Colonisation of Remote Oceania: New dates for the Bapot-1 site in the Mariana Islands

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Abstract:
The colonisation of the Mariana Islands in Western Micronesia is likely to represent a long distance ocean dispersal of more than 2000 km, and establishing the date of human arrival in the archipelago is important for modelling Neolithic expansion in Island Southeast Asia and the Pacific. In 2010, Clark et al. published a paper discussing a number of radiocarbon dates from the Bapot-1 site on Saipan Island, but a disparity between charcoal and marine shell (*Anadara* sp.) results prevented the calculation of a definitive age for the site and left open the possibility that Bapot-1 was first settled as early as 3500 cal BP. Here we present new research using a combination of stable isotope ($\delta^{13}C$ and $\delta^{18}O$) and ^{14}C information to demonstrate that *A. antiquata* from the lowest layers of Bapot-1 is affected by hardwaters. These new results indicate human arrival at Bapot-1 occurred around 3200-3080 cal. BP (1250-1130 BC). We recommend a similar isotopic evaluation for other sites in the Marianas that are dated by marine shell.

Keywords: Colonisation, Remote Oceania, Mariana Islands, Hardwater, Radiocarbon, *Anadara*.

Introduction

Recent archaeological investigations point to a rapid phase of Neolithic expansion that took place in Island Southeast Asia (ISEA) and parts of the West Pacific between 4000 and 3000 years ago (Spriggs 2011; Anggraeni et al. 2014). In this vast area the age of sites containing red-slipped and decorated pottery, especially punctate/dentate- and circle-stamped, is central to understanding Austronesian migration patterns that connected, however briefly, distant landmasses in Asia and the Pacific. One of the most enigmatic Neolithic dispersals in the region is the colonisation of the Mariana Islands at ~3500 cal. BP. This date implies that the longest ocean voyage of its time (in excess of 2000 km) occurred at the very beginning of the exploration and colonisation of Remote Oceania. All other Neolithic movements into Western Micronesia (Palau and Yap), and settlement of islands east of the main Solomon Islands by Lapita people, did not occur until ~3000 cal. BP (Clark 2004; Liston 2005; Sheppard et al. 2015).

If human arrival in the Mariana Islands occurred as early as ~3500 cal. BP then the northern-central Philippines should be the most plausible Marianas 'homeland' (Hung et al.

2011; Carson et al. 2013; Carson 2014:139) because dentate- and circle-stamped pottery is thought to date later elsewhere in ISEA. Furthermore, the restricted distribution of zoned incision with punctate or circle-stamped infilling to ceramics in northern Luzon Island, the Marianas Islands and Bismarck Archipelago, is taken as evidence for migration routes that extended from the Philippines to island New Guinea, but which largely avoided eastern Indonesia and mainland New Guinea (Bellwood 2011). An alternative view, is that colonisation of the Mariana Islands occurred later and from south of Luzon Island (Clark et al. 2010; Winter et al. 2012; Fitzpatrick & Callaghan 2013) indicating that pottery-making groups, who decorated vessels with dentate- and circle-stamping, expanded to Indonesia-northern New Guinea and were involved in maritime dispersals to the Pacific. Testing these, and other, hypotheses about Austronesian movement is difficult in ISEA where many islands have received little archaeological work, radiocarbon chronologies are poorly resolved, and site affinities and migration routes have been determined mainly from the presence/absence of a small number of ceramic traits.

In this paper, we examine the age of colonisation of the Marianas by re-dating the oldest levels of the Unai Bapot-1 (Bapot-1) site on Saipan Island in the Northern Mariana Islands. Bapot-1 is identified by Carson (2014:Fig. 4.1) as the oldest site in the Mariana Islands with a 'confirmed' earliest date range for settlement of between 3562 and 3508 cal. BP (1612-1558 BC) consistent with an early migration from the Philippines. This age range is based on three radiocarbon (^{14}C) determinations on *Anadara* sp. shellfish (Carson & Kurashina 2012:430) that were rejected by Clark et al. (2010) because they were older than results on charcoal and other marine shell species from comparable deposits. Excluding these *Anadara* sp. dates, Clark et al (2010) instead suggested human arrival at the Bapot-1 site occurred around 3400-3200 cal. BP, and perhaps as late as 3300-3100 cal. BP. This younger age range is similar to that proposed for the arrival of people in other parts of Remote Oceania and allows for a source of the oldest Marianas pottery outside the Philippines. Differentiating between the various Bapot-1 chronologies has been hampered by a lack of information about the magnitude of the marine reservoir correction value (commonly referred to as ΔR) needed to correct the ^{14}C dates of different shellfish species, the possibility of inbuilt age[1] in unidentified charcoal and shell artefact specimens, and differing views about the stratigraphic integrity of dating samples in the lowest cultural deposit. To investigate these issues we isolated and dated charcoal from short-lived material, and bird bone from the 2008 excavation (Clark et al. 2010), and compared these results to new ^{14}C and stable isotope values from marine shellfish. We then combined this new dating evidence with a detailed assessment of the stratigraphy and artefact distribution (Winter 2015), and refined the chronological interpretation using Bayesian statistical methods.

