Dating the appearance of Lapita pottery in the Bismarck Archipelago and its dispersal to Remote Oceania

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Abstract

The Bayesian calibration program OxCal v.4.1.5 is applied to two chronological datasets for early Lapita derived from two comprehensive reviews. The two datasets are supplemented by published ages for early Lapita sites in two key island groups within Remote Oceania: Vanuatu and Fiji. The analyses provide statistically robust chronologies for the emergence of Lapita on Mussau at *3470–3250 cal BP* and in the rest of the Bismarck Archipelago at *3360–3240 cal BP*. After a period of 130–290 years, Lapita dispersed to Vanuatu by *3250–3100 cal BP* and to Fiji by *3130–3010 cal BP*.

The appearance of Lapita pottery, primarily dentate-stamped, in the Bismarck Archipelago is a major event in Pacific history (e.g. Kirch 1997), yet it is relatively poorly dated (Specht 2007). Lapita pottery is generally considered to be derived from red-slipped pottery in Island Southeast Asia (Bellwood 1997; Kirch 1997), with dentate-stamped decorative innovations emerging in the Bismarck Archipelago. In this paper, the focus is upon the chronology of early or formative Lapita pottery in the Bismarck Archipelago and the timing of its dispersal to the islands of Remote Oceania, where this dispersal represented the first human colonization. Several key debates associated with Lapita pottery, principally those focused on cultural associations, geographical and chronological variations, social practices and ultimate demise, are not considered here (Green 1979, 1991a; Anson 1986; Kirch 1997; Spriggs 1997; Summerhayes 2000).

Surprisingly, given the importance of Lapita pottery to Pacific archaeology and the ways in which archaeologists have been 'ensnared' by radiocarbon dating in the region (Bedford and Sand 2007), there has been no systematic attempt to derive an explicitly chronological model for its appearance in the New Guinea region and subsequent dispersal into Remote Oceania. Two exceptions are the application of Bayesian approaches 1) at the Nanggu site in the southeast Solomons (Green *et al*. 2008), and 2) to dates on human bone from a range of Lapita pottery contexts (Petchey *et al*. 2011). Despite the lack of precision in regional syntheses of radiocarbon dates, given that they have been derived from *ad hoc* interpretative approaches rather than Bayesian modelling, various conclusions regarding the nature of the dispersal of Lapita pottery have been drawn, especially a fast dispersal rate that implies a structured process (Kirch and Hunt 1988; Anderson 2001).

There have been various reviews of the radiocarbon dates for early Lapita sites, especially within the Bismarck Archipelago (Kirch and Hunt 1988; Specht and Gosden 1997; Kirch 2001; Summerhayes 2001, 2010; Spriggs 2003; Specht 2007). The resultant dates proposed for the appearance of Lapita pottery, however, are impressionistic assessments based largely on the range of individual age determinations through an effective 'eye-balling' of calibrated age ranges, e.g. 3300–3200 cal BP (Specht and Gosden 1997: 189; Spriggs 2001: 240; Summerhayes 2010), 3350–3250 cal BP or ca. 3550 cal BP 'at the earliest' (Kirch 2001: 219), and 3450–3350 cal BP (Specht 2007: 54). Overlaps between date ranges have enabled only tendencies and approximate chronologies to be ascertained. Other proposed dates for the emergence of Lapita have relied heavily upon the results from individual sites or island groups (Kirch 2001; Summerhayes 2001). Although Kirch's (2001) application of summed probability distributions is an attempt to interpret data in summary form, it is not a model-based approach that includes statistical interrogation of sets of geographically and historically restricted radiocarbon age determinations.

