– ARTICLE –

Bayesian Re-evaluation of Lapita Settlement in Fiji: Radiocarbon analysis of the Lapita occupation at Bourewa and nearby sites on the Rove Peninsula, Viti Levu Island

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ABSTRACT

80 radiocarbon dates are presented for Lapita-era sites on the Rove Peninsula, southwest Viti Levu Island, Fiji. Of these, 67 are from the Bourewa site which is the largest and probably the earliest in the area. Of these, 10 are rejected as not being demonstrably associated with its Lapita occupation.

Constraints on date interpretation arising from sample materials are highlighted. In particular, charcoals that have not been identified to short-lived tree species, twigs or seeds are evaluated according to observed contextual associations and established understanding of inbuilt age offsets using Bayesian outlier analysis. It is concluded that many of the dates on charcoal are imprecise indicators of settlement age and have an average offset of 149 years. Shell radiocarbon results are similarly evaluated and it is concluded that the majority have ^{14}C values that are in equilibrium with the marine radiocarbon reservoir and therefore yield ages that are accurate indicators of Lapita occupation of Bourewa.

Results suggest that initial occupation at Bourewa occurred 2816 ± 25 calBP (2838–2787 calBP [68.2% prob.]; 2866–2771 calBP [95.4% prob.]) and ended 2654 ± 21 calBP (2675–2640 calBP [68.2% prob.]; 2689–2613 calBP [95.4% prob.]). Similar analyses applied to other dated Lapita sites in Fiji shows that, while Bourewa is among the earliest, the Matanamuani (VL 21/5) site on Naigani Island remains the earliest to be securely dated.

Keywords: Lapita, Fiji, Bourewa, radiocarbon dating, colonization

INTRODUCTION

Within the Southwest Pacific Ocean, the chronology of human (Lapita) colonization between the Bismarck Archipelago in the west and the island groups of Tonga and Samoa in the east continues to excite attention (Denham *et al.* 2012). The case of the Lapita colonization of Fiji is of particular interest, given that compelling dates for early settlement in the islands of Vanuatu (to its west) and Tonga (to its east) have been published (Bedford & Spriggs 2008; Burley *et al.* 2012). This paper describes the radiocarbon dating of what is likely to be one of the earliest settlements (Bourewa) in the Fiji Islands group as well as that of satellite settlements on the Rove Peninsula in southwest Viti Levu Island and discusses how this might be interpreted.

Published ages for Lapita sites in Fiji suggest settlements were established between about 1100–550 BC (3050–2500 calBP) in most parts of the archipelago (Figure 1). The earliest such settlements are regarded as having been in its western parts, the later farther east (Clark & Anderson 2001, 2009a), with the Lau Islands perhaps being settled from Tonga (to the east) rather than from elsewhere in Fiji (Burley & Dickinson 2010): a conclusion that agrees with the evidence from historical linguistics (Geraghty 1983). For many years it was believed that the Lapita settlements at Natunuku (northern Viti Levu Island) and Matanamuani (VL 21/5, Naigani Island) might be the earliest in the group (Best 1981; Davidson *et al.* 1990) but subsequent research and more precise dating of these sites and others revealed a number of apparently earlier sites (Clark & Anderson 2009b). These include Naitabale (Moturiki Island) as well as a number of sites along the Rove Peninsula in southwest Viti Levu Island, the largest and probably the earliest of which is named Bourewa (Nunn 2009; Nunn *et al.* 2004, 2007).

LAPITA SETTLEMENT OF THE ROVE PENINSULA, SOUTHWEST VITI LEVU ISLAND

Aside from already published dates, there are other indications that Bourewa was the site of an early Lapita

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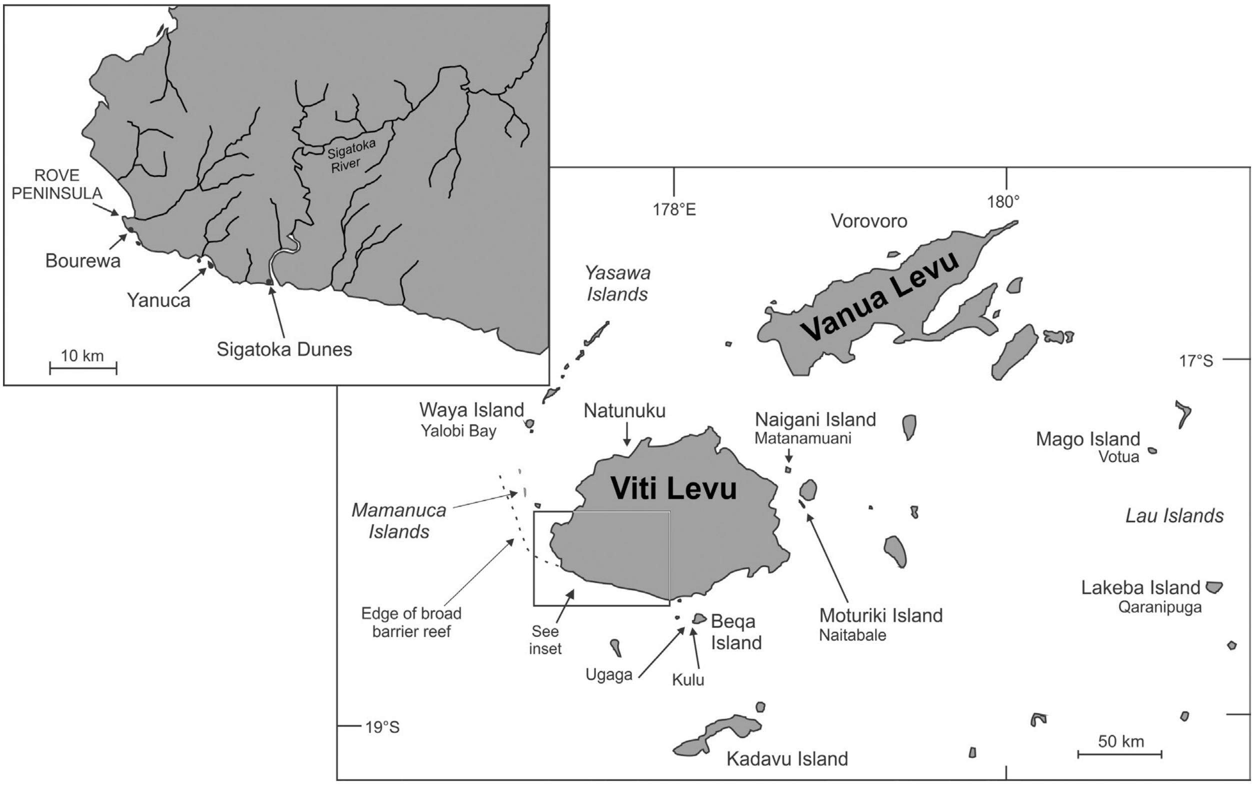

Figure 1. Lapita settlements in the Fiji archipelago.

settlement. These include the decorative motifs on the potsherds, the presence of contemporaneous postholes suggesting a stilt-house occupation, and the dominance of marine foraging for subsistence during at least the earliest period of occupation (Nunn 2007, 2009). The other early site in the area is at Qoqo Island which shares these traits yet is much smaller and perhaps slightly more recent (Nunn *et al.* 2006).

At the time of Lapita arrival in Fiji, the Rove Peninsula in southwest Viti Levu Island was a small island offshore the larger (now Viti Levu) island (Nunn 2005). Its location at the first place (along a west to east route) where the broad barrier reef off the Mamanuca Islands in the western part of the archipelago first meets land has been argued as making it a likely location for an early settlement in Fiji (Nunn 2007). In addition, as elsewhere in the Lapita realm, it may be that a small (reef-fringed) island off a larger island was the preferred site configuration for Lapita colonizers (Spriggs 1984; Specht 2007; Nunn & Heorake 2009).

Seven sites of Lapita age have been identified along the Rove Peninsula, including offshore Qoqo Island (Figure 2). By far the largest is at Bourewa where the earliest Lapita occupation was on stilt platforms and which accommodated perhaps 250–300 people at its maximum extent. The only other stilt-house occupation on the Rove Peninsula (and perhaps in all Fiji) was at Qoqo.

From December 2003 to February 2009, seven phases of investigation (excavation, mapping and in-field analyses) were carried out at the Lapita sites along the Rove Peninsula (Figure 3 shows the excavation plan at Bourewa). While several studies of the findings have been published, the final report is still incomplete. Yet as fieldwork at these sites has ended and is unlikely ever to recommence, it is of interest to publish the radiocarbon dates for Bourewa and other Rove Peninsula sites and discuss their interpretation.

