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New Radiocarbon Dates from the Bapot-1 Site in Saipan and Neolithic Dispersal by Stratified Diffusion

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ABSTRACT

The colonisation of the Mariana Islands in Western Micronesia is likely to represent an early ocean dispersal of more than 2000 km. Establishing the date of human arrival in the archipelago is important for modelling Neolithic expansion in Island Southeast Asia and the Pacific, particularly the role of long-distance dispersals. This paper presents new ^{14}C results and a ΔR estimate from the Bapot-1 site on Saipan Island, which indicate human arrival at *ca.* 3400–3200 cal. BP. Archaeological chronologies of long-distance dispersal to Western Micronesia and the Lapita expansion (Bismarcks to Samoa) show that the Neolithic dispersal rate was increasing during the period *ca.* 3400–2900 cal. BP. The range-versus-time relationship is similar to stratified diffusion whereby a period of relatively slow expansion is succeeded by long-distance movement. An increase in new colonies created by long-distance migrants results in accelerating range expansion.

Keywords: Colonisation, stratified diffusion, radiocarbon dating, Pacific

INTRODUCTION

Austronesian dispersal from Island Southeast Asia to Remote Oceania (southeast Solomons-Samoa) at *ca.* 4500–3000 cal. BP is widely held to result from the demic diffusion of agriculturalists (Grey and Jordan 2000; Fort 2002; Diamond & Bellwood 2003; Bellwood 2005; but see alternative views in Anderson 2003a; Oppenheimer 2004; Szabó & O'Connor 2004). The role of long-distance maritime movements in the settlement and colonisation of oceanic territory is difficult to determine, in part because the establishment of remote dispersal foci followed by demic expansion and the backfilling of unoccupied territory could be confused with wave-of-advance expansion (Cavalli-Sforza 2002). In this paper, we present new radiocarbon dates and ΔR values from the Unai Bapot-1 site on Saipan in the Commonwealth of the Northern Mariana Islands (Figure 1), and consider briefly whether the chronological evidence for long-distance human movement is consistent with Neolithic dispersal by stratified diffusion.

Theories of extra-range human dispersal in prehistory suggest that major expansions were facilitated by two basic dispersal strategies. In the first, the relatively rapid long-distance movement of early humans from Africa to Asia and Australia-New Guinea 70,000–50,000 years ago is thought to have used 'corridor' coastal/estuarine environments that provided migrants with predictable subsistence returns and required only limited economic and technological adaptations (Mellars 2006; Bulbeck 2007; Bailey 2008). In contrast, the Neolithic farming-technology hypothesis of dispersal by demic diffusion involved the incremental creation of predictable subsistence environments through agriculture, producing a 'wave-of-advance' or 'leading-edge' dispersal pattern (Ammerman & Cavalli-Sforza 1984; Sokal *et al.* 1991; Ackland *et al.* 2007; Pinhasi *et al.* 2009). The dispersal pathways that result from the two subsistence-mobility modes are potentially distinct, with rapid movement possible in environmental zones that offer the least resistance to range increase contrasted with slower rates of dispersal (but high population density) under agricultural expansion.

But the two types of movement are not necessarily exclusive (Ravenstein 1885; Anthony 1990), and the study of biological invasions emphasises the variety of dispersal pathways (Hengeveld 1988; Shaw 1995; Hastings *et al.* 2005; Nanthan 2005), including the significance of long-distance dispersals (Paradis *et al.* 2002; Wilson 2008). Stratified diffusion is the term used when short-distance dispersal and long-distance (jump) dispersal occur together, and it has been modelled as a two-stage process. First, the initial rate of expansion is conditioned by neighbourhood diffusion of a founding population. Second is a

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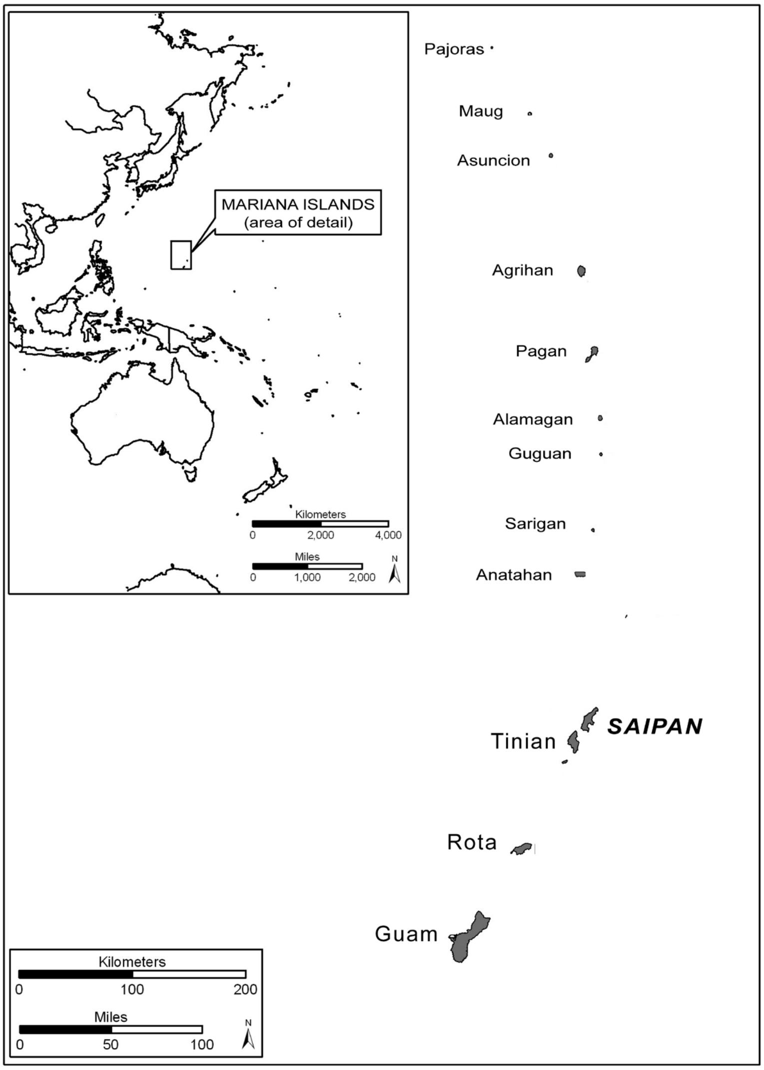

Figure 1. Location of the Mariana Islands and Saipan.

phase of rapid range expansion from the growth of colonies by long-distance migrants (Shigesada & Kawasaki 2001; Suarez *et al.* 2001). It follows that dispersal by stratified diffusion produces a nonlinear range-versus-time curve as a result of accelerated range expansion (Shigesada *et al.* 1995).

