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New dates for the Makekur (FOH) Lapita pottery site, Arawe Islands, New Britain, Papua New Guinea

Jim Specht and Chris Gosden

Abstract

Estimates for the start of Lapita pottery in the Bismarck Archipelago, Papua New Guinea, have ranged from 3550–3450 cal. BP to 3300–3200 cal. BP. These estimates in turn overlap date ranges of 3480–3150 cal. BP and of 3360–3040 cal. BP for the W–K2 volcanic eruption in northern New Britain and reoccupation of the area by people with Lapita pottery (Petrie and Torrence 2008, 95.4 per cent probability). Here we review issues surrounding existing ^{14}C dates for the start of Lapita pottery throughout the archipelago and present six new dates for the Makekur Lapita site in the Arawe Islands. Based on a non-Bayesian assessment of the dates, we estimate a possible start of Lapita pottery around 3250–3150 cal. BP, at the late end of the ranges for the Witori eruption and reoccupation of the Willaumez Peninsula and close to initial dates for the Lapita expansion into Remote Oceania. Refinement of this estimate for the introduction of pottery to the Bismarck Archipelago through application of Bayesian statistics requires resolution of issues relating to existing dates and pottery analyses, and incorporation of results from current and planned redating programs of Lapita pottery sites within the archipelago.

Introduction

Over the last 20 years, progress has been made in dating the origins and subsequent dispersal of Lapita pottery in the Western Pacific Islands, particularly across the Near/Remote Oceania boundary (Bedford 2015; Sheppard 2011). Recent dating programs throughout the western part of Remote Oceania have suggested that this expansion began around 3000 or so years ago, slightly later than previously accepted (Burley et al. 2015; Clark and Anderson 2009; Galipaud and Swete Kelly 2007; Green and Jones 2008; Green et al. 2008; Jones et al. 2007; Nunn and Petchey 2013; Petchey et al. 2014, 2015; Sheppard et al. 2015). This has led to calls for reconsideration of the starting date for Lapita pottery in the Bismarck Archipelago of Papua New Guinea (Bedford 2015; Petchey et al. 2015:241; Sheppard et al. 2015:34–35), thus reviving the question of whether there was a period during which the Lapita Cultural Complex developed within the archipelago before the pottery-makers dispersed into Remote Oceania (e.g. Sheppard 2011; Specht 2007; Specht et al. 2014).

The starting date for Lapita pottery in the Bismarck Archipelago (Figure 9.1) is poorly resolved. Working with limited data, Kirch and Hunt (1988) initially estimated the starting date in the Bismarck Archipelago at 3550–3450 cal. BP (Figure 9.2). With the accumulation of radiocarbon dates this has been adjusted to 3300–3200 cal. BP (Specht and Gosden 1997; Summerhayes 2007, 2010), and 3450–3350 cal. BP (Specht 2007). These estimates based on 'eyeballing' the data used different protocols for sample selection and calibration procedures. A later study (Denham et al. 2012), applying Bayesian statistics, compared a set of terrestrial-only samples with one combining terrestrial and marine samples, and concluded that pottery appeared in the Mussau Islands around 3470–3250 cal. BP (68.2 per cent probability). This was slightly earlier than the rest of the archipelago, where the appearance of pottery was placed around 3360–3240 cal. BP. As those authors stated, the spread of Lapita pottery within the Bismarck Archipelago cannot be determined through these ranges, as the Mussau date range does not appear to be significantly older than in the rest of the archipelago (Denham et al. 2012:44). This study was based on assumptions about the origins and stylistic development of Lapita pottery in the Mussau Islands that are open to question (cf. Summerhayes 2010:20–23). A more recent study (Rieth and Athens 2017) also applied a Bayesian analysis, using several models that combined and separated out marine shell and plant samples. They concluded that Mussau could have been settled earlier than the rest of the archipelago but could not discount contemporaneous settlement (Rieth and Athens 2017:8, Figure 4). Their model, combining marine shell and short-lived nutshell samples, placed initial Lapita pottery occupation as likely 3304–3177 cal. BP (68.2 per cent).

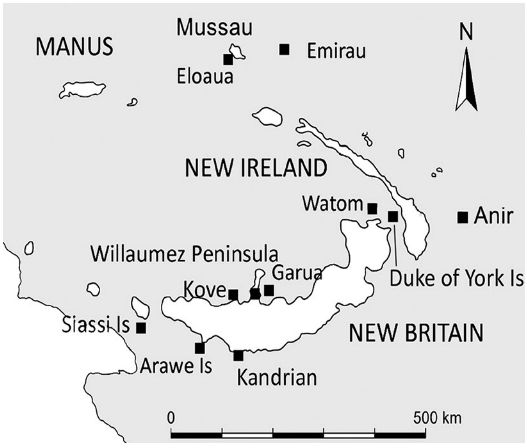

Figure 9.1. Location map of the Arawe Islands, Papua New Guinea and other Bismarck Archipelago Lapita pottery sites and island groups mentioned in the text and tables.

Source: Drawing by J. Specht.

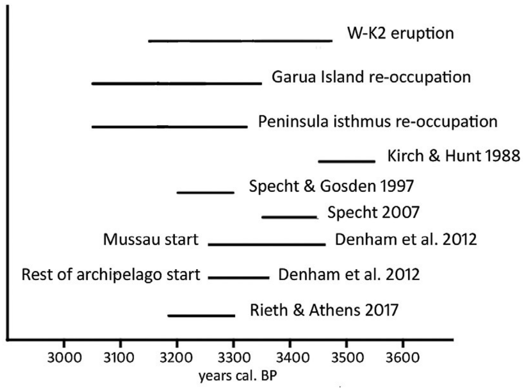

Figure 9.2. Date ranges proposed for the start of Lapita pottery (68.2 per cent) in the Bismarck Archipelago, Papua New Guinea, in relation to the W–K2 volcanic event and the reoccupation of Garua Island and the Willaumez Peninsula isthmus (95.4 per cent), New Britain.

Source: Prepared by J. Specht from the sources cited.

The ranges derived by Denham et al. and Rieth and Athens fall within or overlap with that of 3480–3150 cal. BP for the W–K2 volcanic eruption in northern New Britain (Figure 9.2). This range is based on a Bayesian analysis of a large suite of dates on charred wood and nutshell samples from Willaumez Peninsula and Garua Island, New Britain (Petrie and Torrence 2008: Table 5, range listed at 95.4 per cent probability; the 63.2 per cent value provided by that earlier version of OxCal was 3420–3260 cal. BP: C. Petrie pers. comm. 4 June 2017). This event deposited c. 50 cm of tephra over the island and peninsula and would have resulted in extensive destruction and abandonment of the area. Reoccupation occurred around 3330–3040 and 3360–3040 cal. BP (95.4 per cent) for the peninsula and island respectively (Petrie and Torrence 2008: Table 6). These ranges establish a maximum age for Lapita pottery in the region, which occurs here only in the palaeosol formed on the W–K2 tephra (Specht et al. 1991:284, 287). These results led Torrence (2016:7) to suggest that the W–K2 event and the start of Lapita pottery were essentially 'synchronous', though they potentially open a wide window between the appearance of pottery in the archipelago and the dispersal into Remote Oceania.

A problem with these attempts to define a starting date for Lapita pottery has been a reluctance to apply rigorous 'chronometric hygiene' (Spriggs 1989) to the various date sets. One exception to this was the reassessment of dates for Lapita pottery in the Bismarck Archipelago that excluded all marine shell samples on the grounds that there were too few locality-specific ΔR values to enable meaningful calibrations (Specht 2007: Table 1), though the 26 plant samples used were only lightly vetted. Here we apply more rigorous culling protocols for both marine and terrestrial samples than have been used in previous studies, taking advantage of locality-specific ΔR values for parts of the archipelago (Petchey and Ulm 2012). The study incorporates six new AMS dates on plant materials from the Makekur Lapita site in New Britain (Gosden and Webb 1994). Combining these new dates with the existing ones throughout the Archipelago, this chapter concludes that the starting date for Lapita pottery in the Bismarck archipelago could be younger than existing estimates and close to the initial dates for the settlement of Remote Oceania.

Materials and methods

Radiocarbon dates used in this chapter have been calibrated in OxCal 4.2.4 (Bronk Ramsey 2009) using the IntCal13 and Marine13 curves (Reimer et al. 2013). Within the main text, age ranges are rounded to the nearest five- or 10-year interval and are cited at 68.2 per cent probability to 'reflect the central tendency in the probability distributions' (Denham et al. 2012:43), except where a quoted range was published elsewhere only at 95.4 per cent probability. The tables show both probability distributions. Significance tests for comparing date results, and calculation of pooled means were carried out using Calib 7.0.2.

We employ an 'eyeballing' approach rather than a Bayesian statistical analysis, which we believe would be premature at this stage for several reasons. As Bronk Ramsey (2009:358) observes, 'any analysis of this [Bayesian] kind is very strongly dependent on the information that goes into it', noting:

> however much statistical analysis we do, ^{14}C dates are still reliant on the underlying assumptions of the ^{14}C method—any problems with the samples, their contexts, their associations with each other, or with the calibration curve, will have implications for the accuracy of our chronologies. (2009:358)

This warning is relevant in the present context as there are issues of sample material, context, association and calibration that have to be resolved before there can be consensus on the corpus of dates to be used.

A literature search revealed over 120 ^{14}C dates for Lapita pottery contexts at 40 sites in the Bismarck Archipelago (Appendix 9.1). This list was initially reduced according to the excavator's commentary, and whether a date was unlikely to relate to the beginning or early stage of Lapita pottery. Any sample with a calibrated range falling below 3000 cal. BP at its upper limit was rejected on the grounds that all existing proposals place the start well before that time. As pottery production was introduced into the Bismarck Archipelago from Island Southeast Asia (ISEA), its appearance in the archipelago cannot be older than putative ancestral sites in ISEA. Several very old dates for Lapita pottery with ranges exceeding 3600 cal. BP were therefore excluded as unlikely to be relevant. The next stage in the culling process revealed all the problems encountered in the application of 'chronometric hygiene' (Spriggs 1989) and 'chronometric flossing' (Kirch 2001:204) to Southeast Asian and Pacific radiocarbon dates (cf. Allen and Huebert 2014; Allen and Wallace 2007; Anderson 1991, 1995; Clark et al. 2010; Hogg et al. 1998; Spriggs 1990, 1996, 2003; Spriggs and Anderson 1993). Here we discuss some general issues and provide specific comments for each sample in Appendix 9.1.

Reporting issues

With the exception of the comprehensive presentation of the Mussau results (Kirch 2001: Chapter 10, Appendix 10.1), the manner in which many dates have been reported raises issues involving inadequate or missing information on sample context and condition, association with culturally modified items, lack of clarity as to what the date is thought to refer to and suitability of the dating material, particularly its identification and possibility of in-built age (cf. Bayliss 2015; Dye 2015). Few samples were from culturally modified items that represent an event (e.g. house construction) and most are at best average age assessments for the dated context. Several sites have chronologies based on three or fewer dates that were often selected for reasons that are not made explicit, and it is unclear in some cases whether the dated sample refers to what the excavator considered to be the initial occupation level of the site.

Two shell dates for Makekur (Beta–27946: 3200±70, Beta–55323: 2800±50: Gosden and Webb 1994:42; Specht and Gosden 1997: Appendices 1, 3) were not reported as conventional ^{14}C ages, but as 'radiocarbon years before present' (RCYBP), without adjustment for $\delta^{13}C$ fractionation (Stuiver and Polach 1977). Summerhayes (2001a: Table 3) provides an adjusted age for Beta–55323 (3230±70), but not for Beta–27946. If Beta–27946 is adjusted according to Stuiver and Polach (1977: Figure 1), the resulting calibrated range is too old to be relevant.