Sixty-seven radiocarbon dates were obtained for the Bourewa site (Table 1) and a further 13 for others along the Rove Peninsula including offshore Qoqo Island (Table 2). These dates do not include those obtained from sediment coring in the Bourewa palaeolagoon (Lal & Nunn 2011), from intrusive (post-Lapita) human burials at Bourewa, nor dates from other sites beyond the Rove Peninsula and Qoqo that were investigated simultaneously as part of the same fieldwork programme. Of the 80 radiocarbon dates obtained, 26% were from charcoal and 71% from marine shell. Charcoal dates were calibrated using using IntCal09 because of Fiji's location within the South Pacific Convergence Zone (Petchey *et al.* 2009).[3] Shell dates

3 The ^{14}C division between the northern and southern hemispheres is considered to lie along the Inter-Tropical Convergence Zone (ITCZ). This creates additional uncertainty when calibrating terrestrial samples from Pacific locales because

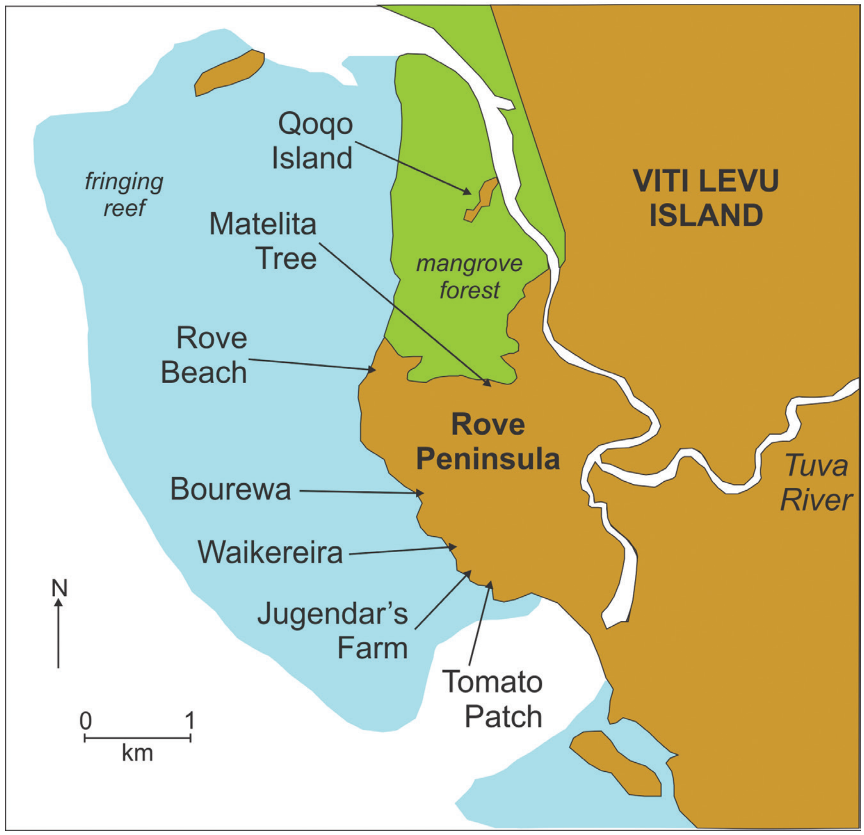

Figure 2. Lapita settlements of the Rove Peninsula and Qoqo Island, showing their modern locations in southwest Viti Levu Island. At the time of their Lapita occupation, all settlements were located on (or slightly offshore) an island, 1–2 km from the Viti Levu mainland (Nunn 2005). The settlement at Rove Beach was probably on a smaller island off this island (Nunn 2009). The settlement at Qoqo, which was on a tombolo between two bedrock islands, was surrounded by coral reef, not the mangrove swamp that exists there today (Nunn *et al.* 2006).

were calibrated using Marine09 (Reimer *et al.* 2009) and corrected using a Fiji-specific marine-correction factor (ΔR) of 11 ± 26 ^{14}C years (Petchey *et al.* 2008). Earlier lists of calibrated dates published from these sites used earlier versions of these and are therefore superseded by the dates in Tables 1 and 2.

ANALYSIS OF RADIOCARBON DATES

Radiocarbon dating is key to determining the chronology of Lapita occupation of Fiji yet for several reasons the provision of precise calendrical ages for site establishment and abandonment has been problematic. These reasons include:

1. Post-depositional disturbance is often high in these early sites because of subsequent human activity as well as the activities of burrowing organisms.
2. Obtaining samples that date the event in question can be problematic especially in the case of marine shells which may have been collected from old beach deposits, or charcoals from longer-lived trees or drift wood.
3. Dates of particular materials are sometimes hard to correctly interpret because many animals inhabit more than one radiocarbon reservoir and our understanding of carbon variation in nature is limited. Examples include shellfish that may ingest carbon from ancient sources like bedrock limestone, or terrestrial sources of ^{14}C that cause shells to give younger dates.

There are two main ways of dealing with radiocarbon dates that are outliers (Bronk Ramsey 2009). The first is to identify and eliminate all results from further analysis based on a set of established parameters. When using this approach we can be sure that the data used are robust and

many island groups, including Fiji, straddle the South Pacific Convergence Zone, which merges with the ITCZ to the west. Because the southern hemisphere calibration curve (SHCal04: McCormac et al. 2004) was developed from trees younger than 1000 calBP collected above 25°S (South Africa [25° S], New Zealand [40° S] and Southern Chile [55° S]) we have opted to use the Northern Hemisphere calibration curve (IntCal04: Reimer et al., 2009) for terrestrial calibrations from Fiji [20° S]. This will make charcoal ages slightly older by 56 ± 24 ^{14}C years than if calibrated using SHCal04.

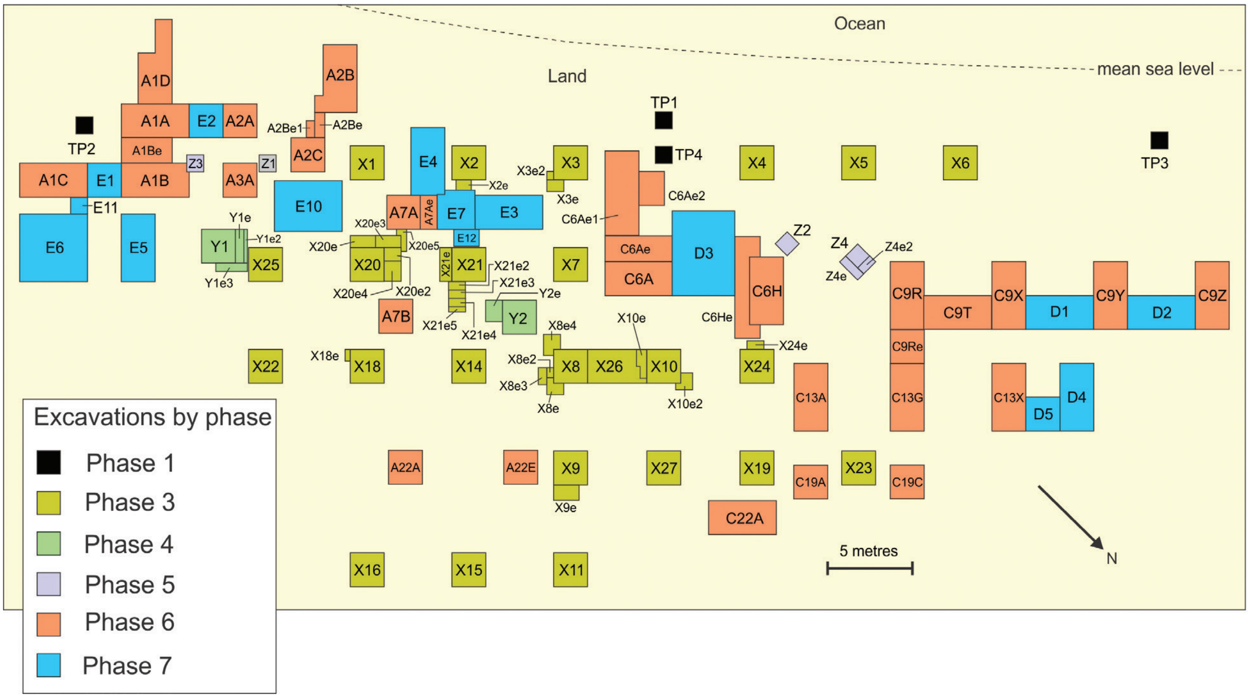

Figure 3. Map of excavated pits in the central part of the Bourewa site.