Bayesian statistical programs are model-based applications for the analysis of radiocarbon age determinations that are being increasingly applied to archaeological problems in order to generate higher resolution and statistically valid calibrated date ranges. These enable information on groups of events to be evaluated quantitatively, thereby eliminating the problems associated with interpretation of multiple calibrated radiocarbon dates 'by eye' (Bronk Ramsey 2008). Using Bayesian methods it is possible to evaluate the start, end and duration of groups of sample ages with quantified uncertainties (Buck *et al*. 1994, 1996; Bronk Ramsey 2009). Within the Pacific, they have been used to generate date

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ranges for major episodes of wetland drainage at Kuk Swamp, Papua New Guinea (Denham *et al*. 2003); to determine the chronology of volcanic eruptions impacting the Willaumez Peninsula, Papua New Guinea, as well as the nature and timing of recolonisation (Petrie and Torrence 2008); and, to provide a revised chronology for the occupation of the O18 site on Hawai`i (Dye and Pantaleo 2010).

Background

In this short report, the Bayesian calibration program OxCal v.4.1.5 (2010; Bronk Ramsey 1995, 2009) is used to interrogate claims about, and to generate chronologies for, the appearance of Lapita in the Bismarck Archipelago and its dispersal to Remote Oceania. The Bayesian analysis is applied to chronological datasets for early Lapita derived from two comprehensive reviews: Spriggs (2003) and Specht (2007). These reviews are starting points for analysis because they adopt quite different chronometric hygiene protocols in their assessment of radiocarbon dates. Consequently, any claims of interpretative bias in the selection of dates subject to Bayesian analysis here can be minimised by a reliance on two previously published studies and an investigation of the differences between them. The two datasets are supplemented by published ages for early Lapita sites in two key island groups within Remote Oceania: Vanuatu (Bedford *et al*. 2006; Galipaud and Swete Kelly 2007) and Fiji (Nunn 2007). The cut off point for inclusion in the analysis was a publication date of 2009. We note that Bayesian calibrations in this article are in italics.

Spriggs (2003, 2007) applied a type of chronometric hygiene to radiocarbon age determinations associated with the dispersal of the 'Island Southeast Asian Neolithic', which he describes as ancestral to Lapita pottery (cf. Donohue and Denham 2010). In this study, a modified version of the Spriggs dataset is used to minimize potential errors and uncertainties (Table 1). The dataset is restricted to radiocarbon ages on plant-derived materials, namely, nutshell, wood and charcoal. Ages on marine shell are excluded due to uncertainties in the application of a marine reservoir correction during calibration (Stuiver *et al*. 1986; Petchey *et al*. 2005; Petchey 2009), potential recrystallisation of new carbonate minerals (Bezerra *et al*. 2000), and 'old shell effects' (Rick *et al*. 2005). Furthermore, the rejection of shell ages for early Lapita sites is clearly necessitated because shell ages are consistently c.100–200 years older than plant-derived ages for the same sites (compare Tables 1 and 2; Specht 2007). Consequently, the dates for the pottery-bearing Kasasinabwana shell midden on Wari Island at the eastern tip of the New Guinea mainland are excluded (Negishi and Ono 2009: Table 1). Although the dates are early, they do not refer to dentate-stamped designs that would identify the site as belonging to the Lapita ceramic series. Ages on bone are also excluded due to potential problems of post-depositional contamination of different dateable fractions and the uncertain contributions of marine and terrestrial carbon to diet (Taylor 1987). Recent re-dating of several Lapita pottery-associated burials suggests that none belongs to the earliest stages that are of interest here (Petchey *et al*. 2011).

Specht (2007) adopted a more critical and stringent chronometric protocol than Spriggs, and includes only those on plant materials. He discounted all radiocarbon ages on bone and shell, and those on plant materials that have standard errors larger than 115 years as their calibrated age