Plant samples

Taxonomic identification of wood and charcoal samples is essential to eliminate those likely to have in-built age, where the sample may refer to a growth stage substantially predating the archaeological event being investigated. Ideally, plant materials with minimum in-built age should be selected for dating, such as plant parts (e.g. leaves, fruits and nuts) that have growth cycles lasting a few months rather than many years, though this is not always possible. No charcoal samples from Lapita contexts in the archipelago have been identified to any taxonomic level, though Kirch (2001: Table 4.2) provides several wood identifications. Posts B1 (ANU–5790) and B2 (ANU–5791) from the ECA Area B structure are from *Intsia bijuga* (Colebr.) O. Kuntze, a tree that grows to 25 m height and reaches maturity in 75–80 years. It is fast-growing in the early stages, reaching 150 mm diameter in eight years, and increases in diameter by 14–18 mm per annum (Thaman et al. 2006). Post B2 was 180 mm in diameter (Kirch 2001: Table 4.2) and is unlikely to have significant in-built age; the diameter of Post B1 is not given. As the two posts gave virtually the same ^{14}C age, we assume that Post B1 also has little in-built age. Post C3 (Beta–30686) is identified as *Diospyros* sp. This is a speciose genus and without specific identification, it is impossible to discuss growth rates. Unidentified stake B30 (Beta–20452) is only 30 mm in diameter, and so is assumed to have little in-built age. Among the plant samples with short growth cycles, usually less than one year, are *Cocos nucifera* endocarp at SAC on Watom Island and ECA in the Mussau Islands (Anson et al. 2005: Table 6; Kirch 2001: Chapter 10, Beta–20451), *Canarium* endocarps for Makekur (this study), and probable *Canarium* sp. endocarps for Garua Island and Willaumez Peninsula (Petrie and Torrence 2008: Tables 2, 3; Torrence and Stevenson 2000: Table 1).

Calibration of marine samples

Many dates in the Bismarck Archipelago were on marine shells, reflecting the absence or scarcity of charred plant materials in many sites, and the fact that many samples were run before the AMS technique became widely available for processing milligram-sized plant samples. This heavy reliance on marine shells poses a serious problem, as the marine reservoir of ^{14}C (Stuiver and Braziunas 1993) varies across the Bismarck and Solomon Seas within which the archipelago is situated and has oscillated through time (Edwards et al. 1993; McGregor et al. 2008; Petchey and Ulm 2012). Calculation of ΔR offset values to compensate for this variability has progressed in recent years, but major gaps and issues remain. Petchey and Ulm (2012: Figures 1, p. 55) have summarised the results so far, dividing the archipelago and neighbouring waters into six ΔR regions; two island groups (Mussau and Anir) are not assigned to a specific region but are listed separately with their own local ΔR values (Table 9.1).

Region 1 (38±14 years) is based on four sets of live-collected, pre-1950 shells from the north-east and south-west parts of the Solomon Sea that form a tight group of values. Region 2 (273±216 years), in contrast, is derived from widely divergent calculations based on ^{14}C and U/Th dates on corals or ^{14}C dates on pre-1950 live-collected shells from the Huon Peninsula coast of New Guinea (Petchey and Ulm 2012: Tables 1, 3). One coral sample, Sialum (a) (–199±50 years) is suspect as it appears to have been collected around 1955 and is likely to reflect the impact of nuclear bomb testing (F. Petchey pers. comm. 4 March 2016). Region 3 (314±74 years) is specific to Watom Island at the eastern end of New Britain and is based on paired archaeological charcoal and marine shell samples (Petchey et al. 2005). Although Watom Island is close to Rabaul and the Duke of York Islands that are placed in Region 1, the Watom value is markedly different. Region 4 (18±100 years) embraces Muschu Island and the Ramu River delta on the western side of the archipelago and, as in Region 2, is based on ^{14}C and U/Th dates on corals and ^{14}C dates on pre-1950 live-collected shells. Region 5 (40±19 years) covers the northern and southern ends of the Bismarck Sea. As no samples from the northern (Manus) end are included here, calibrations for the Boduna (FEA) site off the northern coast of New Britain employ the value for nearby Kimbe Bay (45±19 years). Region 6 (141±131 years) embraces the northern end of New Ireland and New Hanover Island, and the value is based on pre-1955 live-collected shells. It does not include the Mussau Islands, for which Kirch (2001: Chapter 10) calculated four ΔR values from paired archaeological charcoal and shells that Petchey and Ulm (2012: Figure 1) recalculate as –293±92 years. Finally, Table 9.1 includes a value for the Anir Islands (–69±51 years) derived from two archaeological pairs of charcoal and shells (Summerhayes 2007:154).

Table 9.1. ΔR offsets for localities in the Bismarck and Solomon seas, Papua New Guinea, based on Petchey and Ulm (2012: Figure 1, p. 55) and references as cited.

Region	Location	Delta-R	Calculation basis	Regional value
1	Samarai	26±34	pre-1950 shell	38±14
	Kiriwina I.	44±17	pre-1950 shell	
	Duke of Yorks	43±68	pre-1950 shell	
	Rabaul	23±35	pre-1950 shell	
2	Finschhafen	333±14	pre-1950 shell	273±216
	Sialum (a)	−199±50	1955 coral	
	Sialum (b)	63±65	^{14}C v U/Th coral	
	Sialum (c)	84±53	^{14}C v U/Th coral	
3	Watom (a)	321±103	archaeological pair	314±74
	Watom (b)	307±105	archaeological pair	

Region	Location	Delta-R	Calculation basis	Regional value
4	Muschu (a)	−48±74	^{14}C v U/Th coral	18±100
	Muschu (b)	−159±46	^{14}C v U/Th coral	
	Muschu (c)	70±60	pre-1950 shell	
	Ramu mouth	41±17	pre-1950 shell	
5	Manus I.	18±13	pre-1950 shell	40±19
	Lou I.	8±108	archaeological pair	
	Kimbe Bay	45±19	pre-1950 shell	
6	New Hanover	111±17	pre-1950 shell	141±131
	Kavieng (a)	365±50	pre-1950 shell	
	Kavieng (b)	305±110	pre-1950 shell	
Mussau	ECA/B (a)	−290	archaeological pair	−293±92 (Petchey & Ulm 2012: Figure 1) −320 (Kirch 2001:201–204)
	ECA/B (b)	−350	archaeological pair	
	ECB (a)	−350	archaeological pair	
	ECB (b)	−370	archaeological pair	
Anir	Kamgot	−69±51	2 archaeological pairs	−69±51 (Summerhayes 2007:154)

Source: See references in table.

It is thus obvious that many areas of the Bismarck Archipelago do not have a locality-specific ΔR value. In such cases, where the sample location falls within the boundaries of a proposed ΔR region of Petchey and Ulm (2012: Figure 1), this value can be used, but the results should be treated with caution. The Arawe Islands off the south-west coast of New Britain are peripherally included within Region 2 by Petchey and Ulm (2012: Figure 1), but the neighbouring Kandrian area lies outside both this and Region 1. Consequently, no marine shell dates for Kandrian sites are included in the study. Shell dates used in calculations of local ΔR values are excluded as they do not constitute independent determinations. This affects four dates for ECA and ECB in the Mussau Islands, two for ERA in the Anir Islands, and one from SAC on Watom Island (Appendix 1).

Environmental/dietary influences on marine shells

For all marine shell samples reviewed in this study, the marine contribution of ^{14}C is assumed to be 100 per cent, although local environmental and geological factors can influence the radiocarbon concentration in shells (Anderson et al. 2001:38; Dye 1994; Petchey and Clark 2010; Tanaka et al. 1986). Most of the Lapita pottery sites reviewed here are located on palaeo-reef limestone platforms, and in areas such as south-west New Britain, limestones of Pleistocene and older age dominate the geology. The extent to which these limestone contexts have influenced shell radiocarbon concentrations is not known at this stage.

Dietary factors can also be a significant influence on the composition of shells and consequently also ^{14}C age determinations (Dye 1994; Nunn and Petchey 2013:29; Petchey 2009; Petchey et al. 2012a, 2012b). The species most frequently selected for dating Lapita sites in the Bismarck Archipelago have been members of the Tridacninae subfamily that are suspension/filter feeders through their adult life (Lucas 1988:31). These molluscs fall into Nunn and Petchey's (2013: Table 2) 'high reliability' category as suitable for dating, provided the samples are not from long-lived individuals. Four other species used for dating in the archipelago (*Conomurex luhuanus*, *Tectus niloticus*, *Turbo marmoratus*, *Anadara antiquata*) are in the 'medium reliability' category. Two other taxa, *Chama* sp. and *Spondylus* sp., are not discussed by Nunn and Petchey. These sessile molluscs attach themselves to hard substrates (Yonge 1967:78, Table 1), and are suspension/filter feeders. This presumably places them in the 'medium/high' to 'medium' reliability categories of Nunn and Petchey, which qualifies them as reasonably suitable for dating. No shell sample is excluded solely for reasons relating to either environmental or dietary conditions.

Issues of association

There is a common assumption that because a dating sample was recovered from the same sediment matrix as culturally modified items, they must be isochronous. This is not necessarily so. Sandy beaches, the most common contexts for Lapita pottery sites, are notorious for perturbation by animal and natural agencies such as land crabs, pigs, humans, tsunamis, storm surges and tree-falls. Each of these can displace and mix cultural and non-cultural materials of different ages, so dating only one or two samples for a site can give misleading or incorrect results. Lilley (1986: Appendix 1, 505) dated three shells from present-day beaches on Umboi and Tuam Islands between New Guinea and New Britain to assess the possible presence of old shells on modern beaches. One shell from each island returned a Modern age (ANU–3802, ANU–3805). In contrast, a third shell, from Tuam gave a CRA of 690±70 BP (ANU–3880) (Lilley 1986: Appendix 1, Table 1). Using the Region 2 ΔR value, this calibrates to 490–55 cal. BP. Similarly, for the FAQ site on Garua Island, New Britain, Torrence (unpublished data) dated three surface shells, one of which (Beta–63618: 550±60, *Tridacna* sp.) gave a result of 240–70 cal. BP using the Kimbe Bay ΔR value of 45±19 years. Finally, six surface shells of *Anadara antiquata* on a Lizard Island midden in Queensland calibrate to c. 500–600 years before present using a locally calculated ΔR offset (Aird 2014: Table 3). Clearly, the inclusion in a dating sample of old shells that were not contemporary with the archaeological context within which they were found can lead to misleading interpretations and may explain some anomalous dating results (cf. Dye 1994). This possibility of 'old shell' (cf. Rick et al. 2005) has obvious implications for the calculation of ΔR values from paired archaeological plant/shell samples (cf. Petchey 2009; Petchey et al. 2008). These calculations usually rely on only one or two pairs of samples, when ideally multiple pairs should be used to eliminate the possibility of calculating an inaccurate ΔR value. The assumption that the paired materials selected for dating were deposited at more or less the same time has only been addressed at the SZ–8 site in Solomon Islands, where charcoal adhering to the interior of a shell suggests that the death of the mollusc and the combustion event were near-contemporary events (Sheppard et al. 2015:30 and Table 1).

Redating Makekur

The Makekur Lapita pottery site (FOH) on Adwe Island is one of six Lapita sites in the Arawe Islands of south-west New Britain (Figure 9.3). Three seasons of excavation (1989–91) revealed rich assemblages of pottery, plant remains and other cultural materials (Gosden and Webb 1994; Matthews and Gosden 1997; Summerhayes 2000). The basic stratigraphy comprises three main stratigraphic units (SU), with the Lapita-era materials coming from SU3, the lowest, waterlogged part of the site. This consists of unconsolidated calcareous sand and reef detritus resting on a limestone platform, and locally contained dense wood and other plant remains as well as Lapita pottery and other artefacts (Figure 9.4). Pottery from the D–E–F trench (a group of nine excavation squares) has been assigned to an early stage of the development of Lapita pottery termed Early Lapita (Summerhayes 2000, 2001a, 2001b). Partly on the basis of stylistic comparisons between the pottery of Makekur and other sites, and partly on consideration of the dates then available for Makekur, Summerhayes (2007:145, 2010:12) proposed that the Lapita occupation there began around 3300 years ago. The oldest dates for Makekur, however, are younger than this (Summerhayes 2001a:32, Table 3), and younger than those for the Mussau and Anir sites (Summerhayes 2010: Table 2), with which the Makekur pottery shares many similarities. To examine this apparent discrepancy, a redating program for Makekur was undertaken in 2015.