Table 1. *All radiocarbon dates from the Bourewa site. Dates are in order obtained. All dates from the University of Waikato Radiocarbon Dating Laboratory corrected using marine correction factor (ΔR) of 11 ± 26 ^{14}C years (Petchey* et al. *2008) and calibrated using the IntCal09 and Marine09 curves (Reimer* et al. *2009) in OxCal v4.1.7 (Bronk Ramsey 2012).*

Pit	Sample identifier	Laboratory number	Sample material	Depth (cm)	$\delta^{13}C$	Conventional radiocarbon age (BP)	Calibrated* radiocarbon age BP at 95.4% probability	Calibrated* radiocarbon age AD/BC at 95.4% probability
Phase 1 (December 2003)								
TP1	Bourewa-33	Wk-14598	charcoal	54	−23.3 ± 0.2	2612 ± 41	2845–2815 2810–2695 2640–2615 2590–2540	895–590 BC
TP1	Bourewa-31	Wk-14239	marine shell (*Trochus niloticus*)	71	3.5 ± 0.2	3027 ± 42	2910–2700	960–750 BC
TP1	Bourewa-34	Wk-14599	charcoal	85	−24.9 ± 0.2	2894 ± 42	3205–3185 3165–2920 2910–2885	1255–935 BC
TP2	Bourewa-23	Wk-14238	marine shell (*Fimbria fimbriata* and *Codakia punctata*)	55	2.5 ± 0.2	2740 ± 43	2650–2620 2615–2315	700–365 BC
TP2	Bourewa-26	Wk-14597	charcoal	57	−23.8 ± 0.2	2717 ± 40	2920–2905 2885–2750	970–800 BC
TP3	Bourewa-17	Wk-14594	marine shell (*Codakia punctata*)	105	2.9 ± 0.2	2944 ± 38	2830–2565	880–615 BC
TP3	Bourewa-15	Wk-14236	charcoal	109	−25.2 ± 0.2	2867 ± 40	3145–3120 3115–3090 3085–2865	1195–915 BC
TP3	Bourewa-13	Wk-14235	charcoal	123	−27.6 ± 0.2	2896 ± 40	3205–3185 3165–2920 2905–2890	1255–940 BC
TP4	Bourewa-22	Wk-14237	marine shell (*Tellinidae*)	52	−13 ± 0.2	3259 ± 42	3235–2920	1285–970 BC
TP4	Bourewa-20	Wk-14595	charcoal	54	−23.7 ± 0.2	2915 ± 42	3215–2945	1265–995 BC

* Unmodelled

Table 1 *continued*

Pit	Sample identifier	Laboratory number	Sample material	Depth (cm)	$\delta^{13}C$	Conventional radiocarbon age (BP)	Calibrated* radiocarbon age BP at 95.4% probability	Calibrated* radiocarbon age AD/BC at 95.4% probability
Phase 2 (November–December 2004)								
B3	Bourewa-48	Wk-16207	marine shell (*Codakia* sp.)	90	2.9 ± 0.2	2940 ± 41	2825–2540	875–590 BC
B4	Bourewa-53	Wk-16216	charcoal	134	–24.6 ± 0.2	164 ± 37	290–240 235–60 40–0 (recent)	AD 1660–1955
L4	Bourewa-44	Wk-16206	marine shell (*Strombus gibberulus, Strombus labiatus, Fimbria fimbriata, Vasum turbinellus*)	82	3.6 ± 0.2	1590 ± 39	1260–1020	AD 690–930
Phase 3 (June–July 2005)								
X1	Bourewa-X1/105	Wk-17541	charcoal	105	–26.1 ± 0.2	2506 ± 32	2740–2470	790–520 BC
X2	Bourewa-X2/20	Wk-20282	marine shell (*Trochus niloticus*)	20	3.6 ± 0.2	3014 ± 39	2890–2690	940–740 BC
X2	Bourewa-X2/90	Wk-20281	marine shell (*Trochus niloticus*)	90	3.6 ± 0.2	3038 ± 40	2920–2710	970–760 BC
X2	Bourewa-X2/120	Wk-17548	marine shell (*Anadara* sp.)	120	1.6 ± 0.2	2938 ± 36	2810–2550	860–600 BC
X2	Bourewa-X2/196	Wk-17540	charcoal	196	–26.7 ± 0.2	133 ± 31	280–170 155–55 45–5	AD 1670–1945
X3	Bourewa-X3/30	Wk-20284	marine shell (*Trochus niloticus*)	30	3.6 ± 0.2	3044 ± 40	2925–2715	975–765 BC
X3	Bourewa-X3/70	Wk-20283	marine shell (*Trochus niloticus*)	70	4.3 ± 0.2	2976 ± 39	2860–2650	910–700 BC
X3	Bourewa -X3/104	Wk-17549	marine shell (*Trochus niloticus*)	104	4.4 ± 0.2	3046 ± 39	2925–2715	975–765 BC
X3	Bourewa-X3/121	Wk-17973	charcoal	121	–26 ± 0.2	2870 ± 30	3140–3130 3105–3095 3080–2875	1190–925 BC
X3	Bourewa-X3/124	Wk-17546	marine shell (*Codakia punctata, Gafrarium tumidum, Turbo* sp.)	124	2.4 ± 0.2	2951 ± 38	2840–2590	890–640 BC
X3	Bourewa-X3/135	Wk-17542	charcoal	135	–24.4 ± 0.2	2920 ± 31	3205–3185 3165–2960	1255–1010 BC
X6	Bourewa-X6/68	Wk-17968	marine shell (*Atactodea striata*)	68	2.4 ± 0.2	3107 ± 35	2995–2750	1045–800 BC
X6	Bourewa-X6/94	Wk-17547	marine shell (*Trochus niloticus*)	94	4.5 ± 0.2	3006 ± 39	2880–2685	930–735 BC
X8	Bourewa-X8/55	Wk-17967	mandible of *Sus scrofa*	55	–19.6 ± 0.2	198 ± 30	305–360 225–140 25–0 (recent)	AD 1645–1955
X8	Bourewa-X8/68	Wk-17969	marine shell (*Strombus gibberulus*)	68	2.9 ± 0.2	1740 ± 30	1365–1185	AD 585–765
X8	Bourewa-X8/95	Wk-17539	charcoal	95	–25.1 ± 0.2	383 ± 30	510–425 395–315	AD 1440–1635
X10	Bourewa-X10/78	Wk-17970	marine shell (*Tridacna squamosa*)	78	2.3 ± 0.2	2866 ± 31	2730–2475	780–525 BC
X20	Bourewa-X20/60	Wk-17971	marine shell (*Turbo chrysostomus*)	60	3.8 ± 0.2	2831 ± 39	2710–2400	760–450 BC
X20	Bourewa-X20/69	Wk-17972	marine shell (*Turbo* sp.)	69	3.0 ± 0.2	2824 ± 36	2705–2395	755–445 BC
X21E	Bourewa-X21E/45	Wk-17974	charcoal	45	–25.4 ± 0.2	891 ± 33	910–840 835–730	AD 1040–1220
X23	Bourewa-X23/98	Wk-17545	marine shell (*Codakia punctata*)	98	2.9 ± 0.2	2851 ± 38	2725–2435	775–485 BC
X24E	Bourewa X24E/52	Wk-17543	marine shell (*Trochus niloticus*)	52	4.1 ± 0.2	3006 ± 39	2880–2685	930–735 BC
X25	Bourewa-X25/140	Wk-17544	marine shell (*Conus* sp.)	140	3.2 ± 0.2	3474 ± 39	3455–3215	1505–1265 BC
Phase 4 (February 2007)								
Y1	Bourewa Y1/85	Wk-23222	marine shell (*Hippopus hippopus*)	85	3.0 ± 0.2	2997 ± 38	2870–2680	920–730 BC
Y1	Bourewa-Y1/E3/W3	Wk-20858	marine shell (*Codakia punctata*)	98	3.3 ± 0.2	2901 ± 45	2765–2475	815–525 BC