Island/region	Site	Radiocarbon age BP	Material	Lab. code	Cited reference
Nissan	DGD/2, Yomining	2990 ± 60	Charcoal	ANU 6809	Spriggs 1991
Nissan	DGD/2, Yomining	2820 ± 70	Charcoal	ANU 8301	Spriggs 1991
Mussau	ECA, Eloaua Island	3260 ± 90	Charcoal	ANU 5080	Kirch 2001
Mussau	ECB, Eloaua Island	3200 ± 70	Charcoal	Beta 20453	Kirch 2001
Mussau	ECA, Eloaua Island	3100 ± 110	Wood	Beta 30684	Kirch 2001
Mussau	ECA, Eloaua Island	3050 ± 70	Wood	Beta 20452	Kirch 2001
Mussau	ECA, Eloaua Island	3030 ± 180	Charcoal	GX 5498	Kirch 2001
Mussau	ECA, Eloaua Island	2970 ± 50	Wood	Beta 30682	Kirch 2001
Mussau	ECA, Eloaua Island	2950 ± 80	Wood	ANU 5790	Kirch 2001
Mussau	ECA, Eloaua Island	2930 ± 80	Wood	ANU 5791	Kirch 2001
Mussau	ECA, Eloaua Island	2860 ± 60	Wood	Beta 30681	Kirch 2001
Mussau	ECA, Eloaua Island	2850 ± 70	Wood	Beta 30686	Kirch 2001
Mussau	ECA, Eloaua Island	2840 ± 115	Charcoal	ANU 5079	Kirch 2001
Anir, New Ireland	EAQ, Malekolon	3220 ± 170	Charcoal	ANU 11193	Summerhayes 2001
Anir, New Ireland	ERG, Feni Mission	3090 ± 170	Charcoal	ANU 11191	Summerhayes 2001
Anir, New Ireland	ERA, Kamgot	3075 ± 45	Charcoal	Wk 7563	Summerhayes 2001
Anir, New Ireland	ERA, Kamgot	3035 ± 45	Charcoal	Wk 7561	Summerhayes 2001
New Ireland	Balof Shelter 2	3120 ± 190	Charcoal	ANU 4972	White *et al*. 1991
West New Britain	FYS II, Garua Island	3060 ± 60	Nutshell	Beta 72144/ CAMS 13076	Torrence and Stevenson 2000
West New Britain	FYS II, Garua Island	3030 ± 69	Nutshell	NZA 3734	Torrence and Stevenson 2000
West New Britain	FYS II, Garua Island	2883 ± 64	Nutshell	NZA 3733	Torrence and Stevenson 2000
Arawe islands	FOH, Makekur	2850 ± 80	Charcoal	Beta 54165	Summerhayes 2001
Arawe islands	FOH, Makekur	2800 ± 110	Charcoal	ANU 11186	Summerhayes 2001

Table 1. Earliest radiocarbon age determinations derived from plant materials for Lapita pottery for a given island or group (after Spriggs 2003: Table 1, excluding outliers).

Island/region	Site code	Radiocarbon age BP	Lab. code	Cited reference
Mussau	EHB, Emananus Island	3510 ± 90	ANU 5088	Kirch 2001
Mussau	EKE, Boliu Island	3420 ± 70	Beta 30693	Kirch 2001
West New Britain	FLF, Alanglongromo	3430 ± 80	Beta 63616	Specht and Gosden 1997
West New Britain	FEA, Boduna Island	3330 ± 60	Beta 41578	White *et al*. 2002
Nissan	DGD/2, Yomining	3350 ± 80	ANU 5228	Spriggs 1991, 2003
Anir, New Ireland	ERA, Kamgot	3350 ± 45	Wk 7562	Summerhayes 2001
Anir, New Ireland	ERA, Kamgot	3260 ± 45	Wk 7560	Summerhayes 2001
Siassi Islands	KLK, Tuam	3300 ± 80	ANU 4621	Lilley 2002
Arawe islands	FOH, Makekur	3230 ± 70	Beta 55323	Summerhayes 2001
Arawe islands	FOJ, Apalo	3230 ± 50	Beta 29245	Summerhayes 2001
Solomons, Reef Islands	SE-SZ-8, Nanggu	3250 ± 70	SUA-111	Green 1991b
Solomons, Reef Islands	SE-SZ-8, Nanggu	3140 ± 70	SUA-112	Green 1991b
Vanuatu, Efate	Mangaasi	3160 ± 50	Wk 6601	Bedford 2006
Vanuatu, Erromango	Ifo	3120 ± 60	ANU 10680	Bedford 2006
Fiji, Viti Levu	Bourewa	3259 ± 42	Wk-14237	Nunn 2007
Fiji, Viti Levu	Bourewa	3107 ± 35	Wk-17968	Nunn 2007

Table 2. Earliest radiocarbon age determinations derived from marine shell for Lapita pottery for a given island or group (after Spriggs 2003: Table 1 and excluding outliers).

ranges are too wide to be useful, as well occasionally yielding results which are anachronistic with respect to others for the same site or island. Samples from potentially disturbed contexts that lack clear archaeological associations are also excluded (Table 3).