Applied to Austronesian expansion, stratified diffusion might be recognised by the establishment of farming groups in northern Island Southeast Asia, and their relatively slow expansion from demic growth linked to agricultural subsistence (high population density and low mobility). A second phase of long-range dispersal – including new colonised patches far from the resident range – with distant colonies initially sustained by a generalised subsistence strategy involving the harvesting of wild food resources (low population density and high mobility) is consistent with the model. The evidence for a long-distance dispersal phase can be examined in a preliminary fashion from Western Micronesia's archaeological record, particularly the antiquity of the region's oldest sites like that of Bapot-1 reported here.

Background

The Bapot-1 site (SP-1-0013) is located in the north of Laulau (Laolao, Magicienne) Bay on the east coast of Saipan (Figure 2), with archaeological deposits concentrated on a coastal sand plain bordered to the north by limestone terraces and outcrops of Pleistocene (Tanapag limestone) and Miocene (Tagpochau limestone) age (Dickinson 2000). The site is one of three locations east of the large Laulau site containing remains of *Latte* structures defined by worked limestone pillars and capstones, called Bapot-1, 2 and 3 by Spoehr (1957: Fig. 6; Figure 2). Behind and intruding into the limestones are rocks of the geologically diverse Hagman Formation, containing andesitic breccia, tuff, conglomerate and tuffaceous limestones (Carruth 2003; Reagan *et al.* 2008). Vegetation is

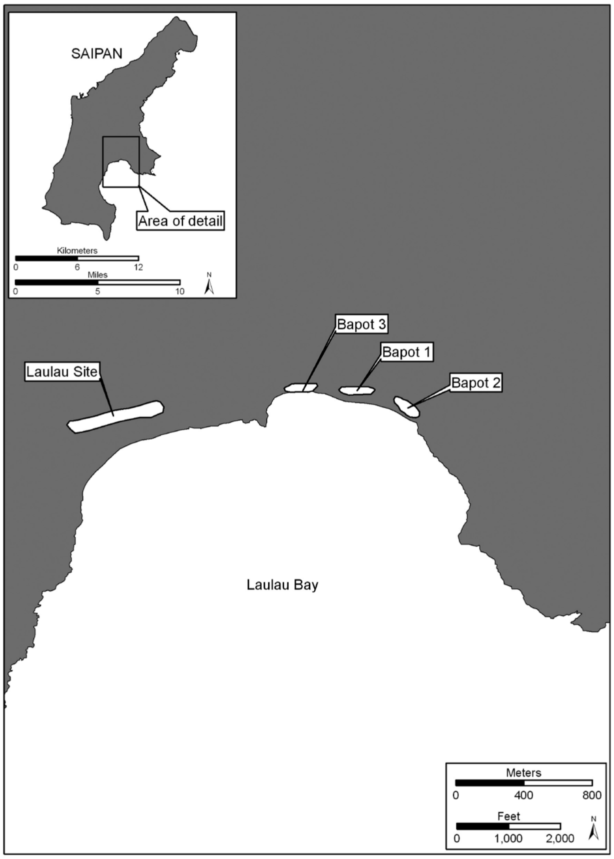

Figure 2. Laulau Bay and location of the Bapot-1 site.

characterised as mixed forest (*Acacia confusa*, *Cocos nucifera*, *Carica papya*, *Barringtonia asiatica*), with stands of introduced Tangantangan (*Leucaene leucocephala*) (Liu and Fischer 2006). Rainwater from the low-permeability upland volcanics forms small streams that in the wet season transport black volcanic sands to the coast where they form placer deposits. The Laulau Bay reef platform extends to a fringing reef around 100 m from the shore and contains echinoderms (Holothuriidae), marine shellfish (e.g. *Tridacna*, *Trochus*, *Conus*, *Lambis*, *Cyprea*, *Turbo*, *Conus*) and a variety of fish taxa, especially Acanthuridae, Labridae and Scardiae. Saipan did not experience forearc uplift as did Rota and northern Guam. Dickinson (2000, 2006) suggests that coastlines on Saipan expanded after a post-mid-Holocene drawdown in sea level estimated at 1.75 m, which is likely to have led to coastal progradation and the infilling of sheltered embayments colonised by mangroves (*Rhizophora*). Another effect of sea-level fall and mangrove stranding was the loss of quiet intertidal settings preferred by the gregarious bivalves *Anadara* cf. *antiquata* and *Gafrarium* sp., which were a popular prehistoric food source used by colonising groups in Remote Oceania (e.g. Clark *et al.* 2001). In early prehistoric sites in the Mariana Islands *Anadara* sp. and *Gafrarium* sp. are often the dominant shellfish species collected, while in prehistoric deposits post-dating sea-level fall, the main taxa is *Strombus* sp. (Amesbury *et al.* 1996), which favours rocky-intertidal settings.

Previous research in the Laulau region

Archaeological investigations of the Laulau area began in the 1920s with the recording of a rock-art site in a cave by Hans Hornbostel (Thompson 1932), and the site survey and subsurface investigations of Spoehr (1957: 52–58). Spoehr examined a *Latte* structure (Laulau House A) and a rock shelter containing lime-impressed pottery in its lower levels, which were overlain by extended and secondary burials and an upper cremation deposit. Excavations at Bapot-1 (SP-1-0013) were carried out in April-May 1977 by Jeffrey Marck, who excavated a 3 m x 3 m square between two *Latte* structures after initial test pits suggested the presence of an ancient occupation (Figure 3). The main excavation (Squares K-M: 36–38) was taken down to sterile beach sands at 1.9 m to 2.2 m below surface, with two dates on charcoal from an oven filled with refuse debris that was cut into a sterile beach deposit. Marck (1978) reported pottery, stone flakes, adzes, shell ornaments and fish hooks. The pottery sequence began with carinated (shouldered) 'redware' jars with sharply everted rims, which gradually became less everted and were followed by 'transitional' plainware ceramics associated with tray/bowl vessels forms. Late prehistoric ceramics were distinguished by bowls with abruptly thickened rim profiles.

Ross Cordy (1979) conducted surface survey of the coastal plain in the Bapot area, and Graeme Ward and John Craib excavated Bapot-1 in 1985 under contract to the Historic Preservation Office (CNMI). The investigations collected stratigraphic information over the site in an extensive program of test pitting and excavation. Based on test-pit results, the site has an area of some 12,000 sq. m from the southern margins of the coastal plain inland to the elevated limestone ridge. The investigation of the oldest deposit was by a 1 m x 2 m test pit (Bapot-1/85), with excavation reduced to a 1 m x 1 m square at 1.95 m below datum. Bapot-1/85 was located just south of a long east-west aligned test trench and Marck's 3 m x 3 m excavation (Figure 3). Cultural material (pottery, adzes, flakes, shell ornaments, fish hooks) was infrequent below 3 m depth. Occasional marine bivalves and charcoal fragments were reported at 3.5 m depth, unlike Marck's (1978) excavation where prehistoric material did not occur below 1.9–2.2 m depth. Six radiocarbon results on *Anadara antiquata* were obtained for the deposit (Bonhomme & Craib 1987; Table 1), and megascopic observation of mineral grains showed that calcareous sand (CST) was the dominant temper in the earlier redware ceramics (3.1 m to 1.1 m depth), and volcanic sand temper (VST) and mixed (CST+VST) temper dominated ceramics from the upper levels (Ward 1985).