* Unmodelled

Table 1 *continued.*

Pit	Sample identifier	Laboratory number	Sample material	Depth (cm)	$\delta^{13}C$	Conventional radiocarbon age (BP)	Calibrated* radiocarbon age BP at 95.4% probability	Calibrated* radiocarbon age AD/BC at 95.4% probability
Phase 4 *continued*								
Y1	Bourewa-Y1/E4/N4	Wk-20852	marine shell (*Codakia punctata*)	110	2.9 ± 0.2	2911 ± 39	2765–2495	815–545 BC
Y1	Bourewa-Y1/E4/N5	Wk-20853	marine shell (*Codakia punctata*)	113	3.1 ± 0.2	2969 ± 38	2850–2645 2630–2610	900–660 BC
Y1	Bourewa-Y1/E4/N3	Wk-20851	marine shell (*Codakia punctata*)	128	2.9 ± 0.2	2978 ± 42	2870–2650 2625–2615	920–665 BC
Y1	Bourewa-Y1/E4/N1	Wk-20850	marine shell (*Codakia punctata*)	139	2.9 ± 0.2	2924 ± 46	2795–2490	845–540 BC
Y2	Bourewa-Y2/E/1	Wk-20855	marine shell (*Codakia punctata*)	33	3.0 ± 0.2	2821 ± 39	2705–2385	755–435 BC
Y2	Bourewa-Y2/E/2	Wk-20854	marine shell (*Gafrarium* sp.)	39	0.6 ± 0.2	2988 ± 47	2895–2650 2625–2615	945–665 BC
Phase 6 (November 2007–February 2008)								
A1A	Bourewa A1A/65	Wk-23223	marine shell (*Hippopus hippopus*)	65	3.0 ± 0.2	2985 ± 36	2855–2670	905–720 BC
A1A	Bourewa A1A/85	Wk-23117	charcoal	85	−26.7 ± 0.2	2603 ± 40	2790–2695 2640–2610 2595–2535 2530–2510	840–560 BC
A1A	Bourewa A1A/175	Wk-23067	marine shell (*Anadara scapha*)	175	2.6 ± 0.2	2969 ± 39	2855–2645 2630–2610	905–660 BC
A1D	Bourewa A1D/85	Wk-23118	nut shell charcoal	85	−22.3 ± 0.2	2727 ± 35	2920–2910 2885–2755	970–805 BC
A2B	Bourewa A2B/170	Wk-23226	marine shell (*Hippopus hippopus*)	170	2.9 ± 0.2	3016 ± 39	2890–2690	940–740 BC
A2B	Bourewa A2B/194	Wk-23068	marine shell (*Tridacna squamosa*)	194	2.1 ± 0.2	2921 ± 30	2770–2535	820–585 BC
A2B	Bourewa A2B/205	Wk-23069	marine shell (*Tridacna squamosa*)	205	2.4 ± 0.2	2923 ± 39	2785–2510	835–560 BC
A2Be	Bourewa A2Be/28	Wk-23073	marine shell (*Anadara scapha*)	28	2.3 ± 0.2	2973 ± 38	2855–2650 2625–2615	905–665 BC
A7Ae	Bourewa A7Ae/110	Wk-23119	charcoal	110	−23.8 ± 0.2	2672 ± 31	2845–2745	895–795 BC
A22A	Bourewa A22a/110	Wk-23120	charcoal	110	−26.6 ± 0.2	2657 ± 45	2860–2725	910–775 BC
C6H	Bourewa C6H/55	Wk-23224	marine shell (*Hippopus hippopus*)	55	2.8 ± 0.2	2963 ± 39	2850–2640 2635–2605	900–655 BC
C9R	Bourewa C9R/125	Wk-23225	marine shell (*Hippopus hippopus*)	125	2.7 ± 0.2	3899 ± 40	4000–3695	2050–1745 BC
C9X	Bourewa C9X/96	Wk-23077	marine shell (*Anadara scapha*)	96	1.9 ± 0.2	2856 ± 41	2730–2435	780–485 BC
C9Y	Bourewa C9Y/42	Wk-23074	marine shell (*Anadara scapha*)	42	1.7 ± 0.2	2913 ± 41	2775–2495	825–545 BC
C22A	Bourewa C22A/40	Wk-23075	marine shell (*Anadara scapha*)	40	2.3 ± 0.2	2821 ± 42	2705–2380	755–430 BC
J1	Bourewa J1/32	Wk-23076	marine shell (*Anadara scapha*)	32	2.4 ± 0.2	2966 ± 45	2865–2595	915–645 BC
Phase 7 (January 2009–February 2009)								
E4	Bourewa E4/85	Wk-28027	marine shell (*Hippopus hippopus*)	85	3.1 ± 0.2	3005 ± 39	2880–2685	930–735 BC
E7	Bourewa E7/65	Wk-28030	marine shell (*Hippopus hippopus*)	65	2.9 ± 0.2	2994 ± 40	2870–2670	920–720 BC
E7	Bourewa E7/3	Wk-29601	marine shell (*Tridacna maxima*)	75	2.4 ± 0.2	2822 ± 25	2700–2420	750–470 BC
E7	Bourewa E7/2	Wk-29600	marine shell (*Tridacna maxima*)	95	2.4 ± 0.2	2850 ± 27	2715–2460	765–510 BC
E7	Bourewa E7/97	Wk-28029	marine shell (*Hippopus hippopus*)	97	2.9 ± 0.2	3027 ± 40	2905–2700	955–750 BC
E7	Bourewa E7/1	Wk-29599	marine shell (*Tridacna maxima*)	115	2.6 ± 0.2	2816 ± 25	2695–2405	745–455 BC
E7	Bourewa E7/115	Wk-28028	marine shell (*Hippopus hippopus*)	115	2.7 ± 0.2	2884 ± 39	2745–2475	795–525 BC

* Unmodelled

Table 2. *All radiocarbon dates from other sites along the Rove Peninsula. Dates are by site (alphabetical order), then in order obtained. All dates from the University of Waikato Radiocarbon Dating Laboratory corrected using marine correction factor (ΔR) of 11 ± 26 ^{14}C years (Petchey* et al. *2008) and calibrated using the IntCal09 and Marine09 curves (Reimer* et al. *2009) in OxCal v4.1.7 (Bronk Ramsey 2012).*

Pit	Sample identifier	Laboratory number	Sample material	Depth (cm)	δ^{13}C	Conventional radiocarbon age (BP)	Calibrated* radiocarbon age BP at 95.4% probability	Calibrated* radiocarbon age AD/BC at 95.4% probability
Jugendar's Farm								
JF	Bourewa JF/52	Wk-23071	marine shell (*Anadara scapha*)	52	2.0 ± 0.2	2747 ± 39	2650–2625 2615–2320	700–675 BC 665–370 BC
Matelita Tree								
M1	Bourewa M1/80	Wk-23072	marine shell (*Anadara scapha*)	80	1.1 ± 0.2	2909 ± 41	2765–2490	815–540 BC
Qoqo Island								
F1	Qoqo-30	Wk-16208	marine shell (*Trochus niloticus*)	188	3.2 ± 0.2	2925 ± 35	2780–2525	830–575 BC
R2	Qoqo-32	Wk-16209	marine shell (*Anadara* sp., *Codakia punctata*, *Gafrarium tumidum*)	87	−0.15 ± 0.2	2990 ± 38	2865–2675	915–725 BC
R2	Qoqo-16	Wk-16218	charcoal	118	−24.7 ± 0.2	2790 ± 41	2990–2780	1040–830 BC
Rove Beach								
1	Rove-4	Wk-14240	charcoal	65	−25.4 ± 0.2	155 ± 34	285–240 235–165 160–55 45–5	AD 1665–1960
1	Rove-17	Wk-14242	charcoal	75	−24.8 ± 0.2	95 ± 40	270–185 150–10	AD 1680–1940
1	Rove-12	Wk-14241	charcoal	95	−25.1 ± 0.2	187 ± 56	310–55 50–5	AD 1640–1960
Tomato Patch								
surface	Tomato-1	Wk-16215	charcoal	90	−27.1 ± 0.2	370 ± 37	505–420 415–315	AD 1445–1635
surface	Tomato-2	Wk-16205	marine shell (*Trochus virgatus* [?], *Trochus moculatus*)	88	3.5 ± 0.2	1720 ± 34	1345–1165	AD 605–785
Y3	Tomato-Y3/S/22	Wk-20857	marine shell (*Codakia punctata*)	22	2.8 ± 0.2	2873 ± 38	2735–2465	785–515 BC
Y3	Tomato-Y3/S/24	Wk-20856	marine shell (*Codakia punctata*)	24	2.6 ± 0.2	2917 ± 39	2775–2505	825–555 BC
Waikereira								
W1	Bourewa-W1/60	Wk-23070	marine shell (*Anadara scapha*)	60	0.6 ± 0.2	3034 ± 38	2910–2710	960–760 BC

* Unmodelled

such 'chronometric hygiene' has been the preferred method of many archaeologists in the Pacific. Yet this approach has been extremely harsh on many radiocarbon datasets from Pacific locales because of the difficulties listed above, and may remove many dates that are reliable. The second approach is to weight samples according to how likely they are to be correct based on assumptions outlined within set parameters and rely on a model-averaging approach to arrive at an acceptable hypothesis. Ultimately a methodology that incorporates aspects of both approaches will achieve the most accurate results.

ANALYSIS OF THE RADIOCARBON DATASET FROM THE ROVE PENINSULA

This analysis focuses on the radiocarbon dates from the Bourewa site and treats those from other Rove Peninsula sites, which are far fewer, separately. To improve the outcome of this analysis we first excluded a number of samples that are clear outliers.