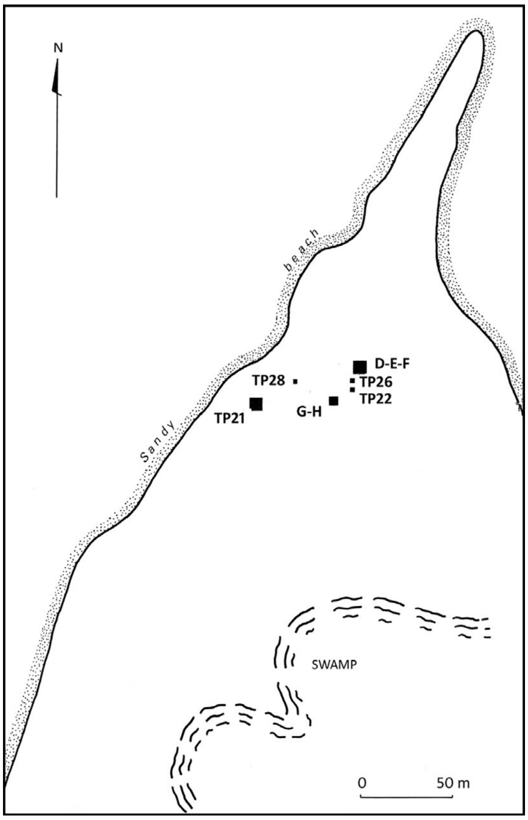

Figure 9.3. Plan of main dated excavation squares at Makekur on Adwe Island, Arawe Islands, West New Britain Province, Papua New Guinea.

Source: Based on original drawing by C. Gosden.

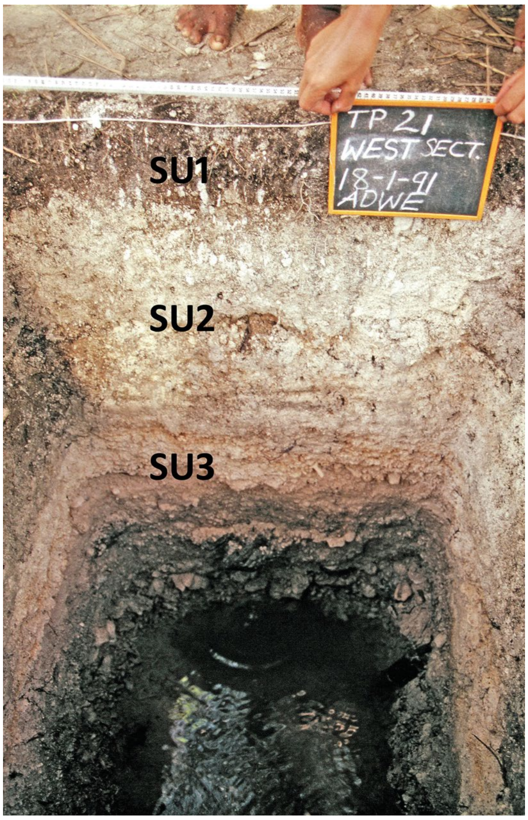

Figure 9.4. Profile of the west face of the original TP21 before extension to 9 m^2, showing the four main stratigraphic units.

The basal SU3 is heavily stained dark grey to black by the large quantity of organic material preserved in the anaerobic waterlogged conditions.

Source: C. Gosden.

Prior to the redating program there were 14 dates for Makekur: 10 on plant materials and four on marine shells (Gosden and Webb 1994; Lentfer et al. 2013; Specht and Gosden 1997: Appendix 1; Summerhayes 2001a: Table 3). These are listed on Table 9.2. Four plant results are not relevant here: Wk–8539 lies outside the oldest likely limit for Lapita pottery, and Beta–27943, Wk–8540 and ANU–11192 were from Post-Lapita contexts (Summerhayes 2001a:32–33, Table 3). The remaining six plant dates relate to the Lapita pottery occupation.

For the redating program, six samples of plant origin were selected from the lowest excavation units (XU) of SU4 in six excavation squares, including three previously dated squares. Two samples were of wood and four of short-lived (<1-year growth) *Canarium* sp. endocarps previously identified by Peter Matthews (cf. Matthews and Gosden 1997) and L. Hayes (1992). Both wood samples had been examined in 1993 by Dr Jill Thompson (Bradford University, UK), after which they were stored in glass phials in distilled water. The wood sample from square G1/XU11 was found embedded vertically in SU4 and is described in the excavation notes as a 'stake'. It is about 200 mm long, and tapers from 55 by 40 mm at the top to 5 by 20 mm at the base. The second wood sample, from TP21/XU17, was taken from a sample of a pole-like item that was too large to remove in its entirety from the field. The pole was found lying horizontally between four upright pieces interpreted as stumps of house posts, though the retained sample of pole does not display obvious signs of working or use. Its narrow diameter (c. 40 mm) suggests no significant in-built age. The samples for dating were cut from the surface of each piece of wood and were about 10 mm long and 5–8 mm thick.

The wood samples were identified by Carol Lentfer using low- and high-powered light microscopy, and by photomicrographs of transverse, radial and tangential sections generated with the Australian Museum's Zeiss Evo LS 15 scanning electron microscope with a Robinson Backscatter Detector. Comparative reference materials included 14 modern reference samples from trees likely to have been growing on the island or nearby, supplemented by wood identification catalogues across a range of possible taxa (Hope 1998; InsideWood 2004; Oteng-Amoako 1990, 1992; Wheeler 2011). The wood samples are poorly preserved, and are assigned provisionally to cf. *Terminalia catappa* L., a common strand tree in New Britain. Although the identification is tentative, it is consistent with the recovery of *Terminalia* sp. endocarps in the lower levels of square G1 (Matthews and Gosden 1997: Table 1).

Before submission for dating, all samples were washed in dilute hydrochloric acid (c. 5 per cent) for 15–20 minutes and rinsed thoroughly in distilled water. They were then oven-dried at 45°C for one hour and left overnight to finish drying. The samples were processed at the Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights, NSW, Australia, where α-cellulose was extracted as described in Hua et al. (2004). The purified α-cellulose was then combusted to CO_2 and reduced to graphite for ^{14}C analyses using the STAR AMS facility at ANSTO (Fink et al. 2004; Hua et al. 2001).

Table 9.2. Radiocarbon dates run prior to 2015 for the Makekur (FOH) site. Arawe Islands, Papua New Guinea.

Lab code	Context	Material	$\delta^{13}C$ (‰)	14C age	Cal. BP 68.2%	Prob.	Cal. BP 95.4%	Prob.
Plant-derived samples								
Beta-27942	FOH/TP2/XU7	charcoal	−25.0‰(A)	310±80	**467–299**	**68.2%**	**514-20**	**95.4%**
							514–267	84.8%
							215–144	8.1%
							20	2.5%
ANU-11192	FOH/D3/XU3	charcoal	n/a	1350±160	**1404–1070**	**68.2%**	**1569–932**	**95.4%**
ANU-11187	FOH/D3/XU9	charcoal	n/a	2730±100	**2945–2753**	**68.2%**	**3160–2542**	**95.4%**
							3160–2701	94.4%
							2631–2618	0.4%
							2561–2542	0.6%
Wk-8540	FOH/E2/XU4	charcoal	n/a	2060±60	**2113–1968**	**68.2%**	**2295–1882**	**95.4%**
					2113–1968	63.1%	2295–2270	2.0%
					1963–1950	5.1%	2155–1882	93.4%
ANU-11186	FOH/E2/XU9	charcoal	n/a	2800±110	**3056–2781**	**68.2%**	**3219–2741**	**95.4%**
Wk-8539	FOH/F1/XU9	charcoal	n/a	3740±60	**4222–3985**	**68.2%**	**4288–3909**	**95.4%**
Beta-54164	FOH/G2/XU13	charcoal	−29.0‰(M)	2640±90	**2874–2541**	**68.2%**	**2961–2460**	**95.4%**
					2874–2700	60.4%		
					2632–2617	2.6%		
					2585–2575	1.5%		
					2563–2541	3.8%		
Beta-54165	FOH/TP21B/XU13	charcoal	−28.6‰(M)	2850±80	**3074–2859**	**68.2%**	**3180–2781**	**95.4%**
Beta-54166	FOH/TP21B/XU17	charcoal	−26.9‰(M)	2730±70	**2917–2760**	**68.2%**	**2993–2744**	**95.4%**
					2917—2913	1.4%		
					2880–2760	66.8%		
Wk-32734	FOH/TP21H/XU14	*Canarium* sp. endocarp	−26.8‰(M)	2730±32	**2850–2785**	**68.2%**	**2916–2760**	**95.4%**

Lab code	Context	Material	δ¹³C (‰)	14C age	Cal. BP 68.2%	Prob.	Cal. BP 95.4%	Prob.
Marine samples								
Beta–27946	FOH/TP1/XU11	'oyster' shell	0‰(A)	3200±70	**2936–2370**	**68.2%**	**3245–2111**	**95.4%**
Beta–37561	FOH/G1/XU6	*Tridacna* sp. shell	0.2‰(M)	2860±70	**2570–1992**	**68.2%**	**2786–1707**	**95.4%**
Beta–54215	FOH/E2/base	coral	–1.2‰(M)	4290±60	**4351–3756**	**68.2%**	**4631–3446**	**95.4%**
Beta–55323	FOH/D1/XU10	unidentified shell	0‰(A)	3230±70	**2990–2412**	**68.2%**	**3291–2148**	**95.4%**
Beta–55456	FOH/TP28/XU14	*Tridacna* sp. shell	2.4‰(M)	2840±60	**2535–1961**	**68.2%**	**2760–1697**	**95.4%**

The dates are calibrated with OxCal 4.2.4 using the Intcal13 and Marine13 curves (Bronk Ramsey 2009; Reimer et al. 2013). Shell dates are calibrated using the Region 2 value of ΔR=273±216 years (Petchey and Ulm 2012: Figure 1, 55), assuming 100 per cent marine contribution of radiocarbon. For the δ¹³C values, A=Assumed, M=Measured.

Source: Authors' summary.

Results

Redating Makekur

Table 9.3 shows the six AMS results for Makekur. Samples OZS476 (*Canarium* endocarp from G2/XU15) and OZS477 (cf. *T. catappa* wood from TP21/XU17) are statistically identical and bracket the range 3000–2880 cal. BP (T=1.560976, χ^2 (1:0.05)=3.84). Three results (OZS475: cf. *T. catappa* wood from G1/XU11; OZS474: *Canarium* endocarp from F3/XU18; OZS478: *Canarium* endocarp from TP22/XU18) are also statistically identical and bracket the range 2750–2500 cal. BP (T=2.906667; χ^2 (2:0.05)=5.99). At 2850–2760 cal. BP, the sixth sample (OZS479: *Canarium* sp. endocarp from TP26/XU17) sits between these two groups.

With the exception of the three youngest dates, the other results are generally comparable with those obtained previously. There are now four dated samples from TP21 (OZS477, Beta–54165, Beta–54166 and Wk–32734). OZS477 is the same as the two Beta Analytic results but differs significantly from Wk–32734 (T=4.912068, χ^2 (1:0.05)=3.84). This difference arguably may be due to the small standard errors of OZS477 and Wk–32734 compared to those of the two Beta Analytic dates.

Table 9.3. New AMS dates on terrestrial plant materials for Makekur (FOH), calibrated with OxCal 4.2.4 using the Intcal13 curve (Bronk Ramsey 2009; Reimer et al. 2013).