Additional survey and testing in the Bapot-1 area was made by Michael Graves during 1986–1987 and Richard Olmo in 1992, with the most recent investigations by Mike

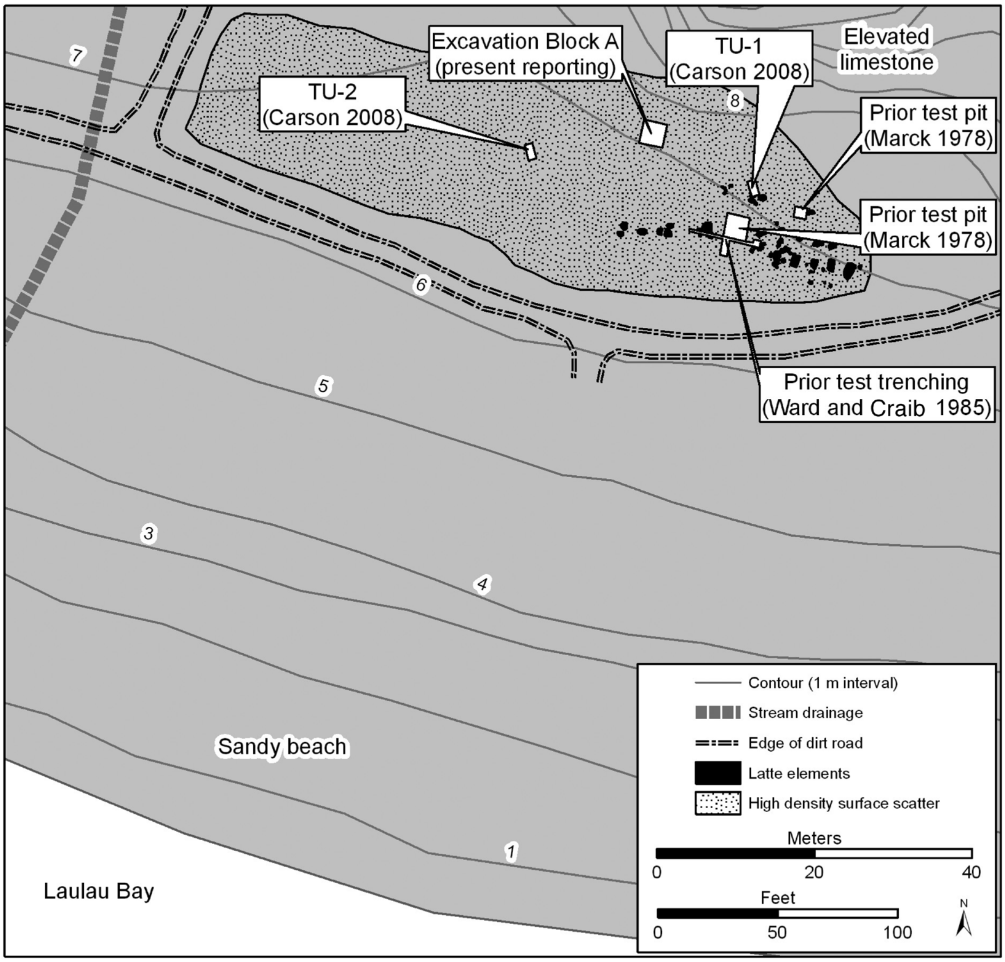

Figure 3. Location of excavations at Bapot-1 made by Marck (1978), Ward (1985), Carson (2008) and the position of the Block A investigation.

Carson (Carson & Welch 2005; Carson 2008), who excavated two 1 m x 2 m test units (TU-1, TU-2) to the east and west of the *Latte* structures where previous excavations by Marck and Ward were located (Figure 3). The cultural deposit in both units extended to *ca.* 2.2 m depth and contained a diverse ceramic assemblage of redware, tool-marked redware, blackware and plainwares. Three ^{14}C results on charcoal (1) and burned *Anadara* sp. shell (2) were obtained, with the oldest shell dates suggesting occupation at 3500 cal. BP (Table 1).

The 2008 Unai Bapot excavation

The antiquity and richness of the early Bapot-1 deposit revealed by Carson's test units prompted excavation in 2008 of a 3 m x 3 m unit called Block A to obtain a larger sample of the oldest deposit for material culture and chronological analysis. Block A was located on the 7 m contour north of the *Latte* remains between units TU-1 and TU-2 (Figure 3). Excavation was by 10 cm levels within natural layers, with all sediment screened through 2 mm mesh and subsamples from each 10 cm layer screened through *ca.* 0.5 mm mesh to check that small elements were not being lost in the 2 mm sieve fraction. In the lowest levels of Block A the calcareous sands were compact and cemented and required hand tools to break apart sediments for sieving and the collection of artefactual remains. Layer stratigraphy was mainly horizontal, but was interrupted by natural pits and intrusive features (tree roots, crab burrows) and prehistoric activity (post holes, fire pits, burials, cache deposits). Depth measurements were taken from a levelled string line *ca.* 20 cm above the ground surface, but all depths are reported here with the ground level set at 0 cm (northwest corner Unit 1) to allow comparison with previous investigations.

Block A, north wall stratigraphy (Figure 4)

Layer I. Very dark brown (10YR 2/2) hard-packed silty calcareous soil with tree roots and fragments of eroded limestone. *Latte*-style pottery with medium-thick plain sherds and abruptly thickened rims with small quantities

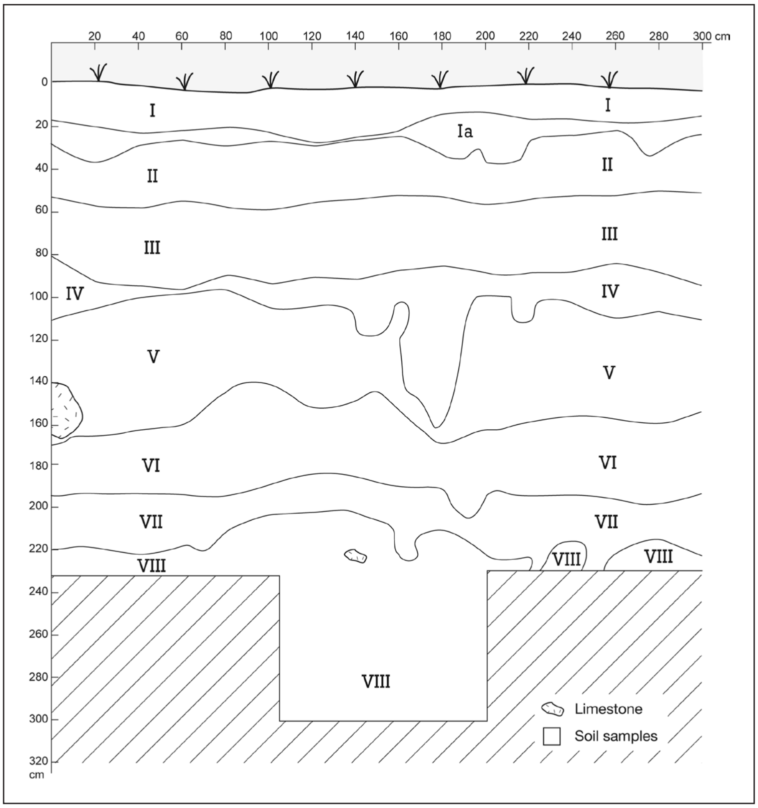

Figure 4. Bapot-1, Block A stratigraphy, north face (see text for layer descriptions).

of fragmented marine shell and fishbone. Material of recent age included modern bottle glass, WWII shrapnel and a few pieces of vulcanised rubber. Marck (1978:18) recovered American bullet casings from a subsurface fire pit near the *Latte* remains.