Despite the application of chronometric protocols, several potential problems need to be considered in the assessment of plant-derived dates in the Specht and purged Spriggs datasets. These include: 'old wood effects' (Schiffer 1986); geomorphological and biological reworking of archaeological deposits at coastal sites (e.g. Specht 1985); and, uncertain archaeological association between dated material and pottery (Specht 2007). Archaeological association between dated material and a pottery sherd cannot be assumed because the two items were excavated from the same level or spit, rather it has to be demonstrated through an engagement with the archaeological record for a site and its chronostratigraphic integrity. Tables 1 and 3 present the modified datasets used in the analyses.

The datasets for Vanuatu and Fiji are all accelerator mass spectrometry (AMS) dates obtained on charcoal during recent studies (Table 4). Vanuatu and Fiji are considered

Island/region	Site code	Radiocarbon age BP	Material	Lab. code	Cited reference
Mussau	ECB, Eloaua	3200±70	charcoal	Beta-20453	Kirch 2001
Mussau	ECA, Eloaua	3100±110	wood	Beta-30684	Kirch 2001
Mussau	ECA/B, Eloaua	3050±70	wood	Beta-20452	Kirch 2001
Mussau	ECA/B, Eloaua	2950±80	wood	ANU-5790	Kirch 2001
Mussau	ECA/A, Eloaua	2950±70	coconut shell	Beta-20451	Kirch 2001
Mussau	ECA/B, Eloaua	2930±80	wood	ANU-5791	Kirch 2001
Mussau	ECA, Eloaua	2970±50	wood	Beta-30682	Kirch 2001
Mussau	ECA/B, Eloaua	2840±115	charcoal	ANU-5079	Kirch 2001
Mussau	ECA, Eloaua	2860±60	wood	Beta-30681	Kirch 2001
Mussau	ECA/C, Eloaua	2850±70	wood	Beta-30686	Kirch 2001
West New Britain	FYS, Garua	3060±60	nutshell	Beta-72144	Torrence and Stevenson 2000
West New Britain	FYS, Garua	3030±69	nutshell	NZA-3734	Torrence and Stevenson 2000
West New Britain	FYS , Garua	2883±64	nutshell	NZA-3733	Torrence and Stevenson 2000
West New Britain	FSZ, Garua	2781±68	nutshell	NZA-6099	Torrence and Stevenson 2000
Anir, New Ireland	ERA	3075±45	charcoal	Wk-7563	Summerhayes 2001
Anir, New Ireland	ERA	3035±45	charcoal	Wk-7561	Summerhayes 2001
Nissan	DGD/2	2990±60	charcoal	ANU-6809	Spriggs 1991, 2003
Nissan	DGD/2	2820±70	charcoal	ANU-8301	Spriggs 1991, 2003
Willaumez Pen, New Brit.	FADC	2963±47	nutshell	Wk-12845	Specht and Torrence 2007
Willaumez Pen, New Brit.	FAAH	2880±59	nutshell	Wk-10463	Specht and Torrence 2007
Willaumez Pen, New Brit.	FAAH	2847±34	nutshell	Wk-19190	Specht and Torrence 2007
Arawe islands	FOH	2800±110	charcoal	ANU-11186	Summerhayes 2001
Arawe islands	FOH	2850±80	charcoal	Beta-54165	Summerhayes 2001
Arawe islands	FOH	2730±100	charcoal	ANU-11187	Summerhayes 2001
Watom	SAC	2860±60	coconut shell	Wk-7370	Petchey *et al*. 2005
Makada	SEP	2730±80	charcoal	SUA-3062	White and Harris 1997

Table 3. Earliest radiocarbon age determinations derived from plant materials for Lapita (and other) pottery for a given island or group (following Specht 2007: Table 1).

