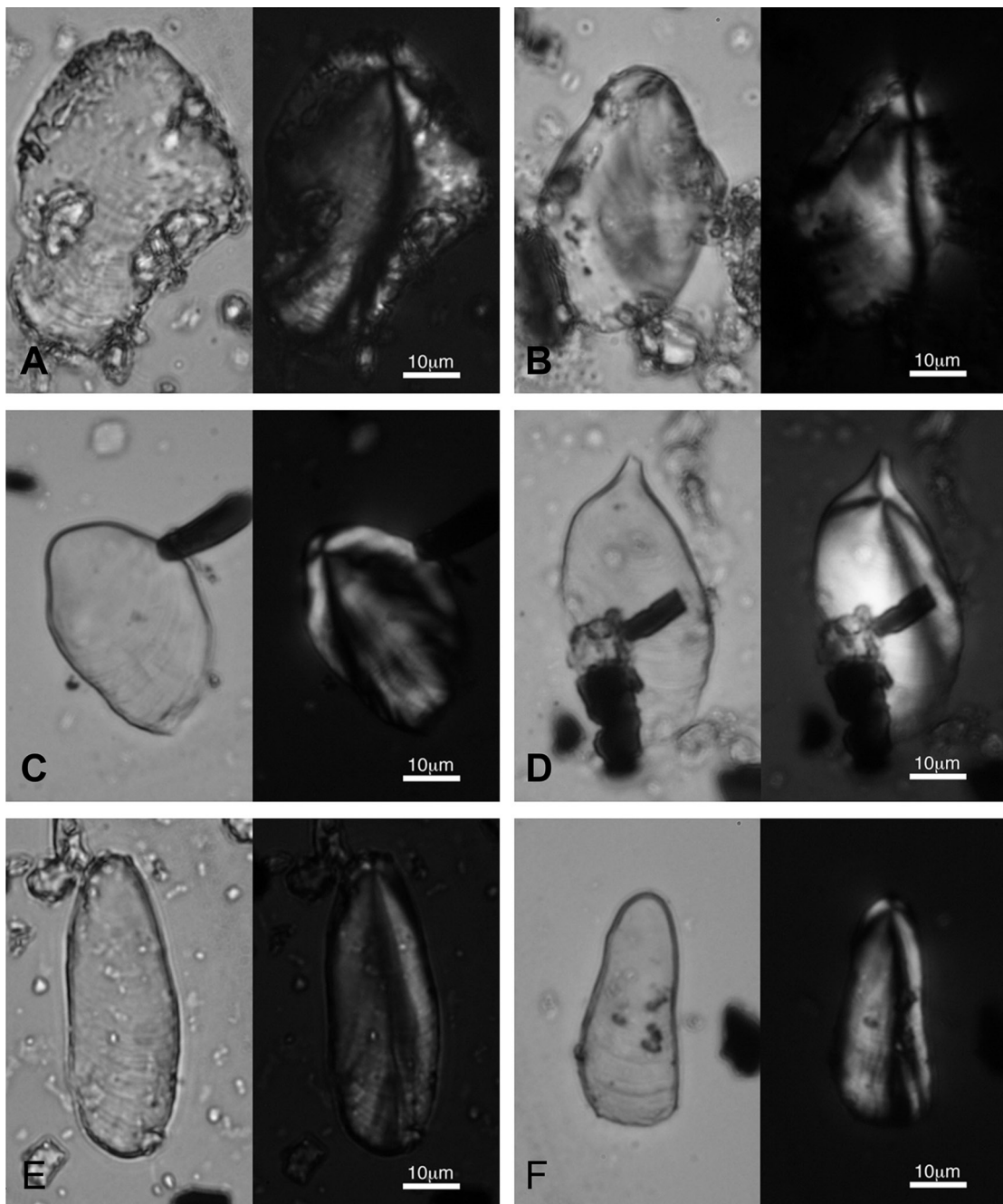
### SE-RF-2

Layer 1—black soil: This assemblage was dominated by polyhedral and elongate morphotypes. Articulated epidermal anticlinal and polygonal morphotypes, indicative of dicotyledonous vegetation, were common. Musaceae morphotypes were also relatively common, comprising >9% of the assemblage. Palm morphotypes, possibly derived from *Cocos nucifera* and *Metroxylon* sp., and panicoid grass morphotypes were also present, but rare. Burnt phytoliths were common, mostly polyhedral morphotypes including epidermal polyhedral morphotypes found frequently in Euphorbiaceae, but also present in other species. Charcoal particles were very rare.