Layer Ia. Grey (10YR 4/4) loose sandy soil. *Latte*-style pottery, along with a few eroded thin red pot sherds that might represent older ceramics that have been mixed with late prehistoric ceramics. No modern artefacts were recovered.

Layer II. Light pale-yellow (7.5YR 6/4) loose aeolian beach sand with little silt. A few sherds of thick-walled red-slipped pottery, sparse chert flakes, marine-shell fragments (especially *Turbo* sp.) and occasional bones of fish, reptile and mammal (mouse/rat).

Layer III. Medium brown silty sand (7.5YR 4/4). In the lower part (110 cm depth) the sand was partially cemented. Increasing quantities of thick-walled red-slipped pottery, including a dense concentration of sherds in Unit 6, along with a few sherds of thin red and black pottery and stone and shell artefacts (basalt-andesite flakes, *Tridacna* adze, shell beads and fragments of pearl shell (*Isognomon*) fish hooks). A human burial was found in the southeast corner of Unit 9 at 70–80 cm depth. The remains were left *in situ* and no further excavations were made in the unit.

Layer IV. Medium brown-yellow (10YR 5/4) silty calcareous sand. The upper part of the layer produced large amounts of thick-walled ceramics (20–55 mm thick) with a heavy red slip from flat-based trays/platters (see Hunter-Anderson & Butler 1995:Figure 9; cf. Carson 2008:Figure 5). From 130 cm to 140 cm and below, the amount of thin red-slipped pottery (2–3 mm thick), known locally as 'Marianas redware', increased, including several tool-stamped pieces at 140 cm. Other artefacts included stone adzes and flakes, as well as shell ornaments, mainly small diameter ?*Conus* sp. shell rings and ground *Cyprea* sp. beads.

Layer V. Yellowish brown partially cemented coarse sand (7.5YR 5/6) in the upper part of the layer and coarse calcareous sand with pockets of cemented sand at layer base. Thin red-slipped pottery from small-medium diameter carinated jars, including concentrations of *in situ* base sherds and shell artefacts (rings/beads), shell fish hook fragments and stone adzes, including a large sub-lenticular volcanic specimen *ca.* 20 cm long and 10 cm wide. Flecks of charcoal were common in the sediment, with larger fragments and *in situ* concentrations indicating shallow fire pits/hearths.

Layer VI. Dark brown (7.5YR 4/3) silty calcareous sand with areas of cemented sand. The layer contained stone artefacts (adzes and flakes) and the southwest corner of

Unit 7 contained a cache of three adzes made in an altered tuff. The layer also had large quantities of thin red-slipped pottery with some sherds less than 2 mm thick, along with shell artefacts (shell rings/beads fish hooks). The faunal remains included bone from bird and fish, in association with dispersed shellfish remains of *Anadara* sp.

Layer VII. Orange-brown (5YR 4/6) hard-packed cemented silty sand. The basal cultural deposit contained similar artefacts (ceramics and shell ornaments) to those in Layer VI. Stone tools were made in a variety of materials (basalt-andesite, altered tuff, chert, quartz/calcite), and faunal remains included abundant bird bone from a rail (*Gallirallus* cf. *philippensis*).The stratigraphic difference between Layers VI and VII was largely due to the orange-red colour of the Layer VII sediment, which was probably caused by incorporation of clay-silts into the calcareous beach sediments and high levels of anthropogenic burning.

Layer VIII. Very pale-yellow coarse calcareous sand (10YR 7/4) compact, cemented and devoid of cultural material. In Unit 2, a 0.5 m by 1 m pit was dug down to 300 cm without encountering prehistoric remains (Figure 4).

Radiocarbon data

All radiocarbon dates, including those from previous excavations at Bapot-1, are presented in Table 1. Marine samples were calibrated using the Marine04 curve of Hughen *et al.* (2004) and terrestrial samples were calibrated using Intcal04 (Reimer *et al.* 2004). All radiocarbon determinations were calibrated using the OxCal program v3.10 (Bronk-Ramsey 2005). We compare calibrated age ranges at 68.2% probability within the stratigraphic sequence as this provides calibrated resolution that is lost when comparing age ranges at 95.4% probability (Table 1, Figure 5). Where possible, we have tried to demonstrate that dates from previous excavations are contemporaneous with the new data presented here, using depth and cultural assemblage information. Dates excluded from further analysis because available contextual information is out of synchrony with the most recent excavation include: ANU-4770, ANU-4767, ANU-4772, ANU-4769, and ANU-4771. Retained is ANU-4768, as the charcoal sample came from excavation levels containing the primary deposit of early CST redware ceramics (150–250 cm), whereas other samples came from levels with VST and mixed CST+VST pottery, or from levels with only small quantities of early redware (Ward 1985; Bonhomme & Craib 1987).

Also excluded is Wk-25210 from Layer VII of Block A because we suspect it is natural shell, although it could be shell midden from an earlier occupation. The existence of an older intact cultural deposit dated by Wk-25210 was not detected in either the material-culture assemblage nor the stratigraphy of the basal levels, and the determination is suspect as it is adrift from other results on samples from the same depth. Wk-23753 was from Unit 7 where a large disturbance feature in the south wall, probably an old tree root or pit feature, may have displaced the charcoal sample, and it has been removed from further consideration. Beta-202744 and Beta-216616 are both burned *Anadara* shells (Carson 2008: 132). Although we are not aware of any published research investigating carbon exchange between combustion environment and shells, there is sufficient circumstantial evidence from cremated bone experiments (Hüls *et al.* n.d.) to suggest caution when dealing with samples that may have been burnt in contact with limestone substrates, either bedrock, or in the case of Block A, limesands.

From Table 1 it is apparent that the upper 80 cm of the deposits are younger than *ca.* 2000 BP. Between 100 cm and 140 cm three dates on unidentified wood charcoal provide a combined age range of 2300–2250 and 2160–2140 cal BP at 68.2% probability. The lower deposits contain culturally similar materials, but charcoal and marine-shell dates show some variability that could attributed either to sample specific effects (e.g. charcoal inbuilt age, shell dietary habits, marine reservoir variability, heirloom effects), or minor disturbance by humans between separate episodes of habitation. These possibilities are discussed in more detail below.