	Makekur dates – ANSTO 2015 – OxCal 4.2.4							
Lab code	Context	Material	δ¹³C	¹⁴C age	Cal. BP 68.2%	Prob.	Cal. BP 95.4%	Prob.
OZS476	FOH/G2/XU15	*Canarium* sp. endocarp	–25.9±0.1‰	2860±20	**3004–2929**	**68.2%**	**3060–2890**	**95.4%**
							3060–2922	91.0%
							2906–2890	4.4%
OZS477	FOH/TP21/XU17	cf. *Terminalia catappa* wood	–25.9±0.1‰	2820±25	**2954–2880**	**68.2%**	**2991–2859**	**95.4%**
OZS479	FOH/TP26/XU17	*Canarium* sp. endocarp	–27.2±0.1‰	2690±25	**2841–2757**	**68.2%**	**2846–2755**	**95.4%**
					2841–2827	11.9%		
					2795–2757	56.3%		

	Makekur dates – ANSTO 2015 – OxCal 4.2.4							
Lab code	**Context**	**Material**	**$\delta^{13}C$**	**^{14}C age**	**Cal. BP 68.2%**	**Prob.**	**Cal. BP 95.4%**	**Prob.**
OZS475	FOH/G1/XU11	cf. *Terminalia catappa* wood	−28.6±0.1‰	2560±25	**2747–2685**	**68.2%**	**2754–2518**	**95.4%**
							2754–2609	78.8%
							2633–2616	5.5%
							2588–2538	10.0%
							2527–2518	1.0%
OZS474	FOH/F3/XU18	*Canarium* sp. endocarp	−25.5±0.1‰	2525±25	**2737–2539**	**68.2%**	**2743–2496**	**95.4%**
					2737–2699	28.7%		
					2632–2617	11.1%		
					2587–2539	28.5%		
OZS478	FOH/TP22/XU18	*Canarium* sp. endocarp	−24.7±0.1‰	2500±25	**2715–2503**	**68.2%**	**2726–2489**	**95.4%**
					2715–2695	10.2%	2726–2650	23.6%
					2635–2615	10.8%	2645–2489	71.8%
					2592–2503	47.2%		

Source: Authors' summary.

Summerhayes' (2000) analysis of pottery from Makekur focused on trenches D–E–F and G–H that now have four dates each. For the G–H trench, Summerhayes (2000:91) analysed the sherds from squares G1 and G2, each of which has two dates. When calibrated, OZS475 (cf. *Terminalia* wood) from G1/XU11 is older than shell date Beta–37561 from G1/XU6, consistent with their stratigraphic relationship. Beta–54164 (charcoal) from G2/XU13 and OZS476 (*Canarium* endocarp) from G2/XU15 are also stratigraphically consistent.

For trench D–E–F, three dates from D1/XU10 (Beta–55323, shell), D3/XU9 (ANU–11187, charcoal) and E2/9 (ANU–11186, charcoal) are statistically the same, as would be expected as they came from similar depths (T=4.067498, χ^2 (2: 0.05)=5.99). The fourth sample (OZS474, *Canarium* endocarp) from F3/XU18 overlaps with only one of these, and is later than the other two, despite being from a comparable depth. This discrepancy might be explained by the OZS474 sample being introduced into XU18 from a higher level when one side of square F3 collapsed during excavation of XU16–XU18.

The three youngest dates (OZS474, OZS475 and OZS478) are later than expected, though the reason for this is not clear. The samples might have been contaminated during selection and preparation, though this seems unlikely as all samples were prepared for submission to ANSTO at the same time and in the same manner. Furthermore, the three youngest dates are consistent with Beta–54168 (2530±70: 2750–2490 cal. BP) for the Late Lapita site of Amalut on the adjacent New Britain mainland (Specht and Gosden 1997: Appendix 1). The late results at Makekur could indicate that site use continued into Late Lapita times, during which there was downward movement of dating materials. This possibility receives support from the pottery analysis of trench D–E–F, which divided the basal deposit (40–45 cm thick) into four analytical units, A to D from base upwards (Summerhayes 2000:22). Conjoining of sherds revealed that parts of the same vessels were recovered across two, three and four analytical units, clearly indicating vertical movement (Summerhayes 2000: Table 3.1). Whatever the reason for the younger dates, they are not relevant to the rest of the discussion.

The results from the four dating laboratories (Beta Analytic, Waikato, ANU and ANSTO) over 30 years are broadly consistent and suggest that the pottery occupation is unlikely to have begun at Makekur before c. 3100 cal. BP, the oldest end of the date ranges. This is at the youngest end of the date range of 3480–3150 cal. BP for the W–K2 eruption, and of 3330–3040 cal. BP and 3360–3040 cal. BP for the reoccupation of the Willaumez Peninsula and Garua Island respectively, both ranges at 95.4 per cent probability (Petrie and Torrence 2008: Tables 5 and 6). This would place the start of Makekur's Lapita pottery occupation around the time of the southerly dispersal into Remote Oceania. If so, this would conflict with the stylistic analysis of the Makekur pottery, as Summerhayes (2001a:35, Figure 4) assigned the D–E–F sherds to his Early stage of Lapita pottery, and those from G–H to his Middle stage. But OZS476 for G2/XU15 is statistically the same as the oldest date for D–E–F, ANU–11186 for E2/XU9. Furthermore, in the Mussau and Anir Islands, the Early Lapita stage is dated around the upper limits of 3450 and 3300 cal. BP (Denham et al. 2012; Kirch 2001; Summerhayes 2007, 2010). To examine this issue further, we now turn to dates for the broader archipelago region.

The Bismarck Archipelago

Only 38 dates from 14 sites (plant: 25 dates, 9 sites; shell: 13 dates, 6 sites) survived the culling process, with only ECA having both plant and shell samples (Tables 9.4 and 9.5). Table 9.4 includes several plant dates from Lapita pottery contexts used by Petrie and Torrence (2008) for calculating the dates of the W–K2 event and subsequent reoccupation (cf. Denham et al. 2012:44). Over half of the samples (20) are from sites in the Mussau Islands, and 16 of these are from the ECA site. The latter are arranged on Tables 9.4 and 9.5 according to the spatial and vertical divisions discussed by Kirch (2001: Chapter 10, Appendix 10.1):

- Airfield transect: 1 plant, 0 shell;
- W200 transect: 1 plant, 0 shell;
- Area A: 1 plant, 2 shell;
- Area B: 3 plant, 0 shell;
- W250 transect: 2 plant, 4 shell;
- Area C: 2 plant, 0 shell.

Although Area C belongs to a late stage of the pottery occupation (Kirch 2001: Chapter 10), two plant dates from this area are included as they fall within the time range of the basal Zone C3 at Area B.

Two samples dating pre-pottery levels are included: Beta–26261 (3158–2951 cal. BP) from Kautaga Island (FPA) in the Kove Islands, and Wk–7558 (3254–3053 cal. BP) from Melele cave (ERD) on Babase Island in the Anir group (Lilley 1991:316, Table 1; Summerhayes 2001a:34, Table 3). These place the start of pottery at these sites well within the range discussed above for the initial occupation of Makekur. This, however, is in marked contrast to other dates with claimed pottery associations that precede these sites by several hundred years.

Table 9.4. Culled list of terrestrial plant dates for Lapita pottery sites in the Bismarck Archipelago, Papua New Guinea, calibrated with OxCal 4.2.4 using the Intcal13 curve (Bronk Ramsey 2009; Reimer et al. 2013).

Area/island group	Location	Site name	Site code	Trench/context/content	Material	Lab code	CRA	68.2%	95.4%
NEW IRELAND PROVINCE									
Mussau	Eloaua	Talepakemalai	ECA	W400/N72 TP9 level 6, top Layer II	charcoal	ANU-5080	3260±90	3579 (68.2%) 3385	3702 (92.8%) 3324
			airfield transect	(base Lapita/top palaeobeach)					3299 (2.6%) 3252
				(8 plain, 1 dentate pottery)					
Mussau	Eloaua	Talepakemalai	ECA	W200/N120 TP19 level 9, Layer III	*Cocos nucifera*	Beta-20451	2950±70	3209 (68.2%) 3000	3339 (5.6%) 3286
			W200 transect	('muck zone', plant remains only)	endocarp				3270 (89.1%) 2924
				(Kirch: equivalent to Area B, Zone C)					2904 (0.8%) 2892
Mussau	Eloaua	Talepakemalai	ECA area A	'oven'	charcoal	GX-5498	3030±180	3440 (0.8%) 3433	3612 (95.4%) 2781
				(dentate pottery)				3401 (67.4%) 2971	
Mussau	Eloaua	Talepakemalai	ECA area B	W200/N150 Post B1	*Intsia bijuga*	ANU-5790	2950±80	3215 (68.2%) 2980	3344 (93.4%) 2920
				(main corner post, dentate pottery)	wood				2909 (2.0%) 2885
Mussau	Eloaua	Talepakemalai	ECA area B	W199/N151 Post B2	*Intsia bijuga*	ANU-5791	2930±80	3206 (1.3%) 3200	3335 (4.2%) 3289
				(main corner post, dentate pottery)	wood			3180 (66.9%) 2962	3265 (91.2%) 2869
Mussau	Eloaua	Talepakemalai	ECA area B	W198/N145 level 7 zone C3, Post B30	wood	Beta-20452	3050±70	3354 (68.2%) 3172	3442 (0.6%) 3430
				(small post or stake)					3403 (94.4%) 3059
				(dentate pottery)					3040 (0.3%) 3040
Mussau	Eloaua	Talepakemalai	ECA	W250/N120 level 9	wood	Beta-30681	2860±60	3065 (58.9%) 2919	3167 (95.4%) 2844
			W250 transect	(stump, dentate pottery)				2900 (9.3%) 2884	
Mussau	Eloaua	Talepakemalai	ECA	W250/N140 level 6	wood	Beta-30682	2970±50	3217 (68.2%) 3062	3330 (4.4%) 3293
			W250 transect	(stump or beam; dentate pottery)					3255 (91.0%) 2971
Mussau	Eloaua	Talepakemalai	ECA area C	W250/N188 Area C level 3 stake	wood	Beta-30684	3100±110	3446 (5.1%) 3420	3563 (95.4%) 3002
			W250 transect	(plain pottery)				3414 (63.1%) 3170	
Mussau	Eloaua	Talepakemalai	ECA area C	W250/N188 Area C Post C3	*Diospyros* sp.	Beta-30686	2850±70	3063 (68.2%) 2872	3164 (95.4%) 2793
			W250 transect	(stump, incised pottery)	wood				

Area/island group	Location	Site name	Site code	Trench/context/content	Material	Lab code	CRA	68.2%	95.4%
Emirau	Emirau	Tamuarawai	EQS	TP2 Layer 4	charcoal	Wk-21345	2917±31	3140 (7.4%) 3126	3160 (95.4%) 2965
				(dentate pottery)				3110 (9.2%) 3094	
								3080 (51.5%) 2999	
Emirau	Emirau	Tamuarawai	EQS	TP1 Layer 4	charcoal	Wk-21349	3044±31	3332 (29.0%) 3290	3350 (95.4%) 3168
				(dentate pottery)				3258 (36.6%) 3209	
								3190 (2.6%) 3185	
Anir	Babase	Kamgot	ERA	TP1 spit 6	charcoal	Wk-7561	3035±45	3334 (21.5%) 3289	3361 (91.2%) 3140
				(dentate pottery)				3264 (46.7%) 3170	3127 (2.0%) 3110
									3083 (2.1%) 3080
Anir	Babase	Kamgot	ERA	TP1 spit 9	charcoal	Wk-7563	3075±45	3350 (68.2%) 3235	3381 (95.4%) 3170
				(dentate pottery)					
Anir	Ambitle	Feni Mission	ERG	TP1 spit 6	charcoal	ANU-11191	3090±170	3544 (0.6%) 3538	3691 (1.1%) 3659
				(dentate pottery?)				3480 (67.6%) 3060	3649 (94.3%) 2856
EAST NEW BRITAIN PROVINCE									
Watom	Watom	Rakival	SAC	G13 zone C2 spit 2	*Cocos nucifera*	Wk-7370	2860±60	3065 (58.9%) 2919	3167 (95.4%) 2844
				(dentate pottery)	endocarp			2910 (9.3%) 2884	
WEST NEW BRITAIN PROVINCE									
Willaumez	Garua	no local name	FYS	II Layer 5 spit 1	endocarp	NZA-3733	2883±64	3140 (3.6%) 3127	3208 (1.2%) 3192
Peninsula				(plain pottery)				3109 (4.4%) 3094	3184 (94.2%) 2853
								3079 (58.4%) 2924	
								2901 (1.8%) 2894	
Willaumez	Garua	no local name	FYS	II Layer 5 spit 3	endocarp	Beta-72144	3060±60	3355 (66.2%) 3209	3392 (93.2%) 3104
Peninsula				(1 dentate sherd)				3190 (2.0%) 3185	3097 (2.2%) 3077
Willaumez	Garua	no local name	FYS	II Layer 5 spit 4	endocarp	NZA-3734	3030±69	3345 (65.7%) 3156	3381 (94.7%) 3021
Peninsula				(no pottery)				3150 (1.2%) 3145	3015 (0.7%) 3005
								3089 (1.3%) 3084	