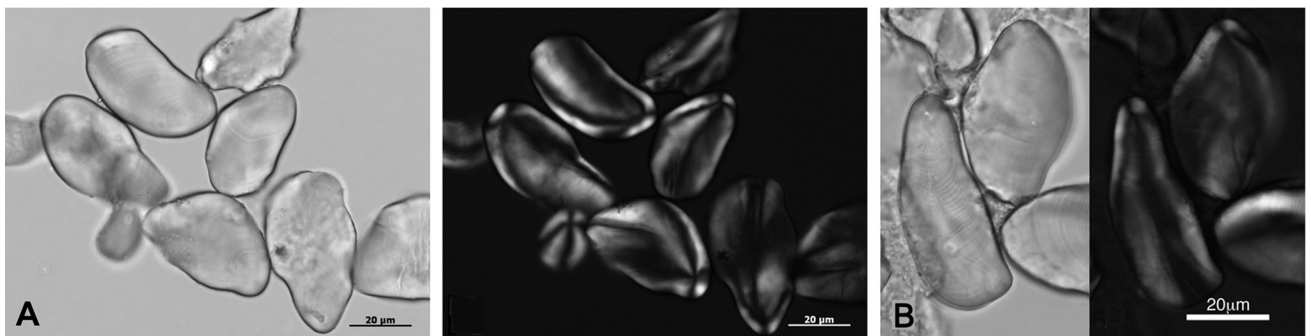
Layer 2—grey sand: Articulated epidermal anticlinal and polygonal morphotypes, indicative of dicotyledonous vegetation also dominated this assemblage. Musaceae morphotypes were very common comprising > 15% of the assemblage. Palm morphotypes represented > 7% of the assemblage; small echinate spheroid morphotypes similar to those found in *C. nucifera* but also present in a range of other genera such as *Licuala* and *Calamus* spp. were most common. Reniform echinate globular morphotypes commonly found in *C. nucifera* were present but larger morphotypes characteristic of *Metroxylon* sp. (Fenwick *et al.*, 2011; Lentfer, 2003) were very rare. Panicoid grass morphotypes, burnt phytoliths and charcoal particles were also very rare.



**Figure 6.** (A) Type 2a2 starch granule from SE-RF-2 Layer 2 posthole feature, and (B) modern *Musa acuminata* starch.



**Figure 7.** Examples of Type 6a (A–D) and 6b (E–F) starch granules from SE-RF-2 sediments in plain (left panel) and cross-polarised (right panel) light. (A, E) Layer 1; (B) Layer 2; (C, D, F) Layer 2 posthole feature.



**Figure 8.** Modern *Musa acuminata* × *schizocarpa* starch granules in plain (left panel) and cross-polarised (right panel) light.

**Table 4.** Composition of phytoliths and charcoal in sediments from SE-RF-2 and SE-RF-6.

phytolith morphotypes and charcoal		% composition of phytoliths				
		SE-RF-2 Layer 1	SE-RF-2 Layer 2	SE-RF-2 Post-hole	SE-RF-6 Layer 1	SE-RF-6 Layer 2 (L25)
Musaceae		9.83	15.11	0.00	0.00	7.49
Palmae	< 10 µm	0.58	6.67	0.98	4.52	5.35
	> 10 µm	0.58	0.44	0.00	1.51	2.14
	cf. <i>Metroxylon</i> sp.	0.00	0.00	0.00	4.02	1.07
Palmae/Zingiberales		0.58	1.33	0.98	0.50	1.07
Gramineae	Bambusoid	0.00	0.00	16.67	0.00	0.00
	Bambusoid ESC	0.00	0.00	2.94	0.00	0.00
	Panicoid ESC	0.58	1.33	0.00	0.00	0.00
Euphorbiaceae	cf. <i>Macaranga</i> sp.	0.58	0.00	0.00	1.51	1.07
Burseraceae	cf. <i>Canarium indicum</i>	0.00	0.00	3.92	0.00	0.00
Malvaceae	cf. <i>Hibiscus tiliaceus</i>	0.00	0.00	1.96	0.00	0.00
Dilleniaceae	cf. <i>Dillenia</i> sp.	0.00	0.00	0.98	0.00	0.00
Rhizophoraceae	cf. <i>Rhizophora</i> sp.	0.00	0.00	1.96	0.00	0.00
Solanaceae	cf. <i>Solanum torvum</i>	0.00	0.00	0.98	0.00	0.00
Fabaceae	cf. <i>Mucuna</i> sp.	1.16	0.00	0.98	1.01	0.00
gl/nod (indet.)		0.58	1.78	1.96	1.01	1.07
other (indet.)		85.55	68.89	62.75	85.93	73.80
burnt phytoliths		5.78	1.78	0.00	6.53	0.53
ratio (charcoal particles : phytoliths)		0.03	0.01	0.00	0.15	0.29
total phytolith count		173	225	102	199	187

Grey sand from the post-hole feature: This sample had the most diverse assemblage of diagnostic phytoliths with at least seven plant families represented. Also, it was the only sample with Bambusoid morphotypes (Fig. 9a). Notably, the culm morphotypes were most common, comprising > 16% of the assemblage, suggesting they were derived from a bamboo post used in construction of the cooking house. By contrast, epidermal short cells from leaves were rare. Palm morphotypes were also present but very rare and Musaceae morphotypes were absent. Morphotypes found in other trees and shrubs were also present including phytoliths from the wood, leaves and nutshell of *Canarium* (Burseraceae). Burnt phytoliths and charcoal particles were absent.