Three samples yielded dates that are much older than expected for Lapita in Fiji (i.e. 1100–550 BC [3050–2500 calBP]):

- Wk-23225 (3899 ± 40 BP) dates a valve of the giant clam *Hippopus hippopus* that was found unusually deep in the sand below the shell midden (Pit C6H). This suggests either that it was present on the beach before human arrival or that humans used an old valve to support a stilt-house structure, for example (Seeto *et al.* 2012).
- A *Conus* sp. shell also returned a date that was unusually old (Wk-17544: 3474 ± 39 BP from Pit X25) and could not be stratigraphically constrained. Given that *Conus* shells were the preferred raw material for manufacturing shell valuables at Bourewa (Nunn 2007; Szabó 2010), it is possible that this particular (dead) shell was collected, brought onshore with the intention of working it, and then discarded for some reason.
- Also excluded is a date on Tellinidae (Wk-14237: 3259 ± 42 BP). This animal is a deposit feeder with a δ^{13}C of −13 ± 0.2‰. δ^{13}C values that are depleted relative to marine shells (~0 ± 2‰) are typical in animals that feed on terrestrial material and the radiocarbon ages are often offset from the marine average (Petchey *et al.* 2012, 2013).

Seven samples are too young and represent later (post-Lapita) activities at the site; while obtained from the dense Lapita midden at the site, these samples were clearly not *in situ*.

- Wk-16216 (164 ± 37 BP: charcoal from Pit B4).
- Wk-17540 (133 ± 31 BP: charcoal from Pit X2).
- Wk-17974 (891 ± 33 BP: charcoal from Pit X21E).
- Wk-16206 (1590 ± 39: mixed shell from Pit L4).
- Wk-17969 (1740 ± 30 BP: *Strombus* sp. from Pit X8).
- Wk-17967 (198 ± 30 BP: *Sus scrofa* bone from Pit X8).
- Wk-17539 (383 ± 30 BP: charcoal from Pit X8).

This leaves us with a total of 58 dates that directly measure the age of the Lapita deposits at Bourewa.

In the analysis of the remaining radiocarbon dates, we have used OxCal Version 4.1.7 (Bronk Ramsey 2012) to determine the age of onset, end and span of Lapita settlement at Bourewa. OxCal uses Bayesian statistical methods to analyse radiocarbon determinations in association with prior information such as stratigraphic sequence and archaeological provenance. The program calculates how successfully the ^{14}C measurements conform to this prior knowledge and narrows down the width of the calibrated dates according to the stratigraphic model, thereby giving more precise results in historical years. The overall model is assessed by the calculation of an agreement index (A) for each sample that tells us how well the model agrees with the observations. If A falls below 60% (the equivalent to the 5% level of a χ^2 test), the sample should be evaluated further by calculating an overall agreement index for the model (A_{model}) (Bronk Ramsey 1995).

Although there is some indication that the Lapita occupation at Bourewa continued for some time, we have minimal prior information by which to order the radiocarbon dates. Therefore for the purposes of the next step of this analysis we have assumed all radiocarbon dates belong to a single phase (a random scatter of events in no particular order) of occupation.

Although there is some evidence of mixing in some areas of the site, both within the Lapita period and by later activity with the inclusion of younger material (e.g., Pits E7 and X8), this appears to be minimal and therefore we have assumed a uniform distribution of events within this phase (defined using the 'Boundary' command in OxCal: Bronk Ramsey 2009).

At this point in our analysis all samples are given equal weight in the model.

The results of this analysis (Model 1) give a mean age for the start of occupation at Bourewa of 2986 ± 28 calBP (3013–2966 calBP [68.2% prob.]; 3040–2930 and 2916–2903 calBP [95.4% prob.]). The mean age for the end of the sequence is 2687 ± 19 calBP (2706–2674 calBP [68.2% prob.]; 2720–2652 calBP [95.4% prob.]). The 95.4% probability range for the basal deposits is similar to previous assessments of the age of the site given in Nunn *et al.* (2004) of 3170–2920 calBP.

Yet the overall agreement is unacceptable (A_{model} = 49.4%). One reason for this may be that our model does not take into account the possibility that some of the charcoals may represent an earlier occupation event at this site. Another possibility is that the shell dates are unreliable and are dating too young. To achieve the most reliable result from this type of analysis, it is essential that model parameters are based on valid assumptions and tested to ensure minimal bias. We discuss these two possibilities as assumptions below.

Assumption 1 – The charcoal dates come from an older period of human activity at the site.

Earlier discussions of the Rove Peninsula sites have highlighted the likely effects of multiple periods of migrant-group arrival (Nunn 2009) and it may be that the earliest Lapita settlers of Fiji made return voyages to island groups to the west (Vanuatu and Solomon Islands). If this is the case, it is plausible to suppose that the first human contact with the Rove Peninsula (and offshore Qoqo Island) was part of an exploratory phase, similar to that envisaged for Vorovoro in the north of the archipelago (Burley 2012). In such a scenario, the first phase of occupation may be represented by charcoal, the shell midden being created only later when a larger, more permanent settlement was established.

On the basis of available stratigraphic and dating evidence there is little support for a distinct earlier phase of activity at Bourewa; although many of the older charcoal samples come from lower levels within each pit (e.g., Wk-14599: TP1 basal; Wk-14235 and Wk-14236: TP3 basal; Wk-14595: TP4 basal; and Wk-17542: Pit X3 basal), none are constrained temporally by other dates[4] nor paired with reliable dating materials, and none were sufficiently well-preserved for identification to short-lived plant material.

It is well established that all wood charcoal determinations will date earlier than the context by an unknown amount (Anderson 1991; Spriggs & Anderson 1993)[5]. Tests undertaken by Allen and Wallace (2007) indicated that radiocarbon results from even identified short-lived wood charcoal from tropical Pacific locations may overestimate the ^{14}C age of a given context by more than a century. Using this prior information we can further improve on our model by building in an outlier correction for charcoal as described by Bronk Ramsey (2009); (Exp (1,–10,0), U(0,2.5),'t') whereby the exponential distribution runs from -10 to 0 with a time-constant of 1 ensuring outliers can only be older. The shifts are then scaled by a common scaling factor that can lie anywhere between 10^0 and $10^{2.5}$ years (Model 2). In our model, we have not applied this correction to Wk-23118, a nutshell sample that represents only 1 year of growth.

Assumption 2 – The shells have ^{14}C values that are out of equilibrium with the marine radiocarbon reservoir.

Food shells are generally considered to give radiocarbon dates that directly date the event in question – the gathering of the shellfish for food. All shells selected for this analysis are those commonly consumed by marine foragers in comparable environments, both today and during Lapita times (Thomas 2007a, 2007b; Szabó & Amesbury 2011). The closeness that shell dates have to the target date is often overshadowed by the complexity in the marine reservoir (Specht 2007; Denham *et al.* 2012). A study of the South Pacific Gyre marine reservoir offset (Petchey *et al.* 2008) found that, as suspension-feeding shellfish were selected, little significant variation in ΔR occurred across this region. Notable exceptions include areas where hardwater effects[6] may be found (e.g. Tongatapu – Petchey & Clark 2011) but even in these instances informed corrections can be made based on observed oceanographic conditions, local geology and understanding of shellfish habitat and dietary preferences.

The shells included in this analysis come from a wide range of genera with differing habitats and dietary preferences (Table 3). One short-lived terrestrial/marine pairing is available from the site (Wk-23067: *Anadara scapha* from Pit A1A, and Wk-23118: nut charcoal from adjacent Pit A1D) to check the local marine offset around Bourewa. This returned a ΔR of −48 ± 50 ^{14}C years, which is statistically identical to the Fiji regional marine reservoir correction value applied in our study (ΔR = 11 ± 26 ^{14}C years) and indicates that there is no apparent hardwater effect in this area. *Anadara scapha* is very similar in shell morphology (Baron & Clavier 1992) and therefore habitat preferences to *Anadara antiquata*, which has been identified as a suitable proxy for the marine radiocarbon reservoir when collected from open coastlines (Petchey *et al.* 2013) even when limestone is present in the hinterland, as is the case for Bourewa. *Gafrarium* sp. tend to show a preference for waters that have a higher freshwater influence but recent studies (Petchey & Clark 2011; Petchey *et al.* 2013) suggest the offset will be small and result in slightly older values in open-coast environments where freshwater aquifers are minimal as is the case at Bourewa (Lal & Nunn 2011).

Direct ingestion of limestone-derived detritus may still affect deposit feeders such as *Codakia punctata*, *Fimbra fimbriata* and *Atactodea striata* (Baron & Clavier 1992; Glover & Taylor 2007). Both *Trochus* and *Turbo* species are herbivorous gastropods that could ingest terrestrial sediment during feeding. *Turbo* in particular shows a preference for calcium carbonate strata (Beesley *et al.* 1998), but again, results are not anomalous compared to other shellfish from Bourewa. Since the results from medium to low-reliability species for radiocarbon dating (~20% of total included in this analysis: Hogg *et al.* 1998) are not anomalous within the body of dated material, they are not excluded from the present analysis. As more information is obtained about these species, this decision may need to be re-visited.