Island/region	Site code	Radiocarbon age BP	Lab. code	Reference
Solomons, Reef Islands	SE-RF-2, Nenumbo	2955 ± 95	I-5747	Green 1991b
Solomons, Reef Islands	SE-RF-2, Nenumbo	2850 ± 130	ANU-6476	Green 1991b
Solomons, Reef Islands	SE-RF-2, Nenumbo	2775 ± 100	I-5748	Green 1991b
Solomons, Reef Islands	SE-RF-2, Nenumbo	2730 ± 120	ANU-6477	Green 1991b
Vanuatu, Aore	Makué	2982 ± 50	Wk-13722	Galipaud and Swete Kelly 2007
Vanuatu, Aore	Makué	2962 ± 32	Wk-19705	Galipaud and Swete Kelly 2007
Vanuatu, Aore	Makué	2957 ± 51	Wk-13721	Galipaud and Swete Kelly 2007
Vanuatu, Aore	Makué	2935 ± 41	Wk-11447	Galipaud and Swete Kelly 2007
Vanuatu, Efate	Teouma	2848 ± 35	Wk-15728	Bedford *et al*. 2006
Fiji, Viti Levu	Bourewa	2920 ± 31	Wk-17542	Nunn 2007
Fiji, Viti Levu	Bourewa	2915 ± 42	Wk-14595	Nunn 2007
Fiji, Viti Levu	Bourewa	2894 ± 42	Wk-14599	Nunn 2007
Fiji, Viti Levu	Bourewa	2870 ± 30	Wk-17973	Nunn 2007

Table 4. Earliest radiocarbon age determinations for Lapita pottery for a given island or group in Remote Oceania. All samples were charcoal and AMS dated. Marine shell ages are excluded due to problems of marine reservoir determination and recrystallisation. The Nenumbo, Reef Islands dates were not used in the analysis for reasons provided in the text; they are presented here for comparative purposes only.

starting points of Lapita colonization for islands further out in Remote Oceania, such as New Caledonia and Samoa-Tonga, thereby representing key stages in Lapita dispersal (Bedford and Spriggs 2008). Relatively intensive archaeological programs have occurred in both archipelagos, including the recent dating of early Lapita sites (e.g. Bedford 2006; Bedford *et al*. 2006; Galipaud and Swete Kelly 2007; Nunn 2007; Clark and Anderson 2009).

Although the southeastern part of the Solomon Islands contains early Lapita sites, and is closer geographically to the Bismarck Archipelago, the radiometric evidence is problematic. The radiocarbon age determinations from Nenumbo, Reef Islands, Solomon Islands (Green 1991b) are excluded because they have large standard errors that hinder the derivation of high resolution calibrations (Table 4). An age determination from Anuta is noteworthy (2830 ± 90 BP, I-6275, Kirch and Rosendahl 1973), but is also excluded because 'one date is no date' (Renfrew and Bahn 1996: 137).

Method

We assume that dispersal proceeded from north to south in four sequential steps. The sites, therefore, are grouped accordingly. Each group of dates is treated as a single phase (Bronk Ramsey 2009) within the model, with no constraints applied between the phases. The date ranges given in Table 5 are for the start boundary of each phase, and provide our modelled estimate for the inception of Lapita to the different regions. The delays are derived from the difference between these inception events.

First, in previous reviews (e.g. Specht 2007) the Mussau group has been regarded as having the earliest Lapita sites – ECA and ECB on Eloaua – based on radiocarbon age determinations and the possibility of a pre-dentate-stamped, red-slipped plainware phase on the palaeobeach at ECA (Kirch 1997, 2001). We follow this assumption, although there has been no attempt to determine if these two sites form a statistically earlier grouping apart from the rest of the Bismarck Archipelago. Recently published dates for site EQS on Emirau (Summerhayes *et al*. 2010), also within the Mussau group, are not included here because they were published after the publication cut-off point (2009). Furthermore, as the EQS dates fall within the range of those from Eloaua, they are unlikely to change significantly the date range for the earliest Lapita pottery in the Mussau group.