ΔR calculation

The accurate calibration of shell dates requires an understanding of the geographical variability in the surface ocean marine ^{14}C reservoir that is caused by variations in upwelling, ocean currents, and climate (Stuiver & Braziunas 1993), as well as an understanding of the habitat and dietary preferences of different shellfish species (Tanaka *et al.* 1986; Hogg *et al.* 1998). A reservoir correction factor, commonly called a ΔR, is used to account for local marine ^{14}C variation. The marine ΔR is the difference between the global average modelled marine reservoir and the actual ^{14}C activity of the surface ocean at a particular location (Stuiver *et al.* 1986). The most common methods of determining ΔR use known-age shells collected before atmospheric bomb testing, or terrestrial and marine ^{14}C samples excavated from archaeological sites (e.g. Petchey *et al.* 2008; Petchey *et al.* 2009). In both cases, it is essential that the age of shellfish death is known. For archaeological ΔR this is determined by dating short-lived charcoal from contemporaneous contexts (commonly referred to as shell/charcoal or marine/terrestrial pairs) (Stuiver & Braziunas 1993), and selection of food shells to avoid possible heirloom effects.

Charcoals were examined by Petchey, with samples identified as from short-lived 'nutshell' or 'unidentified' wood species of unknown inbuilt age. Identification of charcoal to twigs of short-lived species or nuts is essential for ΔR research because inbuilt age may result in large offsets when interpreting ^{14}C results (Petchey *et al.* 2009). Of

Table 1. *Bapot-1 site radiocarbon dates (see text for details and acceptance/rejection criteria). In the 'Sample' column, 'FF'=Filter feeder, 'H'=Herbivore and 'C'= Carnivore.*

Lab. No.	**CRA**	**$\delta^{13}C$ (± 0.2‰)**	**cal. BP (68.2% probability)**	**Sample**	**Depth**	**Reference**
Wk-23750	1386 ± 30	−22.6 ± 0.2	1320–1280	?Coconut shell	Area 2, Unit 8: 30–40 cm	new data
Wk-23751	1581 ± 35	−23.4 ± 0.2	1520–1410	Nut shell cf. *Cocos nucifera*	Area 2, Unit 4: 50–60 cm	new data
Wk-23752	2043 ± 30	−24.3 ± 0.2	2045–1945	Unid. charcoal	Area 2, Unit 2: 70–80 cm	new data
Wk-23754	2189 ± 30	−24.5 ± 0.2	2310–2230 & 2190–2140	Unid. charcoal	Area 2, Unit 2: 100–110 cm	new data
Wk-23755	2168 ± 32	−27.9 ± 0.2	2310–2240 & 2180–2120	Unid. charcoal	Area 2, Unit 8: 130–140 cm	new data
Wk-23756	2175 ± 30	−25.7 ± 0.2	2310–2240 & 2180–2130	Unid. charcoal	Area 2, Unit 5: 130–140 cm	new data
Wk-23757	2907 ± 32	−25.1 ± 0.2	3140–3130, 3110–3090 & 3080–2970	Unid. charcoal	Area 2, Unit 7: 150–160 cm	new data
Beta-214761	2850 ± 40	−25.8	3060–3050 & 3030–2880	Unid. charcoal	TU-2, Layer IIIA: 140–160 cm	Carson (2008)
ANU 4768	3210 ± 80	na	3150–2910	*Anadara antiquata* (FF)	Test pit (1m x 2 m): 170–190 cm	Bonhomme & Craib (1987)
Wk-23760	2866 ± 32	−25.3 ± 0.2	3070–2940	Unid. charcoal	Area 2, Unit 5: 180–190 cm	new data
Wk-23761	2922 ± 30	−24.6 ± 0.2	3150–3000	Unid. charcoal	Area 2, Unit 8: 190–200 cm	new data
UCR 649	2890 ± 100	na	3210–3180, 3170–2920 & 2910–2880	Unid. charcoal	Squares K-L 37–38: 190–220 cm	Marck (1978); Bonhomme & Craib (1987)
UCR 650	2910 ± 100	na	3220–2920	Unid. charcoal	Squares K-L 37–38: 190–220 cm	Marck (1978); Bonhomme & Craib (1987)
Wk-23763	2904 ± 30	−21.8 ± 0.2	3080–2970	Nut shell	Area 2, Unit 3: 200–210 cm	new data
Wk-23764	2910 ± 30	−25.1 ± 0.2	3140–3120, 3110–3090 & 3080–2980	Unid. charcoal	Area 2, Unit 2: 210–220 cm	new data
Wk-23765	2900 ± 30	−25.5 ± 0.2	3080–2970	Unid. charcoal	Area 2, Unit 2: 210–220 cm	new data
Wk-23769	3355 ± 30	1.9 ± 0.2	3290–3170	*Cyprea* sp. (H) artefact	Area 2, Unit 1: 210–220 cm	new data
Wk-23770	3192 ± 30	2.1 ± 0.2	3060–2930	*Cyprea tigris* (H) artefact	Area 2, Unit 1: 210–220 cm	new data
Wk-23766	3013 ± 30	−25.5 ± 0.2	3320–3290 & 3270–3160	Unid. charcoal	Area 2, Unit 5: 220–230 cm	new data
Wk-23771	3182 ± 30	0.6 ± 0.2	3040–2920	*Conus* sp. (C) artefact	Area 2, Unit 4: 220–230 cm	new data
Wk-23767	3010 ± 30	−28.1 ± 0.2	3320–3300 & 3270–3160	Unid. charcoal	Area 2, Unit 1: 230–240 cm	new data
Wk-23768	2908 ± 30	−24.9 ± 0.2	3140–3130, 3110–3090 & 3080–2970	Unid. charcoal	Area 2, Unit 4: 230–240 cm	new data

Table 1. *Continued*

Lab. No.	CRA	$\delta^{13}C$ (± 0.2‰)	cal. BP (68.2% probability)	Sample	Depth	Reference
Rejected dates						
ANU 4771	1040 ± 110	na	690–510	*Anadara antiquata* (FF)	Test pit (1 m x 2 m): 40–50 cm	Bonhomme & Craib (1987)
ANU 4770	2880 ± 90	na	2790–2460	*Anadara antiquata* (FF)	Test pit (1m x 2 m): 90–100 cm	Bonhomme & Craib (1987)
Wk-23753	2386 ± 30	−25.9 ± 0.2	2460–2380 & 2370–2340	Unid. charcoal	Area 2, Unit 7: 100–110 cm	new data
ANU 4767	3040 ± 110	na	3040–2690	*Anadara antiquata* (FF)	Test pit (1m x 2 m): 100–110 cm	Bonhomme & Craib (1987)
ANU 4772	3050 ±110	na	3050–2700	*Anadara antiquata* (FF)	Test pit (1m x 2 m): 135–155 cm	Bonhomme & Craib (1987)
Beta-202744	3590 ± 40	−1.5	3620–3380	*Anadara* sp. (FF)	TU2, Layer IV-A: 200–220 cm	Carson (2008)
Beta-216616	3710 ± 50	−1.1	3810–3530	*Anadara* sp. (FF)	TU2, Layer IV-A: 200–220 cm	Carson (2008)
Wk-25210	3484 ± 35	−0.7 ± 0.2	3500–3260	*Anadara* sp. (FF)	Area 2, Unit 2: 230–240 cm	new data
ANU 4769	3490 ± 110	na	3570–3220	*Anadara antiquata* (FF)	Test pit (1 m x 1 m): 310–330 cm	Bonhomme & Craib (1987)