Area/island group	Location	Site name	Site code	Trench/context/content	Material	Lab code	CRA	68.2%	95.4%
Willaumez	Isthmus	Numundo Hill	FAAH	XVII Layer 9 spit 1	endocarp	Wk–10463	2880±59	3136 (1.0) 3133	3176 (95.4%) 2855
Peninsula				(dentate, incised)				3105 (2.6%) 3069	
								3077 (62.9%) 2925	
								2901 (1.7%) 2895	
Willaumez	Isthmus	Numundo Hill	FAAH	XVII Layer 9 spit 3	endocarp	Wk–19190	2847±34	3001 (54.8%) 2920	3063 (95.4%) 2868
Peninsula				(dentate, incised pottery)				2909 (13.4%) 2885	
Willaumez	Isthmus	Kulu-Dagi	FADC	LVI Layer 9 spit 3	endocarp	Wk–12845	2936±47	3161 (64.3%) 3021	3224 (95.4%) 2953
Peninsula				(plain pottery)				3015 (3.9%) 3005	
Arawe	Adwe	Makekur	FOH	TP21/B spit 13	charcoal	Beta–54165	2850±80	3074 (68.2%) 2859	3206 (0.4%) 3200
				(dentate pottery)					3180 (95.4%) 2781
Arawe	Adwe	Makekur	FOH	E2 spit 9	charcoal	ANU–11186	2800±110	3056 (1.2%) 3050	3219 (95.4%) 2741
				(dentate pottery)				3035 (67.0%) 2781	
Arawe	Adwe	Makekur	FOH	G2 spit 15	*Canarium* sp.	OZS476	2860±20	3004 (68.2%) 2929	3060 (91.0%) 2922
				(dentate pottery)	endocarp				2906 (4.4%) 2890

Source: Authors' summary.

Comparison between Tables 9.4 and 9.5 reveals a marked division between the dates for the Mussau sites and those from the rest of the archipelago. Nine of the 10 shell dates and three of the plant dates for the Mussau sites have ranges that start before 3400 years ago, though the lower end of their ranges, with the exception of Beta–30693, fall within the expected period of the start of Lapita pottery. This contrasts with the rest of the archipelago, where no shell date and only one plant date (ANU–11191) has a range with an upper limit exceeding 3400 years. This raises questions about appropriate ΔR values for the Mussau sites, the nature of the samples and their contexts.

Kirch (2001:199–216) acknowledged the problems with calculation of a single ΔR value for the Mussau sites and noted that use of the 'model surface ocean' ΔR value tends to yield more reasonable results for some dates. Until reliable ΔR values become available, it may be advisable to set aside all shell dates for the Mussau sites and those on the south coast of New Britain. These ΔR issues cannot be resolved here, but it is worthwhile to consider other potential reasons for the old results for both shell and plant samples.

The dating of the Lapita occupation on the palaeobeach of A at ECA has been the subject of discussion over the last 30 years (e.g. Kirch 1987, 2001:205; Summerhayes 2010:22–23), but without resolution, because of the lack of plant materials for dating and the issues surrounding the appropriate ΔR value for shell samples. Three shell dates on Table 9.5 relate to the palaeobeach (Beta–30677, Beta–30678, Beta–30679), plus Beta–30680, which was excluded because the sample was probably an old shell from a Pre-Lapita context (Kirch 2001:228). The three retained dates are all older than those for FPA and Melele cave, and may also derive from a pre-pottery context. A similar explanation may be relevant for Beta–30693 (*Hippopus hippopus* shell) from the EKE site on Boliu Island in the Mussau group, which gives a calibrated range outside reasonable expectations (Appendix 1). This shell was recovered from Layer II along with calcareous sand-tempered plain sherds (Kirch 2001:168–169). Kirch notes that burrowing by land crabs has moved some sand-tempered sherds from Layer II upwards into Layer IC, and further notes the displacement of one sherd downwards into the pre-pottery Layer III. This opens the likelihood that the dated shell sample relates to Layer III and predates the sand-tempered sherds.

ANU–5080 (3579–3385 cal. BP) is the only plant date referring to the ECA palaeobeach and is one of the oldest dates for a Lapita pottery context (Kirch 2001:83). The sample came from Layer II, the top of the palaeobeach, of test pit TP9, about 175 m west of the W250 transect (Kirch 2001: Figure 4.1). This context contained only nine sherds compared with 205 in the overlying Layer IB, suggesting that the Layer II sherds have been displaced downwards. This raises questions about the relevance of ANU–5080: was it also moved downwards with the sherds, was it from old wood, did the sample have large in-built age, or does it relate to a pre-pottery combustion event? The PNG National Museum excavations of 1978 in Area A of ECA also produced a very old date (GX–5499: 3900±280, 4810–3975 cal. BP; Bafmatuk et al. 1981:80) for the fill of a pit with Lapita pottery. This date is clearly irrelevant for dating the pottery (Kirch et al. 1987:125; Spriggs 1990:17). The origin of this sample is not known: it could relate to a Pre-Lapita natural combustion event, Pre-Lapita human use of the area for which there is currently no archaeological evidence, or the burning of old wood during the Lapita pottery occupation. It is impossible to resolve this matter with the currently available evidence, and so the dating of the palaeobeach finds remains uncertain.

The only plant date range exceeding 3400 years at its upper limit from beyond the Mussau Islands is ANU–11191 from the Feni Mission site (ERG) in the Anir Islands off southern New Ireland. The calibrated result shows a very low probability that the true age lies in the range 3544–3538 cal. BP (0.6 per cent), and more likely to be in the range 3480–3060 cal. BP (67.6 per cent). This sample of unidentified charcoal has the potential for in-built age and has a very large standard error of 170 years that extends the range limits.

Table 9.5. Culled list of marine shell dates for Lapita pottery sites in the Bismarck Archipelago, Papua New Guinea, calibrated with OxCal 4.2.4 using the Marine13 curve and assuming 100 per cent marine contribution of radiocarbon (Bronk Ramsey 2009; Reimer et al. 2013).

Area/island group	Island or locale	Site name	Site/area code	Trench/context/content	Material/shell identification	Lab code	CRA	ΔR	68.20%	95.40%
NEW IRELAND PROVINCE										
Mussau	Eloaua	Talepakemalai	ECA area A	W228/N102 level 3, Layer II	*Tridacna gigas*	ANU-5084	3230±70	-293±92	3555–3268	3698–3107
				(red-slipped plainware)						
Mussau	Eloaua	Talepakemalai	ECA area A	W229/N100 level 9	*Hyotissa hyotis*	ANU-5085	3170±70	-293±92	3475–3185	3621–3029
				(red-slipped plainware)						
Mussau	Eloaua	Talepakemalai	ECA	W250/N100 level 2 Palaeobeach	*Spondylus* sp.	Beta-30677	3170±70	-293±92	3475–3185	3621–3029
			W250	(fine dentate pottery)						
Mussau	Eloaua	Talepakemalai	ECA	W250/N110 level 4, Palaeobeach	*Chama* sp.	Beta-30678	3190±80	-293±92	3513–3205	3670–3041
			W250	(fine dentate pottery)	(Kirch: flaked margin)					
Mussau	Eloaua	Talepakemalai	ECA	W250/N110 level 15, Palaeobeach	*Tridacna gigas*	Beta-30679	3080±70	-293±92	3368–3074	3506–2915
			W250	(house posts; fine dentate pottery)	(Kirch: adze preform?)					
Mussau	Eloaua	Talepakemalai	ECA	ECA W250/N150 level 7	*Hippopus hippopus*	Beta-30683	3140±80	-293±92	3450–3144	3591–2969
			W250	(fine & coarse dentate, cut-outs, incised pottery)						
Mussau	Mussau	Epakapaka	EKQ	Unit 2, level 9, Layer III	*T. marmoratus, T. maxima*	Beta-25670	3270±80	-293±92	3614–3319	3778–3155
				(incised pottery)	(Kirch: artificially fractured)					
Mussau	Mussau	Epakapaka	EKQ	Unit 2 level 13, Layer IV	*Conomurex luhuanus*	Beta-25671	3190±90	-293±92	3526–3205	3680–3020
				(incised pottery)	(Kirch: fractured for meat extraction)					
Mussau	Eloaua	rock shelter	EKO	Unit 1 level 4	*Turbo marmoratus*	Beta-25669	3200±70	-293±92	3517–3229	3662–3067
				(mainly plain ware)	(Kirch: artificially fractured)					
Anir	Babase	Melele cave	ERD	TP1B spit 20	*Turbo* sp.	Wk-7558	3245±45	-69±51	3254–3053	3339–2961
				(below pottery)	and unidentified fragments					
WEST NEW BRITAIN PROVINCE										
Willaumez	Boduna	Boduna	FEA	Layer 4 base	*Chama* sp.	Beta-41578	3330±60	45±19	3210–3020	3311–2941
Peninsula				(dentate pottery)						
Kove	Kautaga	Kautaga	FPA	TPI level 7	*Tridacna* sp. – 'degraded'	SUA-2823	3220±70	40±19	3072–2866	3173–2784
				(dentate pottery)						
Kove	Kautaga	Kautaga	FPA	TPI basal beach	*Tridacna* sp.	Beta-26261	3280±70	40±19	3158–2951	3257–2848

Source: Authors' summary.

Most of the remaining results for both plant and shell samples fall around or below 3300 years cal. BP at their maximum range limits, with only five plant date ranges exceeding 3300 years. Three of these samples (EQS: Wk–21349; ERA: Wk–7561, Wk–7563) were unidentified charcoal with unknown in-built age, and two (FYS: Beta–72144, NZA–3734) were based on short-lived nut endocarps, unidentified but most likely to be *Canarium* sp. (Torrence and Stevenson 2000:238, Table 1). The two FYS dates are the oldest plant results for New Britain. Table 9.6 shows the pooled means of the pairs of ERA and FYS dates calculated by Calib 7.0.2. The dates for all three sites fall on a problematic part of the calibration curve, but the probability distributions of the pooled means do not favour strongly an age over 3300 years. Rather, there is almost equal probability that it falls in either 3335–3290 (33.2 per cent) or 3270–3215 (35.0 per cent) cal. BP for ERA, and 3340–3290 (27.9 per cent) or 3270–3210 (34.0 per cent) cal. BP for FYS. These ranges and probability distributions are essentially the same as those for Wk–21349 at EQS, 3330–3290 (29.0 per cent) and 3260–3210 (36.6 per cent) cal. BP.

Table 9.6. Pooled means of dates for five Bismarck Archipelago Lapita sites calibrated with OxCal 4.2.4 using the IntCal13 curve (Bronk Ramsey 2009; Reimer et al. 2013).

Region	Site	Lab code	CRA	Pooled mean	Calibrated mean	Probability
Mussau	ECA/B	ANU-5790	2950±80	2940±57	3171–3001	68.2%
		ANU-5791	2930±80			
Anir	ERA	Wk-7561	3035±45	3055±32	3335–3288	33.2%
		Wk-7563	3075±45		3267–3215	35.0%
Garua	FYS	Beta-72144	3060±60	3047±45	3340–3286	27.9%
		NZA-3734	3030±69		3272–3207	34.0%
					3197–3182	6.3%
Willaumez	FAAH	Wk-10463	2880±59	2855±29	3005–2923	60.7%
Isthmus		Wk-19190	2847±34		2906–2890	7.5%
Adwe	FOH	Beta-54165	2850±80	2858±19	3002–2943	65.4%
		ANU-11186	2800±110		2935–2930	2.8%
		OZS476	2860±20			

The ECA/B dates were on posts from the structure in Area B. Plant samples only.