The large clams (Tridacninæ) also prefer full strength, clear seawater and will quickly die if exposed to brackish or freshwater for long periods. They obtain energy from photosynthetically derived carbohydrate via a symbiotic relationship with zooxanthellae (single celled algae) (Ellis 1999; Hart *et al.* 1998) in addition to filter-feeding (Beesley *et al.* 1998). Petchey and Clark (2011) hypothesized that this preference may exaggerate the levels of atmospheric CO_2 and therefore enrich ^{14}C in the shells in some enclosed lagoon environments. This is clearly an area for

4 One exception to this are radiocarbon determinations from Pit X3. When dates from Pit X3 are evaluated as a sequence A_{model} is low (5) and there appears to be an inversion between charcoal date Wk-17973 (2870 ± 30 BP) and mixed shell date Wk-17546 (2951 ± 38 BP) obtained from 121 cm and 124 cm depth respectively.

5 Inbuilt age is likely to be minimal for most shells studied here – the life span for the majority of bivalves and gastropods is less than 10 years with *Anadara* spp. possibly living for up to 45 years (Petchey et al. 2011 and references therein). The most likely shellfish to have significant inbuilt age belong to the subfamily Tridacninæ (*Tridacna* sp. and *Hippopus* sp.) that, depending on the species, may live for 100 years (Hamel & Mercier 1996). No record of the size of shells or where samples were taken for dating have been kept, but the sheer size of the larger values means sampling was likely to have been from the outer rim, reducing any offset.

6 Hardwaters occur where large amounts of bicarbonate ions, generated by seepage through calcareous strata, result in excessively old ^{14}C ages.

Table 3. *Suggested reliability of shell species from Lapita sites on the Rove Peninsula for radiocarbon dating.*

Taxa	Mode(s) of feeding	Reliability	Shells dated	
			No.	%
Anadara sp.	Suspension feeder	Medium/High	7	14.3
Atactodea striata	Deposit feeder	Low	1	2.0
Codakia sp.	Deposit feeder	Low	9	18.4
Conus sp.	Carnivore	Medium	1	2.0
Fimbria fimbriata[1]	Deposit feeder	Low	0	0.0
Gafrarium sp.	Suspension feeder	Medium/High	1	2.0
Hippopus hippopus	Suspension feeder	High	9	18.4
Strombus sp.	Omnivore	Medium	1	2.0
Tellinidae	Suspension feeder/Deposit feeder	Low	1	2.0
Tridacna sp.	Suspension feeder/symbiont	High	6	12.2
Trochus niloticus	Algae feeder	Medium	8	16.3
Turbo sp.	Herbivore	Medium	2	4.1
Vasum turbinellus[1]	Carnivore	Medium	0	0.0

Number and percentage of shells with **high** (or **medium/high**) reliability dated	23	46.9
Number and percentage of shells with **medium** reliability dated	13	24.4
Number and percentage of shells with **low** reliability dated	11	6.1

1. component of mixed sample

further research. If this is an issue, the results may date slightly too young.

Overall the evidence suggests that shells collected from along the Bourewa coastline, if erroneous, are more likely to date very slightly older because of the proximity of limestone bedrock. The only exception to this may be the Tridacninae but similarity between radiocarbon results on shellfish from a variety of species suggests it is unlikely to affect the results at the level of precision encountered at Bourewa.

RESULTS

Using all available prior information (stratigraphic and sample type data), the results of Model 2 give a mean age for the initial occupation at Bourewa of 2816 ± 25 calBP (2838–2787 calBP [68.2% prob.]; 2866–2771 calBP [95.4% prob.]) and the end of the sequence as 2654 ± 19 calBP (2675–2640 calBP [68.2% prob.]; 2689–2613 calBP [95.4% prob.]) (Figure 4a, b). From this model we are also able to establish that the most likely span of occupation at the Bourewa site was around 126–180 years (Figure 4c).

The overall agreement for Model 2 is acceptable (A_{model} = 144) suggesting this is a valid interpretation of the site given the available information. Our results show an average offset in the charcoals of 149 years (i.e. $10^{2.172}$) (Figure 4d) so, while the possibility remains that the Bourewa site has older occupation deposits, an offset of such a magnitude is in keeping with observations of inbuilt age at other tropical Pacific locales (Allen & Wallace 2007). These determinations supersede previous ones for Bourewa.

Radiocarbon dates for other Lapita sites on and just off the Rove Peninsula are so few (see Table 2) that it is difficult to assess site age independently of that of Bourewa. What is clear is that dates from Qoqo Island, Tomato Patch and Waikereira may be of comparable antiquity to Bourewa (see Figure 5).

DISCUSSION

We conclude that Bourewa was first occupied some time in the period 2838–2787 calBP (889–838 BC). This is younger than the interpretation of Clark and Anderson (2009b: 175) that Lapita colonisation of Fiji occurred in 3050–2950 calBP period, and the estimation by Denham *et al.* (2012) who placed Lapita arrival in Fiji at 3120–3010 calBP. Both evaluations were skewed by the incorporation of unidentified wood charcoal dates from Bourewa with inbuilt age.

Only a handful of early Lapita sites in Fiji have been radiocarbon dated (see Clark & Anderson 2009b [Tables 17 and 19]; Irwin *et al.* 2011; Burley 2012). Applying the same model protocols as outlined above for charcoals not identified to short-lived species, we obtain the following mean ages for initial occupation at the oldest sites[7]: Matanamua-

7 This evaluation excludes sites dated only by charcoal that has not been identified to short-lived species, including Sigatoka, Y2–25 and Y2–39 from Yasawa Island, and Vorovoro Island. Also excluded are any bone dates such as those from Naitabale.

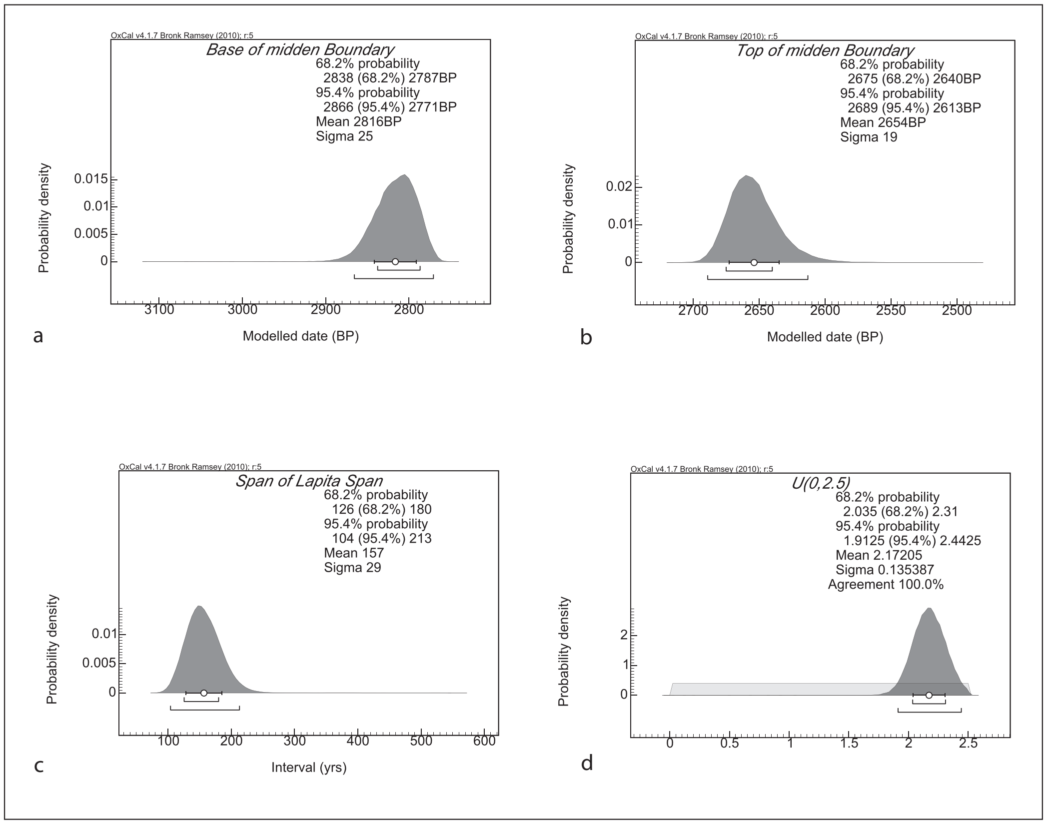

Figure 4. Results of outlier analysis (Model 2) of radiocarbon dates from the Lapita levels at Bourewa (see text for explanation): a – Age of the base of midden (initial Lapita occupation); b – Age of the top of the midden (last Lapita occupation); c – Span of occupation; d – The estimated inbuilt age (in powers of 10; i.e. $10^{2.172}$) for charcoal not identified to short-lived species (see Bronk Ramsey [2009] for explanation).