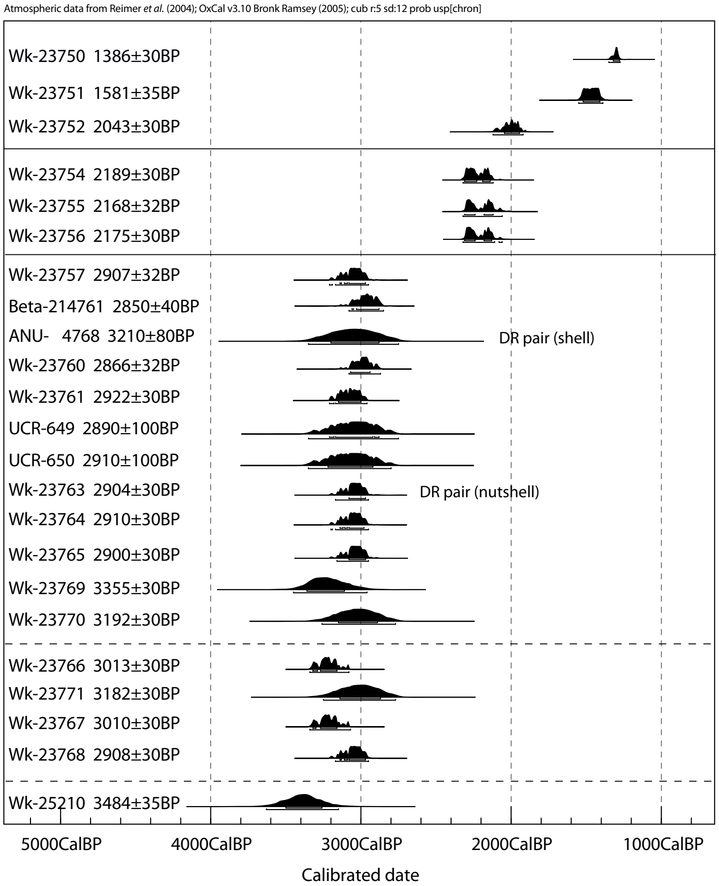

Figure 5. Radiocarbon dates from Bapot-1 arranged by depth (see Table 1 for details). Note that Wk-25210 was rejected (Table 1) because we could not determine if the sample was midden shell or had been naturally deposited. It is included in the figure as it might represent midden from an earlier occupation.

the charcoal dates, only three are identified to short-lived nutshell charcoal (Wk-23750, Wk-23751 and Wk-23763), but only Wk-23763 from below 150 cm is associated with shell dates. More detailed identification of wood charcoals and the sample growth position is clearly needed to refine our site chronology, but this work was not attempted in the current study because no readily available reference collections were available. Of the three shell dates associated with the 150–220 cm deposit (ANU-4768, Wk-23769 and Wk-23770), only sample ANU-4768 is *Anadara* sp., a recognised food shell. Distinctive shell artefacts made in the shell of the herbivore *Cyprea* sp. (Wk-23769 and Wk-23770) were dated because they represented an artefact type that was not found above 210 cm depth, while a *Conus* sp. (carnivore) shell ring came from the deepest cultural deposit (Wk-23771). It is important to note that selection of dating samples was made to answer archaeological questions, and the Bapot-1 radiocarbon results have been used to estimate ΔR because of the small number of prehistoric sites in the Mariana Islands with shell-charcoal radiocarbon pairs. Thus, the two *Cyprea* sp. shells are both ornaments that could have been stored or transported some distance and are from herbivorous species that can ingest particulate carbonates. Either of these possibilities could result in the disproportionate ΔR offsets calculated (Table 2).

Using the nutshell charcoal (Wk-23763) and *Anadara* sp. shell (ANU-4768), we obtain a most probable ΔR value of –16 ± 87 ^{14}C yrs for the deposits between 150 cm and 220 cm depth (Table 2). The combined value for all charcoals from these deposits are indistinguishable ($\chi^2_{8:\,0.05} = 0.206<5.991$), suggesting minimal inbuilt age for the unidentified samples.

Below 220 cm there is significant variability in the radiocarbon data that results in two possible ΔR interpretations for shell sample Wk-23771 (Table 2): –162 ± 47 ^{14}C yrs and –13 ± 70 ^{14}C yrs. It is impossible for both values to be correct. One possible cause for this discrepancy is inbuilt age in the charcoal. Although we have already indicated that there is insignificant inbuilt age in unidentified charcoal samples from the upper deposits, older wood sources are more commonly available to the first inhabitants occupying coastal sites (R. Wallace, pers. comm., June 2009). The pairing of charcoal with a degree of inbuilt age and marine shell would result in a more negative ΔR result. A marine reservoir offset is less likely to be implicated in this instance because the discrepancy in calibrated ages is not specific to the shell dates (compare Wk-23767/Wk-23766 and Wk-23768). Alternatively, continual human reoccupation of the same site may have resulted in mixing of cultural remains from an earlier, but culturally similar, occupation event. However, given the similarity of –13 ± 70 ^{14}C yrs to the ΔR outlined above, we have calibrated all shell results using the value of –16 ± 87 ^{14}C yrs (Figure 5). The combined calibrated age range for deposits between 150 cm and 220 cm is 3065–3000 BP at 1σ (excluding artefactual shell dates Wk-23769 and Wk-23770) ($\chi^2_{9:\,0.05} = 2.799<16.919$). The basal deposits below 220 cm depth appear to date to 3360–3110 cal BP at 1σ, and this value is within statistics ($\chi^2_{3:\,0.05} = 7.251<7.815$). However, sev-

Table 2. *Bapot-1 ΔR results for contemporaneous charcoal/shell pairs.*

Sample material	^{14}C age and error (BP) [Rs(t)]	Pooled values (χ^2 test)	Marine modelled age [Rg(t)]	ΔR (yrs) [Rs(t)–[Rg(t)]**	Lab. No.	Comment
ΔR calculations for deposits above 220cm						
Nutshell charcoal	2904 ± 30	–	3226 ± 33	–16 ± 87	Wk–23763	Meets ΔR protocol
Anadara sp.	3210 ± 80	–	–		ANU–4768	
Cyprea sp. (artefact)	3355 ± 30	–	–	129 ± 45	Wk–23769	Possible heirloom or dietary offset ?
Cyprea sp. (artefact)	3192 ± 30	–	–	–34 ± 45	Wk–23770	Possible heirloom or dietary offset ?
ΔR calculations for deposits below 220cm						
Unid. charcoal	3010 ± 30	3012 ± 21 ($\chi^2_{2:0.05}$ = 0.01<3.84)	3345± 37	–162 ± 47	Wk–23767	Inbuilt age ?
Unid. charcoal	3013 ± 30				Wk–23766	
Conus sp.	3182 ± 30	–	–		Wk–23771	
or						
Unid. charcoal	2908 ± 30	–	3196± 63	–13 ± 70	Wk–23768	Inbuilt age ?
Conus sp.	3182 ± 30	–	–		Wk–23771	