Source: Authors' summary.

This congruence of results from ERA, EQS and FYS contrasts markedly with the pooled means calculated for the three other Bismarck Archipelago sites, whose pooled means do not exceed 3200 years. The FAAH pottery assemblage (Specht and Torrence 2007b) has not been assigned to a specific stage of Summerhayes' (2001b) developmental scheme for Lapita pottery, but several sherds show close similarities to those of his Early Lapita sites (Specht and Torrence 2007b: Figures 8E, 8F and 11G). The similarity between the pooled means for FOH and FAAH supports this, though the pooled mean for the ECA/B house posts is slightly older. Interestingly, the ECA/B and FAAH results fall within that for Beta–20415 (3210–3000 cal. BP, coconut endocarp) from the 'muck zone' on the W200 transect (Kirch 2001:86, 224), though Beta–20451 was associated only with plant remains, and no specific cultural materials. The lack of agreement between the results for ERA, EQS and FYS, and those for ECA/B, Beta–20451 and FAAH remains a matter for further exploration, though the slight preference for the 3270–3210 calibrated range in the ERA, EQS and FYS results brings them closer to the other sites. This would be consistent with the dates for the pre-pottery levels at FPA and Melele cave discussed above, though there is no guarantee that pottery appeared in either site immediately after these dates. The dates do not support its appearance earlier than the upper range limit of Wk–7558, 3250 cal. BP. As a working hypothesis, therefore, we suggest that pottery was introduced to the Bismarck Archipelago after c. 3250 cal. BP (Melele cave, upper range limit of Wk–7558), and possibly as late as c. 3150 cal. BP (Kautaga Island, upper range limit of Beta–26261).

Expansion into Remote Oceania

This revised starting date reduces the length of time between the appearance of pottery in the archipelago and its dispersal into Remote Oceania (cf. Specht et al. 2014). Table 9.7 presents the dates proposed by various authors for initial settlement of several Lapita sites in Remote Oceania based on Bayesian analyses, except for the Atanoasao site in Vanuatu, which is a pooled mean derived through the SHcal13.14C curve (Hogg et al. 2013) of Calib 7.0.2. This curve was used for all other calculations, except for those provided by Sheppard et al., who used the Northern Hemisphere IntCal13 curve.

Table 9.7. Date ranges for first settlement of island groups in Remote Oceania.

Region/site	Start cal. BP	Basis of calculation	Reference
SE SOLOMON IS			
Nanggu SZ-8	2920–2793	Bayesian analysis, 95.4%	Sheppard et al. 2015:31
Nenumbo RF-2	3185–2785	Bayesian analysis, 95.4%	
VANUATU			
Makué	3192–2945	Bayesian analysis, 68.2%	Galipaud et al. 2014: 111, Zone 3 only
	3313–3008	Bayesian analysis, 95.4%	Sheppard et al. 2015: 34, all samples
Atanoasao	2954–2854	Pooled mean	Pineda and Galipaud 1998:778
Teouma cemetery	2940–2880	Bayesian analysis, 68.2%	Petchey et al. 2014:240
Teouma midden	2920–2870	Bayesian analysis, 68.2%	Petchey et al. 2015:104
FIJI			
Bourewa	2838–2787	Bayesian analysis, 68.2%	Nunn and Petchey 2013:30
Naigani	3001–2790	Bayesian analysis, 95.4%	Sheppard et al. 2015:32
TONGA			
Nukuleka	2846–2830	Bayesian analysis, 68.2%	Burley et al. 2015

The Bayesian analyses are those provided by the cited authors using OxCal (see references for details). All authors used the Southern Hemisphere calibration curve SHCal13 (Hogg et al. 2013) except Sheppard et al. (2015:30), who used the Northern Hemisphere IntCal.13 curve. The pooled mean for Atanoasao in Vanuatu was calculated in Calib 7.0.2, and then calibrated with the SHCal13 curve of OxCal 4.2.4 (Bronk Ramsey 2009; Hogg et al. 2013).

Source: See references in table.

The seemingly anomalous dating of Makué (Sheppard et al. 2015:34) is resolved by the revised calculations offered by Galipaud et al. (2014:111) for the basal Zone 3 at Makué.

Setting aside the Sheppard et al. calculation, all of the proposed date ranges sit comfortably with the revised range for the Bismarck Archipelago presented here. The closeness of the results for the Bismarck Archipelago and Remote Oceania suggest that dispersal into Remote Oceania occurred soon after the appearance of Lapita pottery in the archipelago. This is consistent with comparisons between the Makué pottery and that of ECA, ERA and FOH (Bedford and Galipaud 2010: Figure 7; Galipaud 2010: Figure 2; Noury and Galipaud 2011:23, 30, 65), which imply only a brief interval in the archipelago before southerly dispersal.

Discussion and conclusion

The new dates for the Makekur site in the Arawe Islands of New Britain proved to be younger than expected and raise questions about the starting date for Lapita pottery in the Bismarck Archipelago as a whole. In reviewing the Makekur dates in this broader context, the date lists for the archipelago were culled according to more rigorous rules than have previously been used. This process identified several problematic results where contexts, relevance and interpretations are questioned, and confirmed the problems of calibration of shell dates in the Mussau Islands acknowledged by Kirch (2001: Chapter 10). In terms of plant dates, there is a gap between those for the EQS, ERA and FYS sites, and those for other assemblages that should be of similar age on the basis of stylistic studies of the pottery. The reason for this discrepancy is unclear. Several possibilities can be considered:

1. the earliest occupation at Makekur has not yet been dated or excavated;
2. the Makekur dates are correct, and some Lapita pottery sites are indeed much older than others, but we have yet to define adequately the stylistic relationships between their pottery assemblages;
3. older dates reflect in-built age for unidentified charcoal or wood samples, cultural activity predating the introduction of pottery, or old shells from Pre-Lapita contexts.

Which, if any, of these possibilities apply is open to discussion. Option 1 seems unlikely, given the general consistency of dates for Makekur from four laboratories over three decades, though dating of other samples or further excavation could change this picture. Option 2 also seems unlikely, as it would imply that there was an earlier stage of pottery development before the occupation of Makekur that has not yet been recognised. If Option 3 holds, then the starting date for Lapita could be around 3250–3150 cal. BP.

This revised date has several implications. It places the arrival of pottery-making in the archipelago at the late end of the period proposed for the W–K2 eruption, and supports the reoccupation dates for the Willaumez Peninsula and Garua Island proposed by Petrie and Torrence (2008: Tables 5 and 6). It suggests that the interval between the arrival of pottery-making in the archipelago and the dispersal of the pottery-makers into Remote Oceania was short, as the pottery studies indicate. This has ramifications for our understanding of the Lapita phenomenon, as several authors have discussed (e.g. Bedford 2015; Petchey et al. 2015; Summerhayes 2007). On the other hand, questions remain concerning the acceptance or rejection of dates at several key sites, and not the least of these questions concerns appropriate ΔR offsets for marine shell samples. Resolution of some questions may be through redating programs that are currently underway (P.V. Kirch pers. comm. 21 February 2017) or are under consideration (G.R. Summerhayes pers. comm. 8 February 2017), or re-excavation of some key sites to obtain short-lived and identified materials from reliable, well-controlled contexts, preferably avoiding marine shells unless reliable, local ΔR values directly applicable to each site can be established. In addition, it may be necessary to rethink the current models for the development of Lapita pottery, particularly in light of the opportunities offered by the Lapita Design On-Line Project (Chiu 2011, 2013), that may help resolve some apparent conflicts between dates and stylistic analyses.

Although the dates discussed here are less than an ideal set, they are currently the best we have to work with. Once agreement is reached on a 'clean' set of dates for Lapita sites in the archipelago, a formal Bayesian approach will be possible. In the meantime, it is worth bearing in mind Bronk Ramsey's (2009:339) caution that 'most attempts to analyze ^{14}C dates without a proper formal model give misleading results and is perhaps why, when asked to look at a series of calibrated ^{14}C dates from a single phase, almost everyone will instinctively overestimate their spread'. This may well explain, in part, why the preferred date for the beginning of Lapita pottery has oscillated over the decades.

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Appendix 9.1. Culling the dates

This appendix provides a commentary on the dates considered for inclusion in this chapter, with explanations why they were accepted or rejected. Each entry is identified by its site code in the site register at the National Museum and Art Gallery of Papua New Guinea, with the first letter of the three- or four-letter code indicating the province:

- E=New Ireland Province
- F=West New Britain Province
- K=Morobe Province
- S=East New Britain Province.

Strict application of the principles of 'chronometric hygiene' (Spriggs 1989) and 'chronometric flossing' (Kirch 2001:204) to the date lists would have eliminated several important sites that must be early on stylistic grounds. This would have reduced the number of accepted dates to 11, making the dataset 'uncomfortably small' (Allen and Wallace 2007:1177). Some dates that perhaps should be rejected are indicated as Accepted with reservations; this applies to all marine shell dates.

Plant

Table 9A.1. Mussau Islands, New Ireland.

ECA	GX-5498: 3030±180. Accepted with reservations; unidentified charcoal, context unclear. From the same 'oven' as GX-5499, which is much older. Kirch (2001:73) questions whether this was an 'oven' and suggests the charcoal was embedded in cemented coral and sand.
ECA	GX-5499: 3900±260. Rejected; unidentified charcoal from the same 'oven' as the much younger GX-5498. The calibrated date is far too old to be relevant.
ECA/Airfield transect	ANU-5080: 3260±90. Accepted with reservations; unidentified charcoal from the base of the cultural layer and top of the palaeobeach. The early date may reflect old wood or in-built age (Kirch 2001:223) or possibly a pre-pottery combustion event—see main text.
ECA/B	ANU-5075: 2370±120. Rejected; fine flecks of unidentified, dispersed charcoal, too young. One of three samples from zone C1 which is described as 'probably after the abandonment of the stilt-house' (Kirch 2001:224–225). The result is best viewed as an averaged age, but of what is unclear.
ECA/B	ANU-5076: 2430±230. Rejected; unidentified charcoal, too young. See ANU-5075.
ECA/B	ANU-5077: 2450±160. Rejected; unidentified charcoal, too young. See ANU-5075.
ECA/B	ANU-5078: 2600±160. Rejected; combined sample of fine flecks of unidentified, dispersed charcoal from two excavation units in Zone C2–3, 'probably after the abandonment of the stilt house' (Kirch 2001:225). The result is best viewed as an averaged age, but of what is unclear.

ECA/B	ANU–5079: 2840±115. Rejected; unidentified charcoal. Combined sample of fine flecks of dispersed charcoal from two excavation units in Zone C1. See ANU–5075.
ECA/B	ANU–5790: 2950±80. Accepted; Post B1, culturally modified wood of *Intsia bijuga* (Colebr.) O. Kuntze, one of three main corner posts of the Area B stilt structure.
ECA/B	ANU–5791: 2930±80. Accepted; Post B2, culturally modified wood of *Intsia bijuga* (Colebr.) O. Kuntze, second of three main corner posts of the Area B stilt structure. As its maximum diameter is c. 180 mm (Kirch 2001: Table 4.2), the sample probably has little-to-moderate in-built age.
ECA/B	Beta–20451: 2950±70. Accepted with reservations; short-lived coconut (*Cocos nucifera* L.) endocarp. The recovery context was in the 'muck zone' lacking artefacts but with charcoal and plant remains (Kirch 2001:86, 224). It is unclear what is being dated.
ECA/B	Beta–20452: 3050±70. Accepted; stake or Post B30 of unidentified, culturally modified wood from basal Zone C3. Probably has little in-built age as its maximum diameter is 30 mm (Kirch 2001: Table 4.2).
ECA/W250	Beta–30681: 2860±60. Accepted with reservations; post of unidentified, culturally modified wood with unknown potential for in-built age.
ECA/W250	Beta–30682: 2970±50. Accepted with reservations; 'structural beam' of unidentified, culturally modified wood with unknown potential for in-built age (Kirch 2001:229).
ECA/W250	Beta–30684: 3100±110. Accepted with reservations; stake of unidentified, culturally modified wood with unknown potential for in-built age, associated with plain pottery.
ECA/C	Beta–30686: 2850±70. Accepted; stake or Post C3 of *Diospyros* sp. wood, culturally modified. From the earlier of two occupation phases in Area C that are thought to post-date the stilt house of Area B (Kirch 2001:230). The result is older than Beta–30687 from the second construction phase in Area C, and slightly younger than some Area B dates. The stake probably has little in-built age as its maximum diameter is 60 mm (Kirch 2001: Table 4.2).
ECA/C	Beta–30687: 2600±60. Rejected; Post C20 of *Intsia bijuga* wood; too young. This sample came from the second phase of construction in Area C, which is later than Area B (Kirch 2001:230). See Beta–30686.
ECB	Beta–20453: 3200±70. Rejected; unidentified charcoal that received incomplete chemical pre-treatment; unknown potential for in-built age (Kirch 2001:139, 231). This is the oldest calibrated plant date of the Mussau series other than ANU–5080 at ECA. Petchey and Ulm (2012: Table 2, footnote h) reject the sample on the basis that it was unidentified charcoal and not confirmed as a short-lived specimen.