### SE-RF-6

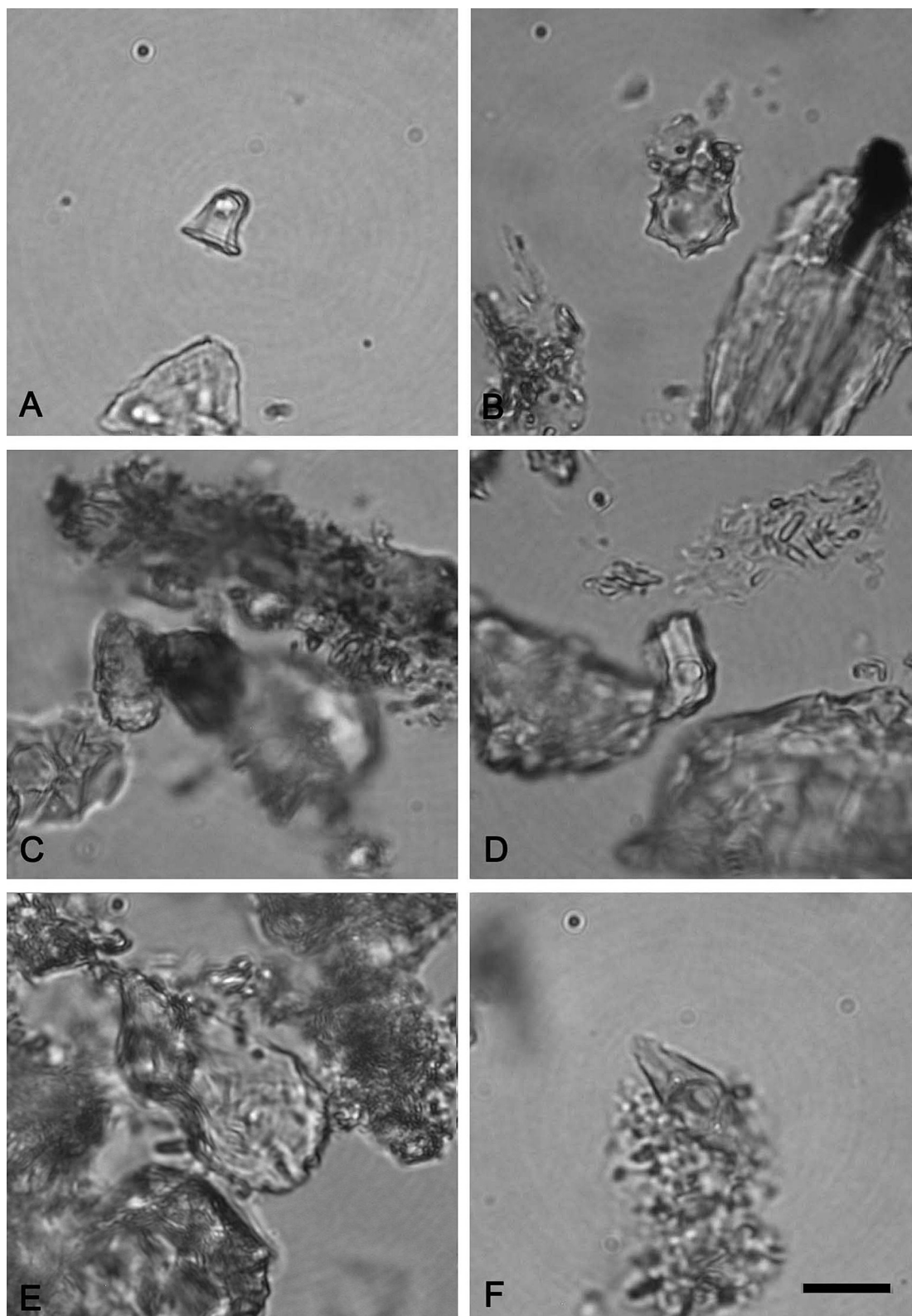
Layer 1—brown soil: The phytolith assemblage was dominated by polygonal, elongate and epidermal morphotypes. These included Fabaceae morphotypes, one cf. *Mucuna* sp., a vine commonly found in regrowth forest (Lentfer, 2003; Peekel, 1984). Articulated epidermal silica skeletons were common. Diagnostic palm morphotypes were also relatively common, representing > 9% of the assemblage including globular echinate leaf morphotypes that occur in a range of palms (cf. SE-RF-2 Layer 2) as well as other morphotypes more typical of *Metroxylon* (Fig. 9b). Fruit morphotypes from *Metroxylon* sp. (cf. *M. sagu*, Fig. 9c) were also present. Diagnostic grass and Musaceae morphotypes were absent. Burnt phytoliths were very common, and similar to SE-RF-2 Layer 1 comprised epidermal polyhedral morphotypes (cf. Euphorbiaceae). Charcoal particles were common.

Layer 2 (L25)—grey sand: The phytolith assemblage was dominated by polygonal, elongate and epidermal morphotypes. Euphorbiaceae cf. *Macaranga* sp. were present. Over 7% of the diagnostic morphotypes were derived from Musaceae and > 8% from palms. Similar to SE-RF-6, Layer 1, leaf morphotypes characteristic of *Metroxylon* and diagnostic fruit morphotypes were present. Grass morphotypes were absent. Burnt phytoliths were relatively rare but charcoal particles very common.