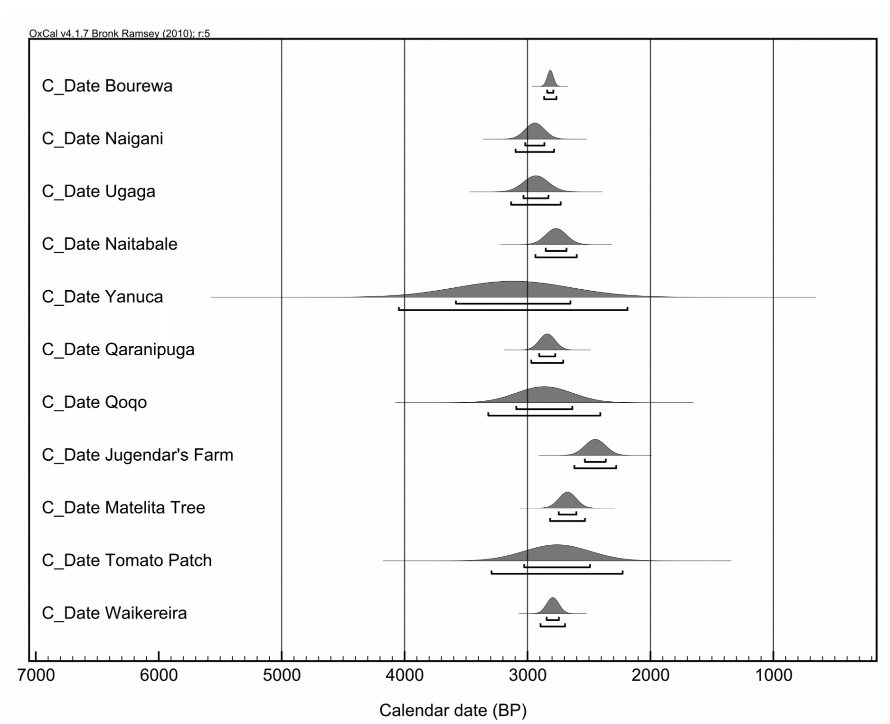

Figure 5. Earliest Lapita radiocarbon dates for Fiji (see text for explanation).

ni (VL 21/5) on Naigani Island (2941 ± 78 calBP); Ugaga on Beqa Island (2932 ± 101 calBP: based on 1 *Trochus* sp. date); Naitabale on Moturiki Island (2768 ± 84 calBP); Yanuca (Zone 3) in southwest Viti Levu Island (3117 ± 466 calBP)[8]; and Qaranipuga (Layer W) on Lakeba Island (2840 ± 65 calBP: based on 1 *Conus* sp. date) (Figure 5). The earliest deposits have not been reliably dated at Natunuku, a site with evidence of pottery typically associated with earlier Lapita occupations in Fiji (Clark & Anderson 2009b), so it is not represented here.

Many of these date estimates are based on a single shell date, including Ugaga which has a calibrated age that overlaps the oldest dates in the Fiji group, and cannot therefore be considered a robust test of site age. In addition, it is possible that the results from Qaranipuga and indeed many of the Rove Peninsula sites are influenced by hardwaters since these sites are located near limestone bedrock. Meaningful analysis of radiocarbon dates from Yanuca is limited by the large error in the modelled age.

Overall, these results place Bourewa within the earliest group of human presence in Fiji but the Matanamuani (VL 21/5) site on Naigani Island (Irwin *et al.* 2011) remains the earliest securely dated site in the Fiji archipelago. If the west-east colonisation of southwest Pacific Island groups was incremental, then colonization of Fiji at Matanamuani 3008–2866 calBP places it after Vanuatu to the west 3200–3000 calBP (1250–1050 BC–Bedford *et al.* 2006; Galipaud & Kelly 2007; Bedford & Spriggs 2008) and possibly slightly earlier than that of Tonga to the east 2850–2800 calBP (900–850 BC) (Burley *et al.* 2012). To confirm these colonization ages we recommend that all these regions undergo a similar radiocarbon age by site evaluation as that presented here for Fiji. We also recommend that researchers endeavour to date only short-lived twig charcoals and nuts, and that additional research is undertaken to identify regional and species-specific ^{14}C variations in shellfish.

CONCLUSIONS

This paper focuses on the 80 radiocarbon dates obtained for Bourewa and other Lapita-era sites on the Rove Peninsula in southwest Viti Levu Island, which is believed to have been the location of one of the earliest human occupations in the Fiji Islands group. This evaluation has demonstrated that there are interpretative risks involved in uncritically comparing the results of date analyses for such sites with the chronologies published for other Lapita-era sites.

In addition to the Fiji-specific implications of the research outlined above, it also demonstrates that there are grounds for re-evaluating the entire chronology of Lapita settlement in the western South Pacific using similar protocols. It would seem likely that the result of such an exercise would include (i) younger ages for commencing Lapita occupation throughout the Lapita realm and (ii) widespread reduction in the duration of the Lapita occupation at particular sites. The implications of such changes for the integrity of the Lapita culture as well as its role in underpinning subsequent cultural changes may be profound.

8 This excludes anomalously young dates (ANU-11415 and ANU-11413) as well as ANU-11414 a date of *Batissa violacea* – a species of shellfish that favours brackish water conditions removed from the ocean reservoir (Petchey et al, 2013), but includes the anomalously old charcoal date (Gak-1226) with charcoal outlier model applied.

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References

Allen, M.S. & Wallace, R. 2007. New evidence from the East Polynesian gateway: substantive and methodological results from Aitutaki, southern Cook Islands. *Radiocarbon,* 9: 1–17.

Anderson, A. 1991. The chronology of colonization in New Zealand, *Antiquity*, 65: 767–95.

Baron, J. & Clavier, J. 1992. Effects of environmental factors on the distribution of the edible bivalves *Atactodea striata, Gafrarium tumidum* and *Anadara scapha* on the coast of New Caledonia (SW Pacific). *Aquatic Living Resources*, 5: 107–14.

Bedford, S. & Spriggs, M. 2008. Northern Vanuatu as a Pacific crossroads: the archaeology of discovery, interaction, and the emergence of the 'ethnographic present'. *Asian Perspectives,* 47: 95–120.

Bedford, S., Spriggs, M. & Regenvanu, R. 2006. The Teouma Lapita site and the early human settlement of the Pacific Islands. *Antiquity,* 80: 812–28.

Beesley, P.L., Ross, G.J.B. & Wells, A. (eds.). 1998. *Mollusca: The Southern Synthesis. Fauna of Australia, vol. 5*. Melbourne: CSIRO Publishing.

Best, S. 1981. Excavations at Site VL 21/5, Naigani Island, Fiji: a preliminary report. Department of Anthropology, University of Auckland, 19p.

Bronk-Ramsey, C. 1995. Radiocarbon calibration and analysis of stratigraphy: the OxCal program. *Radiocarbon*, 37: 425–430.

Bronk-Ramsey, C. 2009. Dealing with outliers and offsets in radiocarbon dating. *Radiocarbon,* 51: 1023–45.

Bronk-Ramsey, C. 2012. OxCal Program v4.1.7. Radiocarbon Accelerator Unit, University of Oxford.

Burley, D.V. 2012. Exploration as a strategic process in the Lapita settlement of Fiji: the implications of Vorovoro Island. *Jour-*

nal of Pacific Archaeology, 3: 22–34.

Burley, D.V. & Dickinson, W.R. 2010. Among Polynesia's first pots. *Journal of Archaeological Science,* 37: 1020–26.

Burley, D., Weisler, M. I., & Zhao, J. X. (2012). High precision U/Th dating of first polynesian settlement. *PloS one*, 7: e48769.

Clark, G. & Anderson, A. 2001. The pattern of Lapita settlement in Fiji. *Archaeology in Oceania,* 36: 77–88.

Clark, G. & Anderson, A. (eds.) 2009a. *The Early Prehistory of Fiji*. Canberra: Australian National University Press.

Clark, G. & Anderson, A. 2009b. Site chronology and a review of radiocarbon dates from Fiji. In: G. Clark & A. Anderson (eds.) *The Early Prehistory of Fiji*. Canberra: Australian National University Press, pp. 153–82.

Davidson, J., Hinds, E., Holdaway, S. & Leach, F. 1990. The Lapita site of Natunuku, Fiji. *New Zealand Journal of Archaeology,* 12: 121–55.