Source: Bafmatuk et al. 1981; Kirch 2001: Chapter 10; Petchey and Ulm 2012.

Table 9A.2. Emirau Island, New Ireland.

EQS	Wk–21345: 2917±31. Accepted with reservations; unidentified charcoal with unknown potential for in-built age.
EQS	Wk–21349: 3044±31. Accepted with reservations; unidentified charcoal with unknown potential for in-built age.

Source: Summerhayes et al. 2010: Table 1.

Table 9A.3. Anir Islands, New Ireland.

ERA	Wk–7561: 3035±45. Accepted with reservations; unidentified charcoal with unknown potential for in-built age.
ERA	Wk–7563: 3075±45. Accepted with reservations; unidentified charcoal with unknown potential for in-built age.
ERA	Wk–7564: 2765±50. Rejected; unidentified charcoal, too young.
EAQ	ANU–957: 2050±210. Rejected; unidentified charcoal, too young.
EAQ	ANU–11193: 3220±170. Rejected; unidentified charcoal with unknown potential for in-built age. The calibrated result is too old at the upper range limit, perhaps reflecting a Pre-Lapita level, as the sample context is described as 'just below the main cultural-bearing layer' (Summerhayes 2001a:34).
EAQ	ANU–11190: 2110±240. Rejected; unidentified charcoal from a reworked sediment, too young. The sample possibly relates to a Post-Lapita volcanic event (Summerhayes 2001a:34).
ERD	Wk–5557: 2400±80. Rejected, unidentified charcoal, too young.
ERG	ANU–11191: 3090±170. Accepted with reservations; unidentified charcoal with unknown potential for in-built age.

Source: Ambrose 1973; Summerhayes 2001a: Table 1.

Table 9A.4. Duke of York Islands, New Britain.

SEP	SUA–3062: 2730±80. Rejected; unidentified charcoal that the excavator assigns to a late context (White and Harris 1997:100). This is supported by the calibrated age exceeding 3000 years only at 2σ.

Source: White and Harris 1997: Table 1.

Table 9A.5. Watom Island, New Britain.

SAC	Wk–7370: 2860±60. Accepted; short-lived endocarp of coconut (*Cocos nucifera* L.).

Source: Anson et al. 2005: Table 6.

Table 9A.6. Garua Island, New Britain.

FAO	NZA–3738: 2439±64. Rejected; unidentified nut endocarp, probably *Canarium* sp.; too young.
FAO	NZA–3729: 2452±67. Rejected; unidentified nut endocarp, probably *Canarium* sp.; too young.
FAQ	Beta–72140: 2540±60. Rejected; unidentified nut endocarp, probably *Canarium* sp.; no pottery association, too young.
FQY	Beta–72141: 2580±60. Rejected; unidentified nut endocarp, probably *Canarium* sp.; too young.
FAAN	Beta–112608: 2670±70. Rejected; unidentified nut endocarp, probably *Canarium* sp.; too young.
FAAQ	Beta–112598: 2450±60. Rejected; unidentified nut endocarp, probably *Canarium* sp.; too young.
FSZ	NZA–6099: 2781±68. Rejected; unidentified nut endocarp, probably *Canarium* sp.; calibrated age exceeds 3000 years only at 2Đ. The pottery from FSZ is very fragmented and the site appears to be disturbed. The associated pottery does not look 'early' (Specht and Torrence 2007a: Figures 10–13).
FYS	NZA–3733: 2883±64. Accepted; unidentified nut endocarp, probably *Canarium* sp.; associated with plain pottery.
FYS	Beta–72144: 3060±60. Accepted; unidentified nut endocarp, probably *Canarium* sp.; associated with one dentate-stamped sherd.
FYS	NZA–3734: 3030±69. Accepted with reservations; unidentified nut endocarp, probably *Canarium* sp.; no pottery at this level.

Source: Specht and Torrence 2007a: Table 5; Torrence and Stevenson 2000: Table 1.

Table 9A.7. Willaumez Peninsula, New Britain.

FAAH	Wk–10463: 2880±59. Accepted; short-lived, unidentified nut endocarp, probably *Canarium* sp.; associated with dentate-stamped pottery.
FAAH	Wk–19190: 2847±34. Accepted; short-lived, unidentified nut endocarp, probably *Canarium* sp.; associated with dentate-stamped pottery.
FACQ	Wk–10478: 2883±63. Rejected; unidentified nut endocarp, probably *Canarium* sp.; surface sherds only.
FACR	Wk–10459: 2831±57. Rejected; unidentified nut endocarp, probably *Canarium* sp.; surface sherds only.
FADA	Wk–12840: 2965±46. Rejected; unidentified nut endocarp, probably *Canarium* sp.; no pottery associated.
FADC	Wk–12845: 2936±47. Accepted; unidentified nut endocarp, probably *Canarium* sp.; plain pottery only. Incorrectly listed as 2963±47 in Table 3 of Specht and Torrence 2007b.

Source: Specht and Torrence 2007b: Table 3.

Table 9A.8. Arawe Islands New Britain.

FOH	Wk–8539: 3740 ±60. Rejected; unidentified charcoal with unknown in-built age, too old.
FOH	Beta–54164: 2640±90. Rejected; unidentified charcoal with unknown in-built age, too young.
FOH	Beta–54165: 2850±80. Accepted with reservations; unidentified charcoal with unknown in-built age, but consistent with short-lived sample OZS476.
FOH	Beta–54166: 2730±70. Rejected; unidentified charcoal with unknown in-built age, too young. Although the CRA is identical to SUA–3062 for SEP in the Duke of York Islands, the smaller standard error keeps the calibrated age below 3000 years.
FOH	ANU–11186: 2800±110. Accepted with reservations; unidentified charcoal with unknown in-built age.

FOH	ANU–11187: 2730±100. Rejected; unidentified charcoal with unknown in-built age. The calibrated result yields a range limit over 3000 years at 2Ð. In contrast, samples Beta–54166 and Wk–32734 with the same age have smaller standard errors that restrict their ranges to below 3000 years.
FOH	Wk–32734: 2730±70. Rejected; short-lived *Canarium* sp. endocarp, too young.
FOH	OZS476: 2860±20. Accepted; short-lived *Canarium* sp. endocarp.
FOH	OZS477: 2830±25. Rejected; wood of cf. *Terminalia catappa* L.; small standard error keeps the calibrated age range below 3000 years.
FOH	OZS479: 2690±25. Rejected; short-lived *Canarium* sp. endocarp; too young.
FOL	Beta–54168: 2530±70. Rejected; unidentified charcoal, too young.

Source: Gosden and Webb 1994; Gosden et al. 1994; Specht and Gosden 1997: Appendix 1; Summerhayes 2001a: Table 3, 2010: Table 2; this chapter.

Shell

Shell dates ANU–5081 to ANU–5089 were originally issued with an assumed $\delta^{13}C$=0.0‰, but in 2000 Matthew Spriggs (pers. comm. to J.S., 17 February 2016) obtained measured values (except for ANU–5081) from John Chappell (then RSES, ANU). Spriggs forwarded the revised $\delta^{13}C$ values to Kirch, but they arrived too late for inclusion in Kirch's analysis of the Mussau dates, where they were listed as a 'Note added in proof' (Kirch 2001:236). Spriggs (2003: Table 1) used some of the revised results in a review of dates from Island Southeast Asia and the western Pacific Islands. The measured $\delta^{13}C$ values and adjusted dates are listed below:

Table 9A.9. Measured $\delta^{13}C$ values and adjusted dates.

ANU Lab code	Age reported in Kirch 2001	Measured $\delta^{13}C$ value	$\delta^{13}C$-adjusted CRA
ANU–5081	3010±80	n/a	No change
ANU–5082	2950±80	1.7±0.2‰	2950±80
ANU–5083	2810±80	1.9±0.2‰	2840±70
ANU–5084	3190±80	2.3±0.2‰	3230±70
ANU–5085	3130±80	2.0±0.2‰	3170±70
ANU–5086	3120±80	1.6±0.2‰	3140±70
ANU–5087	3150±80	1.4±0.2‰	3170±70
ANU–5088	3470±90	2.4±0.2‰	3510±90
ANU–5089	3380±90	2.4±0.2‰	3420±90

Source: Author's summary.

The $\delta^{13}C$-adjusted CRAs are used in Table 9A.10. The ANU dates for the KLK site in the Siassi Islands were calculated on measured $\delta^{13}C$ values (Lilley 1986: Appendix 1), and those for Boduna (FEA) on $\delta^{13}C$=0.0±2.0‰ (Rachel Wood, RSES, ANU, pers. comm. to J.S., 10 February 2016). All shell dates are listed as 'accepted with reservations' even where there is a calculated local ΔR value, to reflect the issues discussed in the text surrounding marine shell as a dating medium.

Table 9A.10. Mussau Islands, New Ireland: Calibrated with ΔR=–293±92 (Petchey and Ulm 2012: Figure 1).

ECA/A	ANU–5084: 3230±70. Accepted with reservations; *Tridacna gigas* (high reliability).
ECA/A	ANU–5085: 3170±70. Accepted with reservations; *Hyotissa hyotis* (medium to high reliability?). The recovery context was Layer IIB, near the base of square W229/N100 (Kirch 2001:85). As the bottom of the cultural deposit was not reached, the sample refers to an unknown point in time after initial occupation.
ECA/B	ANU–5081: 3010±80. Rejected; *Tridacna gigas* (high reliability) associated with post stumps in zone C3. The status of the sample's $\delta^{13}C$ value is unclear. As the sample was used to calculate a ΔR value for Area B (Kirch 2001:200–201), the date cannot be calibrated using that value or that of –293±92 years (Petchey and Ulm 2012: Figure 1) as the calibrated age would not be an independent determination.