### Musaceae starch

Type 6a starches, shown in Fig. 7a–d, are large (50–55 µm), irregular-ovate granules with a highly eccentric, acute hilum end, a generally obtuse, rounded distal end and an enlarged middle. These granules have tightly packed lamellae that are most visible at the distal end. One granule belonging to this type, found in the post-hole sample, has a very distinctive, long, thin protrusion or ‘peak’ from the hilum end (Fig. 7d). This morphotype occurs in the fruit pulp of the triploid *Musa acuminata* (AAA) Cavendish cultivar (Fullagar *et al.*, 2006: fig. 6a–b). Morphotypes of this type have not been found in Australimusa bananas but similar morphotypes with lesser ‘peaks’ have been found in the fruit of *M. acuminata* ssp. *banksii* and *M. acuminata* × *schizocarpa* suggesting that this is a feature unique to the Eumusa section, possibly specific to *Musa acuminata* ssp. *banksii* and its derivatives. Aside from the peaked granule in the Layer 2 post hole, Type 6a starches match closely with *M. acuminata* × *schizocarpa* (Fig. 8) but also occur in the fruit, corms and more rarely leaves and inflorescence of *M. acuminata* ssp. *banksii* as well as AA, AAA and AB cultivars.

Type 6b (Fig. 7e–f) comprises large (39–53 µm), elongate ovate/oblong granules with highly eccentric hila and distinct, tightly packed lamellae that are most visible at the distal end. Similar morphotypes have been recorded in various Musaceae, including *M. acuminata*, *M. acuminata* × *schizocarpa* (Fig. 8c), *M. acuminata* var. *cerifera* (a Malaysian variety), *M. peekelii* (which is endemic to the New Guinea region) and *M. maclayi* (which occurs wild from New Guinea to the Solomon Islands) (Argent, 1976; Daniells *et al.*, 2001). Similar forms also occur in other economic taxa such as *Dioscorea alata* and *D. pentaphylla* (Fullagar *et al.*, 2006; Loy *et al.*, 1992). Many of these possibilities can be eliminated on the basis of granule morphology, assemblage composition or geographical distribution. For example, none of these taxa, with the exception of *M. acuminata* and *M. acuminata* × *schizocarpa*, produce both Type 6a and 6b starches. *Dioscorea alata* starch granules are further differentiated from the SE-RF-2 starches by their typically

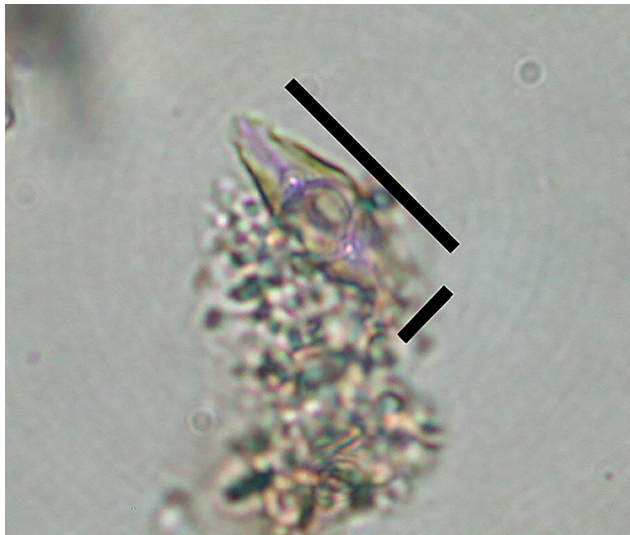


**Figure 9.** (A) Bambusoid epidermal short cell from the post hole sample at SE-RF-2. (B, C) Echiniate globular phytolith and irregular globular phytolith cf. *Metroxylon sagu* from SE-RF-6 Layer 1. (D, E) Volcaniform leaf morphotype and tabular seed morphotype cf. the Australimusa species *Musa maclayi* from Layer 2, SE-RF-2. (F) Boat-shaped volcaniform morphotype from Layer 2, SE-RF-2—the same morphotype was found in leaves from a triploid AAA banana (accession number ENB24) collected from East New Britain (Lentfer, 2003b). Scale bar = 10  $\mu\text{m}$ .

truncated distal margin, which is absent from the Type 6b granules. Likewise, the distinctive ‘sculpted’ hilum end commonly present on larger *D. pentaphylla* starches (i.e. those that occur in the same size range as Type 6b) is also absent from the archaeological granules. Very few starch granules in general were observed in the reference materials from the Australimusa *M. maclayi*, but elongate granules

similar to Type 6b were present in the inflorescence, albeit only rarely. The majority of granules from this taxon were < 30  $\mu\text{m}$  in size and of a simple ovate form that is not represented in the SE-RF-2 assemblages.

Type 2a2 is a medium-sized (24  $\mu\text{m}$ ), sub-elongate ovate granule with a longitudinal fissure and wrinkled surface (Fig. 6a). Similar, but less wrinkled granules have been observed