The second group covers the rest of the Bismarck Archipelago. There are relatively few reliable age determinations for the archipelago, given the number of potentially early Lapita sites; any claimed internal geochronological differentiation most likely reflects sampling biases and sample selection. For instance, in the purged Spriggs dataset, there is a clear gradation from New Ireland to West New Britain to the Arawes (Table 1); this chronological gradient is not apparent in the Specht dataset, which seems to suggest almost simultaneous dispersal to Anir (off New Ireland) and West New Britain, with slightly later dispersal to the Arawes and Watom (Table 3). Until more intensive dating programs are undertaken at several sites, radiocarbon dating will not elicit a robust sequence for the dispersal of Lapita pottery within the Bismarck Archipelago except possibly between the Mussau group and the rest of the archipelago, as is investigated here.

Third and fourth groupings are Vanuatu and Fiji. In both archipelagos intensive dating programs have been undertaken of sites representing early colonization and the dispersal of Lapita pottery. A Bayesian analysis of recent datasets for these archipelagos was designed to establish the timing of dispersal of Lapita pottery from the Bismarck Archipelago. Additionally, it will be possible to determine the duration of the formative period of Lapita in the Bismarck Archipelago before its dispersal to Remote Oceania (Specht 2007; Summerhayes 2007).

In all cases we have used the IntCal09 calibration curve (Reimer *et al*. 2009). Dates that are based on the combination of Bayesian modelling and radiocarbon calibration undertaken here are quoted in italics.

Dataset	Event/Period	95.4% range	68.2% range
Spriggs (Table 1)	Inception of Lapita on Mussau	*3698-3282 cal BP*	*3552-3384 cal BP*
Spriggs (Table 1)	Inception of Lapita in Bismarck Archipelago	*3578-3182 cal BP*	*3423-3255 cal BP*
Spriggs (Table 1)	Delay: Mussau to Bismarck Archipelago	-176 to 402 years	-1 to 247 years
Spriggs (Tables 1, 4)	Delay: Bismarck Archipelago to Vanuatu/Fiji	99 to 478 years	208 to 389 years
Specht (Table 3)	Inception of Lapita on Mussau	*3587-3110 cal BP*	*3472-3245 cal BP*
Specht (Table 3)	Inception of Lapita in Bismarck Archipelago	*3435-3172 cal BP*	*3357-3238 cal BP*
Specht (Table 3)	Delay: Mussau to Bismarck Archipelago	-211 to 315 years	-65 to 190 years
Specht (Tables 3, 4)	Delay: Bismarck Archipelago to Vanuatu/Fiji	36 to 375 years	130 to 293 years
Vanuatu (Table 4)	Dispersal of Lapita to Vanuatu	*3433-3025 cal BP*	*3252-3096 cal BP*
Fiji (Table 4)	Dispersal of Lapita to Fiji	*3293-2973 cal BP*	*3128-3008 cal BP*
Petrie and Torrence 2008	W-K2 eruption, New Britain	3480-3150 cal BP	
Petrie and Torrence 2008	Reoccupation of isthmus (Willaumez Peninsula)	3330-3040 cal BP	
Petrie and Torrence 2008	Reoccupation of Garua Island	3360-3040 cal BP	

Table 5. Summarising key date ranges and time spans for Lapita inception, dispersal and delays within Island Melanesia, based on Spriggs 2003 dataset (Table 1, cleansed of marine samples) and Specht 2007 dataset (Table 3), as well as various dates for dispersal of Lapita pottery to Vanuatu and Fiji (Table 4). 95.4% and 68.2% date and interval ranges are derived from single phase Bayesian models using using OxCal v.4.1.5 (2010; Bronk Ramsey 1995, 2009) and IntCal09 calibration curve (Reimer et al. 2009). Results of Petrie and Torrence (2008) are shown for comparison. The 95.4% probability ranges give the conservative maximum likely range; the 68.2% probability ranges provide the most likely periods. Calibrated date ranges derived from the Bayesian modelling undertaken here are shown in italics.