ECA/B	ANU–5082: 2950±80. Rejected; *Hyotissa hyotis* (medium to high reliability?) associated with post stumps in zone C3. This shell was associated with post stumps in zone C3 (Kirch 2001:226) and was used to calculate the ΔR value for Area B (Kirch 2001:200). See ANU–5081.
ECA/B	ANU–5083: 2810±80. Rejected; *Hyotissa hyotis* (medium to high reliability?), too young; the sample context (zone B1) post-dates initial site occupation (Kirch 2001:226).
ECA/B	Beta–30673: 3110±70. Rejected; *Spondylus* sp. (medium or high reliability) from zone C1. The sample does not refer to an early stage of pottery as it came from 'the upper portion of Zone C' (Kirch 2001:227). See Beta–30674, Beta–30675.
ECA/W250	Beta–30676: 3590±110. Rejected; complete *Turbo marmoratus* operculum from the Pre-Lapita palaeobeach terrace (Kirch 2001:227). Too old, probably of natural origin.
ECA/W250	Beta–30677: 3170±70. Accepted with reservations; *Spondylus* sp. (medium or high reliability) 'from the elevated palaeobeach terrace' (Kirch 2001:227).
ECA/W250	Beta–30678: 3190±80. Accepted with reservations; *Chama* sp. (medium or high reliability) with an 'artificially chipped ventral margin' from the 'foreshore slope of the palaeobeach terrace' (Kirch 2001:228).
ECA/W250	Beta–30679: 3080±70. Accepted with reservations; culturally modified *Tridacna gigas* (high reliability), possibly an adze blank (Kirch 2001:228).
ECA/W250	Beta–30680: 3320±80. Rejected; *Chama* sp. (medium or high reliability). The sample came from above a slightly younger post stump (Beta–30681). The calibrated age is too old (3664–3370 cal. BP) and Kirch (2001:228) suggests that the sample was 'possibly older shell incorporated into deposit?'
ECA/W250	Beta–30683: 3140±80. Accepted with reservations; *Hippopus hippopus* (high reliability).
ECA/C	Beta–30674: 3110±70. Rejected; *Hippopus hippopus* (high reliability). The sample was 'associated with the earlier of two occupation phases' in Area C, which should be later than Area B (Kirch 2001:229), yet Beta–30674 is the same age as Beta–30675 and Beta–30673 (*Spondylus*) from Area B zone C1. Compare with wood date Beta–30686 for Post C3.
ECA/C	Beta–30675: 3110±80. Rejected; culturally modified *Tridacna derasa* (high reliability) 'associated with the earlier of two phases of stilt-house occupation' in Area C that should be later than Area B (Kirch 2001:230). See Beta–30674.
ECA/C	Beta–30685: 2770±70. Rejected; *Hyotissa hyotis* (medium to high reliability?), too young. This sample belongs to the later phase of construction in Area C with incised pottery (Kirch 2001:230).
ECB	ANU–5086: 3140±70. Rejected; *Hyotissa hyotis* (medium to high reliability?). The sample was used with Beta–20453 (charcoal) to calculate a ΔR value for ECB (Kirch 2001:201–203). Using this to calibrate ANU–5086 would yield a result dependent on Beta–24053, which is rejected as it did not receive full chemical pre-treatment.
ECB	ANU–5087: 3170±70. Rejected; *Hyotissa hyotis* (medium to high reliability?). See ANU–5086 regarding calibration.
EHB	ANU–5088: 3510±90. Rejected; *Tridacna gigas* found with finely dentate-stamped sherds. The recovery context is described as 'extensively penetrated' by land crab burrows, and the layer as having 'no meaningful internal stratification' (Kirch 2001:141). The dated shell could be of natural origin displaced by crab burrowing.
EHB	ANU–5089: 3420±90. Rejected; *Hyotissa hyotis* (medium to high reliability?) found with finely dentate-stamped sherds. See ANU–5088.
EKE	Beta–30693: 3420±70. Rejected; *Hippopus hippopus* (high reliability). Calibration yields an improbable range for the start of Lapita pottery, though Kirch (2001:216) notes that it is 'not inconsistent with the shell dates from the paleobeach terrace at ECA'. However, the sample context is suspect—see main text.
EKO	Beta–25669: 3200±70. Accepted with reservations; culturally modified body whorl of *Turbo marmoratus* (medium reliability).
EKQ	Beta–20454: 3280±70. Rejected; mixed sample of unidentified shell fragments that could have different reliability levels and derive from different periods.
EKQ	Beta–21789: 3030±80. Rejected; mixed sample of identified and unidentified species. See Beta–20454.
EKQ	Beta–25670: 3270±80. Accepted with reservations; two culturally modified shells of *Tridacna maxima* (high reliability) and *Turbo marmoratus* (medium reliability).
EKQ	Beta–25671: 3190±90. Accepted with reservations; three complete and four fragments of *Conomurex luhuanus* (medium reliability).

Source: Kirch 2001: Chapter 10; Spriggs 2003: Table 1.

Table 9A.11. Anir Islands, New Ireland: Calibrated with the local ΔR=–69±51 years (Summerhayes 2007:154, note iii).

ERA	Wk–7560: 3260±45. Rejected; mixed sample of *Conus* sp. (low reliability) and *Tridacna* sp. (high reliability). This sample was used with Beta–7561 (charcoal) to calculate a local ΔR value for ERA and does not provide an independent calibrated determination.
ERA	Wk–7562: 3350±45. Rejected; mixed sample of *Turbo* sp. (medium reliability) and *Tridacna* sp. (high reliability). This sample was used with Beta–7563 (charcoal) to calculate a local ΔR value for ERA; see Wk–7560.
ERD	Wk–7556: 2810±50. Rejected; unidentified shell, too young.
ERD	Wk–7558: 3245±45. Accepted with reservations; *Turbo* sp. (medium reliability) and unidentified shell. As this sample was stratigraphically below and older than the first pottery in the cave, it provides a maximum age for pottery at this site.

Source: Summerhayes 2001a: Table 3; Summerhayes 2010: Table 2.

Table 9A.12. Duke of York Islands, New Britain: Calibrated with the local ΔR=43±68 years (Petchey et al. 2004).

SDP	SUA–3061: 2940±60. Rejected; possibly *Tridacna gigas* (high reliability), too young to be relevant to the start of Lapita pottery.
SET	SUA–3063: 3030±60. Rejected; possibly *Tridacna gigas* (high reliability), too young to be relevant to the start of Lapita pottery.
SET	SUA–3064: 3150±60. Rejected; possibly *Tridacna gigas* (high reliability), too young to be relevant to the start of Lapita pottery.
SEE	SUA–3082: 3090±60. Rejected; *Conomurex luhuanus* (medium reliability), too young to be relevant to the start of Lapita pottery.

Source: White and Harris 1997:100.

Table 9A.13. Watom Island, New Britain.

SAC	ANU–5339: 3490±80. Rejected; *Tectus niloticus* (medium reliability), This sample was used with Wk–7370 (coconut endocarp) to calculate a ΔR value for Watom Island, and so calibration with this value would not provide an independent determination. The sample's relationship to Lapita pottery is uncertain as Anson et al. (2005: Table 6) attribute the shell to both Zone C2 and to the Pre-Lapita zone D.

Source: Anson et al. 2005: Table 6; Petchey et al. 2005.

Table 9A.14. Boduna Island, New Britain: Calibrated using ΔR=45±19 years for Kimbe Bay (Petchey and Ulm 2012: Figure 1).

FEA	ANU–5071: 2050±90. Rejected; unidentified shell, too young. Intrusive? See ANU–5072.
FEA	ANU–5072: 3090±80. Rejected; unidentified shell. The result is 1200–1000 years older than ANU–5071 from the same context, but statistically the same as ANU–5073 from a slightly higher context.
FEA	ANU–5073: 3130±90. Rejected; unidentified shell. See ANU–5072.
FEA	Beta–41578: 3330±60. Accepted with reservations; *Chama* sp. (medium or high reliability) from the base of the site.
FEA	Wk–9936: 3211±52. Rejected; *Anadara* sp. (medium/high reliability) embedded in beach rock that includes sherds and obsidian flakes. The temporal relationship between the sample and cultural materials is unknown.

Source: Ambrose and Gosden 1991; Specht and Summerhayes 2007: Table 1; White et al. 2002: Table 2, 105.

Table 9A.15. Kove Islands, New Britain: Calibrated using Region 5 ΔR=40±19 years (Petchey and Ulm 2012: Figure 1).

FCL	Beta–26259: 2990±80. Rejected; *Tridacna* sp. (high reliability) from 'culturally-sterile basal sediment' of 'organic mud and sand-coral debris' within the groundwater (Lilley 1991:316). Deposit is extensively disturbed, and the date is too young to be relevant.
FPA	SUA–2822: 3100±120. Rejected; described as 'degraded marine mollusc shell, probably *Tridacna* sp.' found in 'dark brown, clayey volcanic ash over cemented coralline sand'. As SUA–2822 was found above Beta–26261 and ANU–2823, which are both older, it is not relevant to the start of pottery in the Kove Islands.

FPA	ANU–2823: 3220±70. Accepted with reservations; described as 'degraded fragments of *Tridacna* sp.' (high reliability), found in 'dark brown clayey volcanic ash over cemented coralline sand' below ANU–2822.
FPA	Beta–26261: 3280±70. Accepted with reservations; *Tridacna* sp. (high reliability) from the surface of the cemented basal sand. Thought to date the 'culturally-sterile basal sediment at FPA' (Lilley 1991:316), thus providing a maximum age for Lapita pottery on the island.

Source: Lilley 1991: Table 1; Ian Lilley pers. comm.

Table 9A.16. Tuam Island, Siassi Islands: Calibrated using Region 2 ΔR=273±216 years (Petchey and Ulm 2012: Figure 1).

KLK	ANU–4610: 3870±80. Rejected; complete *Tridacna* sp. (high reliability), too old. Embedded in the top of the basal sand, it probably represents a pre-settlement beach shell.
KLK	ANU–4617: 3010±80. Rejected; unidentified shell, too young.
KLK	ANU–4620: 3040±70. Rejected; unidentified shell, too young.
KLK	ANU–4621: 3300±80. Rejected; unidentified shell. The result conflicts with ANU–4664 from a comparable context; possibly non-cultural in origin?
KLK	ANU–4664: 3000±100. Rejected; probable *Tridacna* sp. (high reliability) adze; too young.

Source: Lilley 1986:126–130, Appendix 1; Lilley 2002: Table 1.

Table 9A.17. Arawe Islands, New Britain: Calibrated using ΔR=273±216 years for Region 2 (Petchey and Ulm 2012: Figure 1).

FNY	Beta–27940: 2870±70. Rejected; 'oyster' shell, too young. The reported age was not $\delta^{13}C$-adjusted, and there is uncertainty about the disturbed nature of FNY trenches (Gosden and Webb 1994).
FOF	Beta–26644: 3530±70. Rejected; *Anadara antiquata* (medium/high reliability). The reported age was not $\delta^{13}C$-adjusted and the result is stratigraphically inconsistent (Gosden et al. 1994).
FOH	Beta–27946: 3200±70. Rejected; 'oyster' shell. The reported age was not $\delta^{13}C$-adjusted. The pottery record sheets for the sample context suggest that no pottery was found in this level.
FOH	Beta–37561: 2860±70. Rejected; *Tridacna* sp. (high reliability), too young.
FOH	Beta–55323: 3230±70. Rejected; unidentified shell, the upper limit of the calibrated age falls below 3000 years. The reported age was not $\delta^{13}C$-adjusted and was originally published as 2800±70 (Specht and Gosden 1997: Appendix 1). The adjusted age (Summerhayes 2001a:32, Table 3) is cited here.
FOH	Beta–55456: 2840±60. Rejected; unidentified shell, too young.
FOJ	Beta–29244: 2960±80. Rejected; *Tridacna* sp. (high reliability), too young.
FOJ	Beta–29245: 3230±50. Rejected; *Tridacna* sp. (high reliability), the upper limit of the calibrated age falls below 3000 years.

Source: Specht and Gosden 1997: Table 1 and 3; Summerhayes 2001a: Table 3; see also this chapter Table 9.3.

Table 9A.18. Kandrian, New Britain: As there is no calculated ΔR value relevant to the Kandrian region, all samples are rejected.

FFS	Beta–63613: 3810±60. Rejected; *Anadara antiquata* (medium/high reliability). Too old, probably non-cultural.
FLF	Beta–57767: 3170±70. Rejected; *Anadara antiquata* shells (medium/high reliability), associated with dentate-stamped pottery.
FLF	Beta–63616: 3430±80. Rejected; *Anadara antiquata* shells (medium/high reliability), some burnt. There is uncertainty about the suitability of burnt shell for dating (Clark et al. 2010:26).
FLQ	Beta–57769: 3220±70. Rejected; *Turbo chrysostomus*; no pottery associated.
FLQ	Beta–63615: 3290±80. Rejected; *Gafrarium* spp. (medium/high reliability); no pottery associated.

Source: Boyd et al. 1999: Table 1; Lentfer et al. 2010: Table 4; Specht and Gosden 1997: Appendix 1.

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