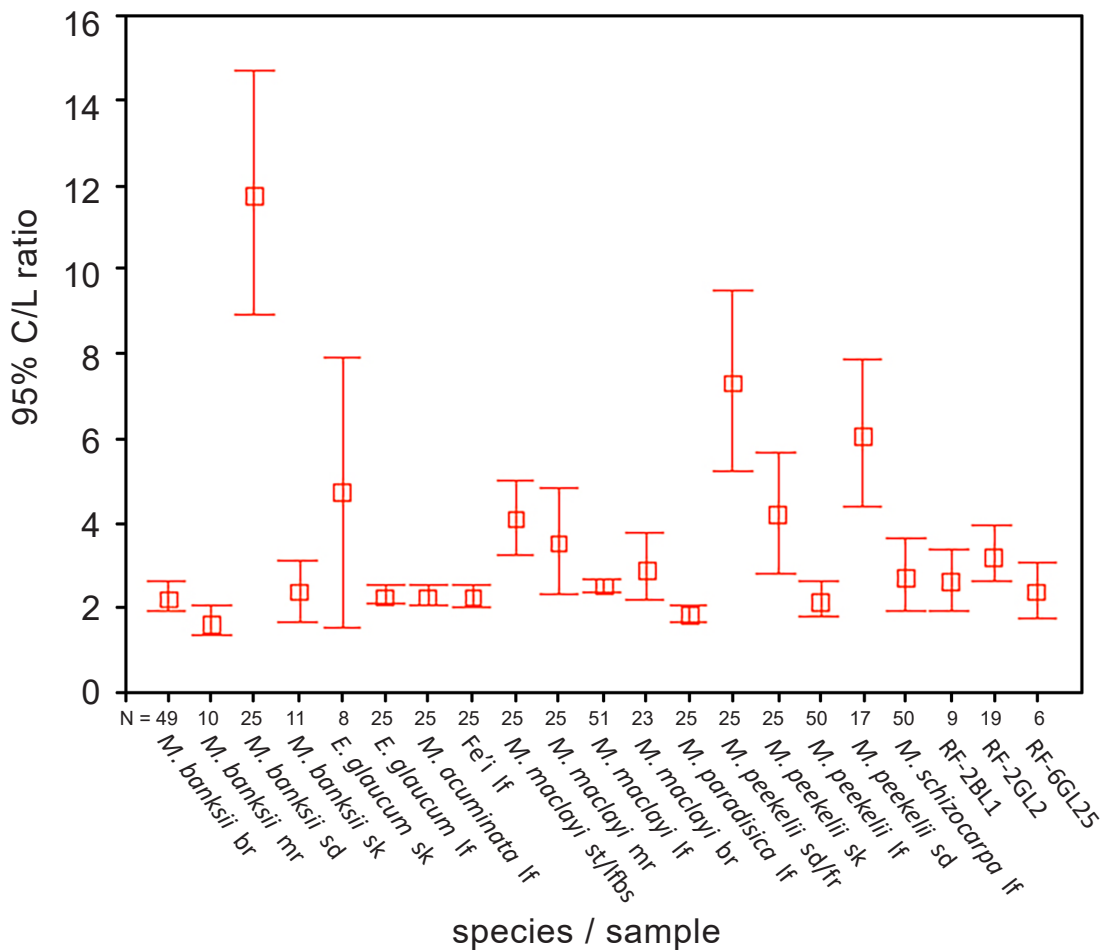


**Figure 10.** The ratio of maximum body length to maximum crater width of phytoliths were calculated and used for statistical analyses.

in the seed of some *Heliconia* spp., but this exact morphotype has also been found in the leaves and pseudostem of an unidentified subspecies of *M. acuminata* from Flores Indonesia (Fig. 6b), and the fruit of an AAA cultivar. It is therefore, most likely that the 2a2 granule is derived from the *M. acuminata* spectrum rather than *Heliconia*, especially given the presence of other distinctive Musaceae starch and phytolith morphotypes in the sediment samples.

### Musaceae phytoliths

Musaceae phytoliths were found in Layers 1 and 2 at SE-RF-2 and Layer 2 (L25) at SE-RF-6 but none were recorded from SE-RF-6 Layer 1. The assemblages consist of a variety of Musaceae phytoliths including globular, polyhedral and volcaniform morphotypes with echinate, nodular or tuberculate decoration and craters, and other morphotypes without craters. Rigorous comparison with modern reference material shows strong similarity between a leaf morphotype from the Australimusa species *M. maclayi* and one of the archaeological morphotypes from Layer 2, SE-RF-2 (Fig. 9d), and again from the same layer, between a boat-shaped phytolith and a Eumusa AAA cultivar (Fig. 9f). Furthermore, some tabular and polyhedral morphotypes from Layer 2 of SE-RF-2 are derived from seeds and are diagnostic to the Australimusa Section bananas (Fig. 9e). Interestingly, no seed morphotypes were found in Layer 1 of SE-RF-2. For Layer 2 (L25) of SE-RF-6 a nodular globular morphotype is possibly derived from Australimusa seeds, and also, an echinate irregular globular morphotype might be from seeded Eumusa bananas, but a stronger similarity with *Metroxylon* fruit phytoliths suggests that this is a more likely derivation. Other than that, the majority of morphotypes with craters, particularly globular and volcaniform morphotypes, are more difficult to differentiate (Lentfer, 2009c) but it should also be noted that *Ensete glaucum* is unlikely to be represented at either site. It has distinctive seed phytoliths (Lentfer, 2003, 2009c; cf. Vrydaghs *et al.*, 2009) that were not present in the assemblages. Also, *Ensete* phytoliths are



**Figure 11.** Error bars of body length/crater width ratios (L/C ratio) of archaeological and modern *Musa* and *Ensete* phytolith morphotypes show that the phytoliths with craters in the SE-RF-2 and SE-RF-6 assemblages were probably derived from plant parts other than seeds of either *Eumusa* bananas or *Australimusa* bananas. (See also the Tukey HSD homogeneity tests, Table 5, based on phytoliths with craters). (lf = leaf, br = bract, bs = base, sd = seed, st = stem, sk = skin, fr = fruit, mr = midrib). Numbers of phytoliths in each sample are indicated below horizontal axis.