Results

The radiocarbon groupings were subject to series of duplicate analyses using the modified Spriggs (2003) and Specht (2007) datasets that addressed corresponding research questions (Table 5). Bayesian analyses provide statistical measures of the significance of resultant date ranges and relationships. The results for each research question are briefly discussed below. Given the lack of precision in most radiocarbon age determinations for early Lapita sites, 68.2% probability date ranges have been included in the discussion of what is most likely, although 95.4% probability date ranges are more robust bases for inference. In this case, the use of 68.2% date ranges is defensible because they reflect the central tendency in the probability distributions for a given dataset allowing a broad interpretation for the occurrence of Lapita pottery within a given region during a specific period, especially given the limitations of a fairly small dataset.

What is the timing for the inception of Lapita on Mussau?

The Spriggs dataset generates date ranges of *3700–3280 cal BP* (95.4%) and *3550–3380 cal BP* (68.2%) for the emergence of Lapita in Mussau, whereas the Specht dataset has slightly later date ranges of *3590–3110 cal BP* (95.4%) and *3470–3250 cal BP* (68.2%). At 95.4%, the date ranges are broad, being approximately 400 years in both cases, and of limited value for refined historical interpretation. At 68.2% the date ranges reduce to approximately 200 years and are more useful for interpretation, although less statistically significant. Spriggs' date ranges are slightly earlier than Specht's, reflecting the former's inclusion of age determinations with broader standard errors. Consequently, and based on Specht's more conservative dataset, the earliest Lapita pottery in Mussau dates to *3470–3250 cal BP* (68.2%).

What is the timing for the inception of Lapita in the rest of the Bismarck Archipelago?

The Spriggs dataset generates date ranges of *3580–3180 cal BP* (95.4%) and *3420–3260 cal BP* (68.2%) for the appearance of Lapita in the Bismarck Archipelago (excluding Mussau), whereas the Specht dataset has slightly later date ranges of *3440–3170 cal BP* (95.4%) and *3360–3240 cal BP* (68.2%). As for the Mussau group, the date range for the Spriggs dataset is 400 years at 95.4% and consequently of limited interpretative value, whereas that for Specht's is 270 years. At 68.2% the date ranges reduce considerably to 160 years (Spriggs) and 120 years (Specht). Spriggs' inclusion of slightly older ages and some with broader standard errors accounts for his slightly earlier and broader date ranges. Given Specht's more stringent chronometric hygiene protocols, the inception of Lapita pottery in the Bismarck Archipelago (excluding Mussau) is *3360–3240 cal BP* (68.2%).

Is there a delay between the earliest Lapita sites on Mussau and for the rest of the Bismarck Archipelago?

Based on the Spriggs dataset (and restricting the discussion to 68.2% probability distributions), there is a difference of -1 to 247 years between the appearance of Lapita in Mussau and its earliest occurrence in the rest of the Bismarck Archipelago. For the Specht dataset there is greater overlap between the two date distributions suggesting a difference of between -65 and 190 years, which would imply that the Mussau dates are slightly earlier. Consequently, the Mussau dates are suggestive of Lapita pottery being earlier there than elsewhere, but Mussau could be included with the rest of the Bismarck Archipelago for interpretative purposes; it is a question of the spatial resolution needed for inference or interpretation. On balance, the Mussau dates provide a robust chronology for the appearance of Lapita pottery at *3470–3250 cal BP* (68.2%).

What is the timing of Lapita dispersals to Vanuatu and Fiji?

The dispersal of Lapita pottery to Vanuatu occurred at *3430–3030 cal BP* (95.4%) and *3250–3100 cal BP* (68.2%). The dispersal of Lapita pottery to Fiji occurred at *3290–2970 cal BP* (95.4%) and *3130–3010 cal BP* (68.2%). Current radiocarbon dating is suggestive of a slightly earlier dispersal of Lapita pottery to Vanuatu than to Fiji, and is slightly earlier than previously considered (Bedford *et al*. 2006; Clark and Anderson 2009). At present, the points of departure for the colonisation events represented by the dispersal of pottery to Vanuatu and Fiji are unclear, however, they are reasonably chronologically discrete.