Denham, T., Bronk Ramsey, C. & Specht, J. 2012. Dating the appearance of Lapita pottery in the Bismarck Archipelago and its dispersal to Remote Oceania. *Archaeology in Oceania*, 47: 39–46.

Ellis, S. 1999. Aquafarmer information sheet: lagoon farming of giant clams (Bivalvia: Tridacnidae). Centre for Tropical and Subtropical Aquaculture, Publication No. 139, Pohnpei, FSM (College of Micronesia, Land Grant College Program).

Galipaud, J-C. & Kelly, M.C.S. 2007. Makué (Aore Island, Santo, Vanuatu): a new Lapita site in the ambit of New Britain obsidian distribution. In: S. Bedford, C. Sand & S. Connaughton (eds.) *Oceanic Explorations: Lapita and Western Pacific Settlement.* Canberra: Australian National University Press (Terra Australis 26), pp. 151–62.

Geraghty, P.A. 1983. The history of the Fijian languages. *Oceanic Linguistics Special Publication* No. 19. Honolulu: University of Hawai'i Press.

Glover, E.A. & Taylor, J.D. 2007. Diversity of chemosymbiotic bivalves on coral reefs: Lucinidae (Mollusca, Bivalvia) of New Caledonia and Lifou. *Zoosystema*, 29: 109–81.

Hamel, J.F. & Mercier, A. 1996. The secret of the giant clam. *Freshwater and Marine Aquarium*, 19: 112.

Hart, A.M., Bell, J.D. & Foyle, T.P. 1998. Growth and survival of the giant clams, *Tridacna derasa*, *T. maxima* and *T. crocea*, at village farms in the Solomon Islands. *Aquaculture,* 165: 203–20.

Hogg, A.G., Higham, T.F.G. & Dahm, J. 1998. ^{14}C dating of modern marine and estuarine shellfish. *Radiocarbon,* 40: 975–84.

Irwin, G., Worthy, T.H., Best, S., Hawkins, S., Carpenter, J. & Matararaba, S. 2011. Further investigations at the Naigani Lapita site (VL 21/5), Fiji: excavation, radiocarbon dating and palaeofaunal extinction. *Journal of Pacific Archaeology,* 2: 66–78.

Lal, K.K. & Nunn, P.D. 2011. Holocene sea levels and coastal change, southwest Viti Levu Island, Fiji. *Australian Geographer,* 42: 41–51.

McCormac, F.G., Hogg, A.G., Blackwell, P.G., Buck, C.E., Higham, T.F.G. & Reimer, P.J. 2004. SHCal04 southern hemisphere calibration, 0–11.0 cal kyr BP. *Radiocarbon*, 46: 1087–1092.

Nunn, P.D. 2005. Reconstructing tropical paleoshorelines using archaeological data: examples from the Fiji Archipelago, southwest Pacific. *Journal of Coastal Research, Special Issue,* 42: 15–25.

Nunn, P.D. 2007. Echoes from a distance: progress report on research into the Lapita occupation of the Rove Peninsula, southwest Viti Levu Island, Fiji. In: S. Bedford, C. Sand & S. Connaughton (eds.) *Oceanic Explorations: Lapita and Western Pacific Settlement.* Canberra: Australian National University Press (Terra Australis 26), pp. 163–76.

Nunn, P.D. 2009. Geographical influences on settlement-location choices by initial colonizers: a case study of the Fiji Islands. *Geographical Research,* 47: 306–19.

Nunn, P.D. & Heorake, T.A. 2009. Understanding the place properly: palaeogeography of selected Lapita sites in the western tropical Pacific Islands and its implications. In: P.J. Sheppard, T. Thomas & G.R. Summerhayes (eds.) *Lapita: Ancestors and Descendants*. Auckland: New Zealand Archaeological Association (Monograph 28), pp. 235–54.

Nunn, P.D., Kumar, R., Matararaba, S., Ishimura, T., Seeto, J., Rayawa, S., Kuruyawa, S., Nasila, A., Oloni, B., Rati Ram, A., Saunivalu, P., Singh, P. & Tegu, E. 2004. Early Lapita settlement site at Bourewa, southwest Viti Levu Island, Fiji. *Archaeology in Oceania,* 39: 139–43.

Nunn, P.D., Matararaba, S., Kumar, R., Pene, C., Yuen, L. & Pastorizo, M.R. 2006. Lapita on an island in the mangroves? The earliest human occupation at Qoqo Island, southwest Viti Levu, Fiji. *Archaeology in New Zealand*, 49: 205–12.

Nunn, P.D., Ishimura, T., Dickinson, W.R., Katayama, K., Thomas, F., Kumar, R., Matararaba, S., Davidson, J. & Worthy, T. 2007. The Lapita occupation at Naitabale, Moturiki Island, central Fiji. *Asian Perspectives,* 46: 96–132.

Petchey, F. & Clark, G. 2011. Tongatapu hardwater: investigation into the ^{14}C marine reservoir offset in lagoon, reef and open ocean environments of a limestone island. *Quaternary Geochronology,* 6: 539–49.

Petchey, F., Anderson, A., Hogg, A. & Zondervan, A. 2008. The marine reservoir effect in the Southern Ocean: an evaluation of extant and new DR values and their application to archaeological chronologies. *Journal of the Royal Society of New Zealand,* 38: 243–62.

Petchey, F., Allen, M.S., Addison, D. & Anderson, A. 2009. Evidence of stability over time in the surface marine ^{14}C reservoir over the last 750 years in American Samoa, the Southern Cook Islands and the Marquesas. *Journal of Archaeological Science,* 36: 2234–43.

Petchey, F., Spriggs, M., Leach, F., Seed, M., Sand, C., Pietrusewsky, M. & Anderson, K. 2011. Testing the human factor: radiocarbon dating the first peoples of the South Pacific. *Journal of Archaeological Science,* 38, 29–44.

Petchey, F., Ulm, S., David, B., McNiven, I.J., Asmussen, B., Tomkins, H., Richards, T., Rowe, C., Leavesley, M., Mandui, H. and Stanisic, J. 2012. Radiocarbon marine reservoir variability in herbivores and deposit-feeding gastropods from an open coastline, Papua New Guinea. *Radiocarbon*, 54: 1–11.

Petchey, F., Ulm, S., David, B., McNiven, I.J., Asmussen, B., Tomkins, H., Dolby, N., Aplin, K., Richards, T., Rowe, C., Leavesley, M. & Mandui, H. 2013. High-resolution radiocarbon dating of marine materials in archaeological contexts: radiocarbon marine reservoir variability between *Anadara, Gafrarium, Batissa, Polymesoda* and *Echinoidea* at Caution Bay, Southern Coastal Papua New Guinea. *Archaeological and Anthropological Sciences*, 51: 69–80.

Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Burr, G.S., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hajdas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., McCormac, F.G., Manning, S.W., Reimer, R.W., Richards, D.A., Southon, J.R., Talamo, S., Turney, C.S.M., van der Plicht, J. & Weyhenmeyer, C.E. 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0–50 000 years calBP. *Radiocarbon,* 51: 1111–50.

Seeto, J., Nunn, P.D. & Sanjana, S. 2012. Human-mediated prehistoric marine extinction in the tropical Pacific? Understanding the presence of *Hippopus hippopus* (Linn. 1758) in ancient shell middens on the Rove Peninsula, southwest Viti Levu Island, Fiji. *Geoarchaeology*, 27: 2–17.

Specht, J. 2007. Small islands in the big picture: the formative period of Lapita in the Bismarck Archipelago. In: S. Bedford, C. Sand & S. Connaughton (eds.) *Oceanic Explorations: Lapita and Western Pacific Settlement.* Canberra: Australian National University Press (Terra Australis 26), pp. 51–70.

Spriggs, M. 1984. The Lapita cultural complex: origins, distribution, contemporaries and successors. *Journal of Pacific History,* 19: 202–223.

Spriggs, M. & Anderson, A. 1993. Late colonization of East Polynesia. *Antiquity,* 67: 200–17.

Szabó, K. 2010. Shell artefacts and shell-working within the Lapita Cultural Complex. *Journal of Pacific Archaeology,* 1: 115–27.

Szabó, K. & Amesbury, J. 2011. Molluscs in a world of islands: the use of shellfish as a food resource in the tropical island Asia-Pacific region. *Quaternary International,* 239: 8–18.

Thomas, F.R. 2007a. The behavioral ecology of shellfish gathering in western Kiribati, Micronesia. 1: Prey choice. *Human Ecology,* 35: 179–94.

Thomas, F.R. 2007b. The behavioral ecology of shellfish gathering in western Kiribati, Micronesia. 2: Patch choice, patch sampling, and risk. *Human Ecology,* 35: 515–26.