**Table 5.** Results for the Tukey HSD and B tests for homogeneity using body length/crater width ratios of modern and archaeological *Musa* and *Ensete* phytoliths. Means for groups in homogeneous subsets are displayed.

		subset for alpha = 0.05			
species/sample		N	1	2	3
<b>Tukey HSD<sup>a</sup></b>					
<i>Musa banksii</i>	midrib	10	1.7009	—	—
<i>M. paradisiaca</i>	leaf	25	1.8834	—	—
<i>M. peekelii</i>	leaf	50	2.2030	—	—
<i>M. banksii</i>	bract	49	2.2553	—	—
Fe'i	leaf	25	2.2872	—	—
<i>M. acuminata</i>	leaf	25	2.2975	—	—
<i>Ensete glaucum</i>	leaf	25	2.3367	—	—
<i>M. banksii</i>	skin	11	2.4054	—	—
RF-6GL25	—	6	2.4083	—	—
<i>M. maclayi</i>	leaf	51	2.5328	—	—
RF-2BL 1	—	9	2.6659	—	—
<i>M. schizocarpa</i>	leaf	50	2.7818	—	—
<i>M. maclayi</i>	bract	23	2.9615	—	—
RF-2GL2	—	19	3.2830	3.2830	—
<i>M. maclayi</i>	midrib	25	3.5750	3.5750	—
<i>M. maclayi</i>	stem/leaf base	25	4.1430	4.1430	—
<i>M. peekelii</i>	skin	25	4.2419	4.2419	4.2419
<i>E. glaucum</i>	skin	8	4.7604	4.7604	4.7604
<i>M. peekelii</i>	seed	17	—	6.1248	6.1248
<i>M. peekelii</i>	seed/fruit	25	—	—	7.3475
<i>M. banksii</i>	seed	25	—	—	—
significance			0.071	0.145	0.060
<b>Tukey B<sup>a</sup></b>					
<i>M. banksii</i>	midrib	10	1.7009	—	—
<i>M. paradisiaca</i>	leaf	25	1.8834	—	—
<i>M. peekelii</i>	leaf	50	2.2030	—	—
<i>M. banksii</i>	bract	49	2.2553	—	—
Fe'i	leaf	25	2.2872	—	—
<i>M. acuminata</i>	leaf	25	2.2975	—	—
<i>E. glaucum</i>	leaf	25	2.3367	—	—
<i>M. banksii</i>	skin	11	2.4054	—	—
RF-6GL25	—	6	2.4083	—	—
<i>M. maclayi</i>	leaf	51	2.5328	—	—
RF-2BL 1	—	9	2.6659	—	—
<i>M. schizocarpa</i>	leaf	50	2.7818	—	—
<i>M. maclayi</i>	bract	23	2.9615	—	—
RF-2GL2	—	19	3.2830	—	—
<i>M. maclayi</i>	midrib	25	3.5750	3.5750	—
<i>M. maclayi</i>	stem/leaf base	25	4.1430	4.1430	—
<i>M. peekelii</i>	skin	25	4.2419	4.2419	—
<i>E. glaucum</i>	skin	8	4.7604	4.7604	4.7604
<i>M. peekelii</i>	seed	17	—	6.1248	6.1248
<i>M. peekelii</i>	seed/fruit	25	—	—	7.3475
<i>M. banksii</i>	seed	25	—	—	—

<sup>a</sup> Uses harmonic mean sample size = 17.667

characterised by short nodular ornamentation and irregular rims. Such traits were not seen in the archaeological material that is characterised by phytoliths with regular crater rims and a dominance of tuberculate ornamentation.

The statistical analysis of the ratio of maximum body length: maximum crater width (Figs 10 and 11; Table 5) is significant, pointing to derivation mostly from banana plant parts other than seeds. This analysis, however, was not sufficient to identify the *Musa* banana species and cultivars that were growing at the sites, perhaps not surprising given the strong similarity between *Eumusa* and *Australimusa* morphotypes and the previous work along these lines

(Wilson, 1985). Nevertheless, the tests for homogeneity using the same criteria (Table 5) proved to be very useful by determining degree of similarity between the archaeological *Musaceae* assemblages and modern *Musaceae* morphotypes. There is a clinal variation in the homogeneity scores, showing a greater similarity between the SE-RF-2 Layer 1 and the Layer 2 (L25) of SE-RF-6 rather than the SE-RF-2 Layer 2, an interesting outcome given the relative chronology of the two sites. The tests also show the closest relationship between SE-RF-2 Layer 2, the oldest layer sampled, and *Australimusa* morphotypes. Furthermore, the Layer 2 (L25) assemblage from SE-RF-6 has a closer relationship with species and



**Table 6.** Phylogeny of wild and cultivated bananas (genus *Musa*) found in the Bismarcks, eastern lowland PNG, Bougainville and the western Solomon Islands chain. (Data adapted from Argent, 1976; Daniells *et al.*, 2001, 2016; Sardos *et al.*, 2018).