How long is the interval between the occurrence of Lapita pottery in the Bismarck Archipelago and its dispersal to Vanuatu/Fiji?

The analysis of this interval used chronological datasets for the Bismarck Archipelago (excluding Mussau) and those for Fiji/Vanuatu. Mussau data were not included to avoid any compounding errors because of uncertainties as to the status of Mussau with respect to the rest of Bismarck Archipelago. The interval would probably be greater if the Mussau and Bismarck Archipelago dates were considered together for comparison with those for Remote Oceania.

Based on the Spriggs dataset (and restricting the discussion to 68.2% probability distributions), there is a difference of 210–390 years between the appearance of Lapita in the Bismarck Archipelago and its dispersal to Remote Oceania (Fiji/Vanuatu). For the Specht dataset, the interval reduces to 130–290 years. Again, following a more stringent chronometric hygiene protocol, there was clearly a ‘Bismarck formative phase’ of at least 130–290 years for the emergence and development of Lapita in the Bismarck Archipelago before its spread to Remote Oceania.

Conclusion

A Bayesian analysis has been applied to chronometric datasets for the appearance and dispersal of Lapita pottery. Two datasets for Mussau and the rest of the Bismarck Archipelago were compared; they are derived from different chronometric hygiene protocols applied by Spriggs (2003) and Specht (2007). Recently derived datasets for Vanuatu and Fiji were included in the analysis to determine dates for the dispersal of Lapita to these island groups and to infer the duration of the formative phase in the Bismarck Archipelago.

Well-resolved chronologies have been derived using 68.2% date ranges. In most cases, these overlap with a range of ‘eye-balled’ estimates, but do not allow discrimination between most of them. Date ranges include the emergence of Lapita on Mussau at 3470–3250 cal BP, its occurrence elsewhere in the Bismarck Archipelago by *3360–3240 cal BP*, and after 130–290 years Lapita dispersed to Vanuatu by *3250–3100 cal BP* and to Fiji by *3130–3010 cal BP*. The dispersal of Lapita to Remote Oceania probably occurred after the W-K2 eruption on West New Britain (Table 5; Petrie and Torrence 2008), although there is insufficient data to determine causality.

The start of Lapita pottery in the Mussau area around *3470–3250 cal BP* (68.2%) is slightly earlier than in the rest of the Bismarck Archipelago around *3360–3240 cal BP* (68.2%). These two ranges fully fall within the proposed date range (3480–3150 cal BP) of the cataclysmic W-K2 eruption of New Britain, and overlap substantially with the estimated dates (3360–3040, 3330–3040 cal BP) for human re-colonisation, with dentate-stamped pottery, of areas affected by that event (Petrie and Torrence 2008: tables 5, 6). We note, however, that this is perhaps not surprising, as the age ranges for the W-K2 event and re-colonisation include some samples used in the current analysis.

Based on radiocarbon dating, it is not possible to determine the sequential spread of Lapita within the Bismarck Archipelago. Although the Mussau dates are earlier than elsewhere in the archipelago, they do not seem to be significantly earlier. Any directionality in the spread of Lapita within the rest of the archipelago is solely a function of date selection.

Differences in the chronologies derived from the Spriggs and Specht datasets have been noted, and reflect the different chronometric protocols applied. Date ranges derived from the Specht (2007) dataset are followed here due to the more stringent selection criteria; consequently, the date ranges are more conservative and tend towards a ‘short chronology’. However, these differences do highlight the interpretative problems of using radiocarbon dates to understand social processes in the past. Until an intensive and high-precision dating program is undertaken on early Lapita sites across Near Oceania and Remote Oceania, including the re-dating of previously excavated sites and a focus on short-lived materials, such as nutshell, it is unlikely that a significantly more detailed understanding of the timing and directionality of Lapita origins and dispersals can be resolved.

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