** The ΔR for a specific location '(s)' is calculated using the formula: Rs(t) – Rg(t) = ΔR(s), where (ΔR(s)) is the difference between the global average (Rg(t)) and the actual ^{14}C activity of the surface ocean at a particular location (Rs(t)) at that time. (Stuiver *et al.* 1986). ΔR calculations from archaeological terrestrial/marine pairs as per Ulm (2002).

eral older calibrated ages on shell that we have rejected as being naturally deposited, but which might be midden debris (Wk-25210 and ANU-4769), remain tantalising evidence of possible earlier occupation at Bapot-1. Considering the uncertainty about the age of the oldest levels at Bapot-1, a range of 3400–3200 cal. BP is plausible, although we acknowledge that the site may date to 3300–3100 cal. BP (see Clark 2004). Additional work focusing on the dating of identified wood charcoals combined with the development of a Bayesian chronology for the deposits (cf. Baylis 2009) by the authors should help to refine the chronology of Bapot-1.

Discussion and Conclusion

Colonisation of the Mariana Islands is usually placed at *ca.* 3500 cal. BP (Rainbird 2004: 81), but there are relatively few early sites in the archipelago that are adequately radiocarbon dated (Clark 2004), and the purpose of the 2008 excavations at Bapot-1 was to analyse multiple samples of marine shell and charcoal to determine the age of the oldest cultural deposit. Radiocarbon results from previous excavations indicated, variously, site use at 3000 cal. BP (Bonhomme & Craib 1987), 3200–3000 cal. BP (Marck 1978), and *ca.* 3500 cal. BP (Carson 2008), yet the age estimates were based on relatively few ^{14}C dates and there was no firm ΔR value to apply to marine shell-determinations. The 20 new radiocarbon results from Block A indicate that the oldest Bapot-1 deposit probably dates to *ca.* 3400–3200 cal. BP, and we suggest a modest ΔR value is appropriate for calibrating shell results from the site.

Elsewhere in the Mariana Islands, the only comparable well-dated site is Unai Chulu on Tinian, where excavation of a 12 m x 12 m area recovered abundant remains from an occupation dated by 31 ^{14}C determinations (Haun *et al.* 1999). The oldest age results were three charcoal dates with CRAS of 3120–3100 BP (Beta-81946, Beta-81952, Beta 81948) with a pooled 95.4% probability age range of 3250–3400 cal. BP. Five charcoal results with CRAS of 3080–3040 BP (Beta-83213, Beta-81951, Beta-81947, Beta-81954, Beta-81955) have a pooled 95.4% probability age range of 3220–3360 cal. BP. There is some question about the oldest determinations, as Beta-81948 came from an earth oven containing charcoal identified to *Ficus* sp. (Murakami in Haun *et al.* 1999:Apendix H). *Ficus* sp. is a relatively long-lived strandline taxa and charcoal from it could contain moderate inbuilt age. Nonetheless, the oldest levels of Unai Chulu and Bapot-1 appear to date to *ca.* 3400–3200 cal. BP, and their oldest cultural deposits contain similar ceramics, large amounts of bird bone from rails, and lithic assemblages made in a variety of materials (Haun *et al.* 1999: 95–96, 101).

Setting 3500 cal. BP for human arrival in the Mariana Islands is significant, as the dispersal predates Lapita expansion, and the carinated red-slipped ceramics (some with simple tool-impressed markings) from sites like Bapot-1 are a plausible precursor for the complex dentate-stamped pottery vessels synonymous with Lapita dispersal from the Bismarck Archipelago to Samoa (Craib 1999; Bellwood 2005). The age of Lapita sites in the West Pacific has recently been revised from 3300 cal. BP (Specht & Gosden 1997) to 3450–3350 cal. BP (Specht 2007), but some researchers are doubtful that Lapita ceramics date older than 3300 cal. BP (Summerhayes 2007: 145).

The dating of Unai Chulu and Bapot-1 suggests that colonisation of the Mariana Islands and initial Lapita occupation of the Bismarcks could have taken place in the interval 3400–3200 cal. BP, but differences in their material culture and domesticate assemblages do not support a direct dispersal sequence starting with a movement from Island Southeast Asia to the Mariana Islands, followed by a migration from the Mariana Islands to the Bismarck Archipelago. For example, early remains of the domestic pig do not occur in the Mariana Islands, yet pig bone is found in early Lapita sites in the Bismarck Archipelago (Summerhayes 2007: 148; Anderson 2008). The possible pre-Lapita ceramics at the ECA site (Talepakemalai) on Eloaua Island consisting of large red-slipped jars with everted rims (Specht 2007) appear on available information to differ from the small-medium carinated jars found in early deposits in the Mariana Islands. A detailed comparison of the oldest ceramics from the Indo-Pacific region is a research priority, and it is the topic of PhD research by Winter.

An alternative to linear dispersal is stratified diffusion (Figure 6) in which a period of negligible dispersal (establishment phase) is succeeded by relatively slow expansion, and then a phase of long-distance movement (expansion phase), during which new colonies created by long-distance migrants increase in number and cause accelerating range expansion until the limits of geographical range expansion are reached (saturation phase). In biological invasions, a relatively slow rate of initial expansion can be due to the invaders being ill-adapted to the new environment, or a result of the colonisers' offspring, under low population density, preferentially settling in the neighbourhood range of the parent population. Improved transport systems can increase the dispersal rate. Developments in canoe technology and the onset of weather patterns that might have facilitated long-distance voyaging have been linked in the Indo-Pacific to an increasing rate of Neolithic expansion (Anderson 2003b; Anderson *et al.* 2006). The non-linear range-versus-time curves of expansion by stratified diffusion have been related mathematically to 1) the production of moderate-distance migrants at the periphery of the range, and 2) a number of long-distance dispersers that is proportional to the range area (Shigesada *et al.* 1995; Bowman *et al.* 2002). The latter suggests that the social, economic and demographic conditions favouring long-distance dispersal are more likely to develop when the early phase of expansion takes in a large range. This is feasible in the case of expansion to highly insular