section	<i>Eumusa</i> (syn: <i>Musa</i> )			<i>Australimusa</i> (syn: <i>Callimusa</i> )	hybrids <i>Eumusa</i>		<i>Eumusa</i> × <i>Australimusa</i>
species	<i>M. acuminata</i> ssp. <i>banksii</i>	<i>M. balbisiana</i>	<i>M. schizocarpa</i>	<i>M. maclayi</i> ssp. <i>namatani</i> , <i>M. maclayi</i> ssp. <i>maclayi</i> , <i>M. maclayi</i> ssp. <i>ailuluai</i> , <i>M. peekelii</i> ssp. <i>peekelii</i> , <i>M. peekelii</i> ssp. <i>angustigemma</i> , <i>M. bukensis</i>	<i>M. acuminata</i> × <i>M. balbisiana</i>	<i>M. acuminata</i> × <i>M. schizocarpa</i>	
wild genotypes	AA	BB	SS	TT (unspecified for individual species)	?	AS	?
diploid cultivars	AA	?	—	Fe'i (TT)	AB	AS	AT
triploid cultivars	AAA	?	—	?	AAB, ABB	AAS?	AAT
tetraploid cultivars	AAAA	—	—	?	AABB	?	ABBT, 4x/Ax/BxT

cultivars from both *Australimusa* and *Eumusa* bananas, suggesting higher diversity. Finally, the homogeneity tests showed no relationship between seed morphotypes from the *Eumusa* bananas and any of the archaeological horizons. This is in accordance with the morphological identification of the Musaceae phytoliths for the entire microfossil assemblage, where no positive identifications were obtained for *Eumusa* seed morphotypes.

## Discussion

Green and Pawley (1999: 33) stated that:

the great advantage of prehistoric archaeology over comparative ethnology and historical linguistics is that it can locate particular assemblages of structural and portable artefacts more precisely in space and time.

We consider that this study, which provides evidence for the presence of imported crop plants in the early phase of occupation of the Reef/Santa Cruz islands, supports this view even though starch and phytoliths may not have been among the list of portable artefacts Green and Pawley were referring to at that time. Nevertheless, when associated with imported plants and whether or not they are referred to as ‘artefacts’ or ‘ecofacts’, they are crucial in the context of this study. Indeed, there is very strong support for a well-developed subsistence economy with a sound horticultural base in the early phase of settlement on the Reef Islands, as originally hypothesised by Green. The array of plants identified from phytoliths and starch feature edible and otherwise useful palms and gingers, bananas, taro, *Canarium* sp. and bamboo important for subsistence. There is also evidence of burning, and plants typical of clearance and regrowth, e.g., grass, Euphorbiaceae plants, *Mucuna* sp. and a variety of palms.

The biogeographic distribution of endemic plants on the Santa Cruz Islands, which are phytogeographically more similar to Vanuatu than the main Solomons chain of islands (Mueller-Dombois and Fosberg, 1998: 22), makes for more certainty of some plants being from introductions of plant cultivars by way of human vectors. For example, it is well accepted that bananas, both *Australimusa* and *Eumusa* types, have natural distributions limited to Near Oceania and westwards (Table 6; also see Simmonds, 1959, 1962). As such it can be assumed that all bananas in Remote Oceania would have been imports. Moreover, our evidence from both the starch and phytolith assemblages for a mixed array of bananas, including probable wild-seeded

or partly domesticated *Australimusa* bananas as well as *Eumusa* seedless hybrids (i.e. domesticated bananas) in the oldest layer at SE-RF-2 gives support for a well-planned horticultural portfolio suggesting thoughtful selection and collection during the early phase of Lapita dispersal and occupation of Remote Oceania. The presence of *M. maclayi* is in itself interesting and raises questions about the direction of sea travel and exploration. Although it is endemic to southeast PNG and the Bismarcks along with other *Australimusa* and *Eumusa* species, its distribution extends to the main Solomon Island chain in Near Oceania (Sauer, 1993: 198), outside the natural range of wild *Eumusa* species and also where it is one of only two *Australimusa* species and by far the most common. Therefore, this raises the possibility of it being collected from several different sources including mainland southeast PNG and nearby offshore islands or anywhere along the western Solomon island chain, prior to or during the occupation of the Reef/Santa Cruz Islands. Similar exploratory stop-offs could also explain the presence of Ferguson Island obsidian recovered from SE-RF-2 (Green and Bird, 1989). The presence of hybridised and domesticated *Eumusa* bananas also opens similar possibilities for stop-offs and collection, but in this instance if they weren't sourced from the Bismarcks along with the preponderance of Talasea obsidian at SE-RF-2, collection would be restricted to mainland New Guinea and its closest nearby islands.

Importantly, the relatively high percentage of Musaceae phytoliths in the younger Layer 1 of SE-RF-2 but the absence of Musaceae seed types, and furthermore, the greater similarity between that layer and the Layer 2 (L25) of SE-RF-6, indicates continuity spanning the occupation period of the sites with the implication that horticultural practices involved on-site cross-breeding of selected cultivars, and/or ongoing introductions of domesticated cultivars from further afield. Such practices may have contributed to the development and dispersal of the modern *Australimusa* Fe'i and *Eumusa* plantain bananas that now prevail in the broader region of Remote Oceania (Argent, 1976; Lebot *et al.*, 1993; Perrier *et al.*, 2011; Simmonds, 1959) especially given the geographic context of the Reef/Santa Cruz Islands and their potential role as a stepping off point to more remote islands.

The status of *C. esculenta* taro is probably similar to bananas. Although taro was tentatively identified from starch granules on stone tools from Kulu Cave in the main Solomons chain and dated to between ca 28,700 years BP and 20,100 years BP (Loy *et al.*, 1992), the species may not have occurred

naturally on the Reef/Santa Cruz Islands. Furthermore, the fact that taro starch found at SE-RF-2 was associated with pottery most likely used for cooking and serving, suggests that taro was a component of the diet that would have required cultivation for its sustainable production. This would weigh heavily in favour of it being another imported, high-yielding domesticate. The origins of Pacific Island taro being from a narrow genetic base (Kreike *et al.*, 2004; Lebot *et al.*, 2004; Sardos *et al.*, 2012) and the centre of Aroid diversity and domestication being in the South-east Asian and New Guinea region, provide further support for its likely domesticated status (Lebot *et al.*, 2010; Matthews, 1990).

*Metroxylon* species (sago palms), although endemic to the Solomon Islands, Vanuatu, Fiji and possibly further east as far as Tahiti, are likely to be another domesticated import (e.g., Höft, 1992; Bintoro *et al.*, 2018; Ehara, 2018), but probably became more important much later in the occupation sequence, since the evidence from phytoliths suggest a notable emergence of sago (cf. *Metroxylon sagu*) at the younger site of SE-RF-6 after 2910 cal. BP.

Unfortunately, in the absence of macro-remains and extensive comparative studies of phytolith and starch morphotypes, the status of other plants identified in the microfossil assemblages is less certain. *Canarium harveyi*, for example, is endemic to the Solomons, as are bamboo and several ginger and palm species including the pan-tropical coconut, which very likely had a natural distribution (Yen, 1974, 2009; Harries and Clement, 2014; Lebot and Sam, 2019; Wickler, 2001: 234; see also Gunn *et al.*, 2011). This lack of clarity, however, does not detract from these being important horticultural elements and the potential for them arriving on the Reef/Santa Cruz islands via human transport. Nor does it detract from the possibility of them being selected, collected and grown on-site with bananas and taro, or even selectively bred and modified to improve flavor or other qualities and increase yield (e.g., Yen, 1973, 1974, 1985, 2009; Hather, 1992; Lebot, 1999; Lebot *et al.*, 2004; Lebot and Sam, 2019).

## Conclusion

The results of this study are evidence for the presence and dispersal of domesticated crop plants in the early settlement of the Reef/Santa Cruz islands and are in accordance with similar studies of Lapita settlements in Vanuatu, Fiji, New Caledonia and Samoa that have also yielded evidence for the presence of cultigens. Moreover, the changes in the horticultural assemblage at the two study sites, particularly the disappearance of seeded bananas, have implications not only for plant domestication processes being an important facet of Lapita culture during the early phase of its appearance in Remote Oceania, but also for the exchange of plant products across the broader region of Oceania throughout the period of occupation.

The presence of *M. maclayi* together with Fergusson Island obsidian in the early phase of occupation may shed some light on the nature and course of early voyaging routes, especially with regard to exploratory stop-offs en-route and for the development of early trade networks. The study is limited however, not only by the small sample size, particularly the small number of sediments examined, but also by the small number of available dates and lack of chronological precision. Therefore, while we can be assured that horticulture was indeed an important element in the early settlement of SE-RF-2 and later, SE-RF-6, the issues pertaining to the strand-looper concept and the degree to which initial settlement relied on local terrestrial and marine

resources vs horticultural produce cannot be fully resolved. However, while it makes good sense that it would take considerable time for any sustainable horticultural regime to be established (Lebot and Sam, 2019: 404), the small amount of marine remains recovered from the archaeological excavations at SE-RF-2 and the presence of at least two key plant domesticates points more towards a short rather than a long, drawn out period with reliance on wild resources. As such, the rapid establishment of a viable cropping system would suggest either well-planned voyages with an extensive array of essential commodities on-board at the outset, or obtained through exploration and collection en-route. Also, proximity to other well-established settlements and/or access to early exchange routes need to be considered. All of these options are implicit in Bedford's (2019: 236) comment that:

in Remote Oceania, people became highly mobile, exploring, colonising and interacting at a whole series of regionally based levels and different directions over several generations with continuing input from populations from the west.

Probably all are applicable in one way or another to the Reef/Santa Cruz islands. For now, the evidence presented by our analyses of the SE-RF-2 and SE-RF-6 sites finds due level of support for Green's hypothesis that transported landscapes were instrumental for the successful colonisation and establishment of the Lapita tradition in Remote Oceania. Nevertheless, a much more definitive understanding of settlement processes and time taken for establishment is dependent on additional studies incorporating systematic sampling procedures and more precise dating, with a special focus on identifying and dating subsistence plants, associated garden plants and other ecological changes related to horticultural development.

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