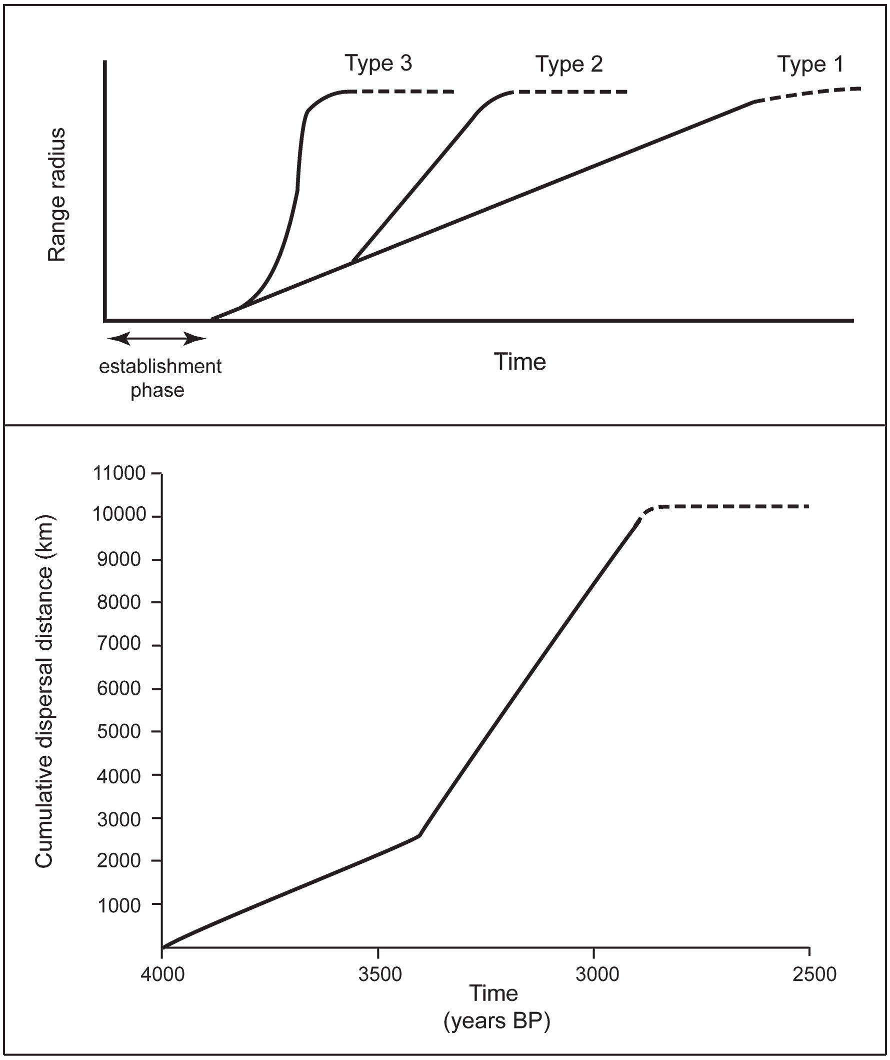

Figure 6. *Top*. Three types of range-versus-time curve (from Shigesada *et al*. 1995: Fig.4) with range expansion divided into three phases: Establishment phase (arrow); Expansion phase (solid line) and Saturation phase (dashed line). The Expansion phase is classified into three types. Type 1 shows linear expansion, Type 2 exhibits biphasic expansion with an initial slow slope followed by a steep line slope typical of stratified diffusion, and in Type 3 the rate of expansion continually increases with time. *Bottom*. The Neolithic expansion curve for the Indo-Pacific based on the archaeological record showing the inflection typical of stratified diffusion. Cumulative dispersal distance (km) is used as a proxy for range area/radius. Note that the 3400–2900 cal. BP expansion value should be considered as a minimum. Yap is not included in the total as its colonisation could have occurred from within Western Micronesia, nor is the presumed dispersal to the Bismarck Archipelago as the source of the Lapita culture is uncertain

environments like those of Island Southeast Asia where large landmasses are separated from each other by relatively short ocean distances, and demic expansion along coastal margins could significantly expand the range area.

The emerging archaeological record of dispersal in Island Southeast Asia suggests the Neolithic arrived in the northern Philippines at 4000 cal. BP from Taiwan, and is manifested archaeologically by red-slipped ceramics, unibevelled stone adzes, the domestic pig and a subsistence focus on the cultigens yam and taro rather than rice (Paz 2005; Piper *et al.* 2009). Reviews of radiocarbon dates by Mahirta (2006), Spriggs (2003, 2007) and Hung (2008) indicate the Neolithic extended to south Indonesia (Maluku) by 3500 cal. BP (average 5.2 km/year). Long-distance dispersal to the Mariana Islands (2100 km from the Philippines) occurred on current evidence at *ca.* 3400–3200 cal. BP. The colonisation chronologies of Palau and especially of Yap need further work, yet there is sufficient archaeological and palaeoenvironmental data to posit human arrival in these archipelagos by 3300–3100 cal. BP (Dodson & Intoh 1999; Liston 2005; Petchey & Clark In Press).

An early model of the colonisation of Western Micronesia featured a linear 'stepping-stone' dispersal northward through Palau and Yap to the Mariana Islands (Osborne 1958), but it has not been supported by archaeological and linguistic data (Clark 2005; and see Anderson 2005 for a critique of 'stepping-stone' dispersal). Instead, it appears that once Neolithic range extension had encompassed the Philippines-southern Indonesia at 4000–3500 cal. BP, there were a number of long-distance movements from different parts of the range. The Mariana Islands were probably colonised by a dispersal from the northern Philippines (Hung 2008), while Palau was likely occupied by a separate dispersal from the southern Philippines-eastern Indonesia region (see Callaghan & Fitzpatrick 2008). The immediate source of Lapita culture is uncertain (the Mariana Islands, southern Indonesia and West Papua are candidates), but Lapita migration at 3400–2900 cal. BP (average 9.4 km/year) demonstrates accelerated range expansion. If dispersals to the Mariana Islands and Palau are included with the Lapita expansion, then the Neolithic dispersal rate increases to 15.3 km/year for the interval 3400–2900 cal. BP. The overall Neolithic expansion rate-versus-time curve has the typical inflection pattern of stratified diffusion (see Figure 6).

Prehistoric human dispersals in the Indo-Pacific are typically biphasic, with episodes of punctuated expansion followed by range quiescence (Anderson 2001), and within phases of expansion it has been observed that the latter stages exhibit an increasing dispersal rate, as with Lapita migration and the colonisation of East Polynesia (Anderson 2003; Clark & Anderson 2009). The pattern in these dispersals is similar to stratified diffusion, where a species expands its range by making both short-distance and long-distance dispersals, although additional testing of stratified diffusion with archaeological data is required to test the hypothesis. Long-distance movements have been suggested for Neolithic expansion in parts of the Indo-Pacific (e.g. Burley & Dickinson 2001; Lilley 2008), but how such movements relate to incremental dispersal, and particularly demic expansion (assumed to be the dominant Neolithic dispersal mode), has not yet been investigated. Long-distance dispersals clearly occurred during the Neolithic in Island Southeast Asia and the Pacific, and the archaeological evidence for colonisation and migration in Western Micronesia is important for understanding dispersal pathways in the late Holocene.

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