Previous age estimates

Radiocarbon results from previous excavations have placed the age of initial site use variously at 3000 cal. BP (Bonhomme & Craib 1987), 3200-3000 cal. BP (Marck 1978) and ~3500 cal. BP (Carson 2008, 2014) (Table 1). Carson (2008:134) excavated two 1m x 2 m units called TU-1 and TU-2 and concluded: “the stratigraphic contexts of the other samples were not reported in a way that would allow unambiguous comparison with the current work", but he thought that the stratigraphic progression in ages confirmed "multiple separated occupation layers" (Figure 3). Most dates were of *Anadara* sp. shellfish where the ΔR correction value was unknown, or wood charcoal that had not been identified to a short-lived material. Clark et al. (2010) attempted to rectify this with 20 new radiocarbon results from a larger excavation (Block A; 3m x 3m), but the results produced as many questions as answers. Clark et al. (2010) excluded several dates on charcoal and shell (including eight *Anadara* sp. dates; ANU-4770, ANU-4767, ANU-4772, ANU-4769, ANU-4771,Wk-25210, Beta-202744 and Beta-216616 from deposits below 220cm; and a charcoal date [Wk-23753] from the upper deposits [100-110cm]) because they did not fit with the available archaeological information.

Even with these dates removed the lower deposits with culturally similar materials returned charcoal and marine-shell dates that were highly variable. Of particular concern was the calculation of marine reservoir offsets for samples from below 220cm. Using paired charcoal and marine shell samples Clark et al. (2010) calculated a ΔR of -16 ± 87 ^{14}C years for *Anadara* sp. shell, but obtained two possible values; -162 ± 47 ^{14}C years and -13 ± 70 ^{14}C years for *Conus* sp. shell. They concluded that it was unlikely that both *Conus* values were correct. Possible explanations included inbuilt age in the charcoal, heirloom effects for the shell artefacts dated, or minor disturbance by humans between separate episodes of habitation. Overall, these arguments did not satisfactorily explain the tantalizing possibility of an earlier occupation dating to ~3500 cal. BP indicated by four rejected dates on *Anadara* sp. (Wk-25210 [3484 ± 35 BP], Beta-202744 [3590 ± 40 BP], Beta-216616 [3710 ± 50 BP], and ANU-4769 [3490 ± 110 BP]).

These anomalies enabled Carson (2014:40) to dismiss much of the work presented by Clark et al. (2010). Carson suggested that charcoal might not have been preserved within the deeper layer of the unstable beach zone, and hypothesized that all charcoal beneath 140-160cm had drifted downward from a stabilised beach surface, or had erroneously been assigned to a deeper provenience. Nine determinations with conventional radiocarbon ages ranging between 3013 and 2850 BP from the 2008 Block A excavation were rejected. Carson (2014) also questioned the ΔR values Clark et al. (2010) obtained for *Cypraea* sp. and *Conus* sp. shells, suggesting the values were offset by a combination of reef specific variations combined with charcoal movement. He further proposed that a regional ΔR value of -44 ± 41 ^{14}C years on the basis of work carried out at Ritidian in northern Guam (Carson 2010, 2014:34, 39) was suitable for the calibration of shell dates from the Mariana Islands generally. Ultimately, he concluded that the old *Anadara* sp. date (Wk-25210) obtained from the 2008 excavation endorsed his earlier conclusions and confidently placed the earliest age of Bapot-1 at 1612-1558 BC (3562-3508 cal BP; 95% prob.) (Carson 2014:40).

New Work

A. Justification

Since 2010, research undertaken at a number of archaeological sites across the Pacific (Petchey et al. 2012, 2013, 2015, Petchey & Clark 2011) and elsewhere (Ascough et al. 2005, Russell et al. 2011, 2015) has advanced our understanding of possible ^{14}C variation between different marine animals. In particular, we now know that there can be variability among different shellfish species because of habitat or dietary preferences, of note being *Anadara antiquata* and *Tegillarca granosa*[2], which can tolerate a wide range of environmental conditions (Broom 1985). Although terrestrial input into estuarine environments can result in apparently more modern ages for these shellfish (i.e., a negative ΔR value) (Petchey et al. 2013), the most problematic environments are those with limestone catchment areas where large amounts of bicarbonate ions, generated by seepage through calcareous strata, make radiocarbon ages anomalously old (i.e., a positive ΔR value). This is of particular concern for Saipan an island with a volcanic core overlain by limestone that forms the principal aquifer providing freshwater that discharges at the coast (Carruth 2003)(this is also the case for Guam [Gingerich 2003], and our comments therefore also apply to the ΔR value calculated for Ritidian). The impact this may have on marine shell ^{14}C ages depends on the rate of water exchange with the open ocean ("residence time") and therefore on current flow, as well as the presence of bays and lagoons (Petchey et al. 2008), and cannot be predicted by the presence of limestone alone. However, even in areas where limestone is minimal and coastlines fully open to marine influence, small but significant offsets have been identified in high-resolution marine reservoir projects depending on the marine shell species sampled (i.e., at Caution Bay higher than average ΔR values were recorded for *Gafrarium* spp., a genera that prefers inner-lagoon habitats; Petchey et al. 2012, 2013).

Based on these geological and hydrological observations it is probable that "hardwaters" have influenced the Bapot-1 shellfish. Moreover, the mix of limestone and volcanic geologies across the Mariana Islands (e.g., Mink & Vacher 1997; Stafford et al. 2005) negates the validity of a uniform ΔR value for certain shellfish species across this region.

For ΔR work it is essential that the charcoal/marine shell pairs used are near contemporaneous within the limitations of both radiocarbon precision and archaeological context (see Petchey 2009). In previous ΔR work at Bapot-1 (Clark et al. 2010) the sample pairs, instead of being part of a carefully planned project investigating reservoir offsets, were selected from different excavations where contexts had to be extrapolated; Wk-23763 and ANU-4768 from the upper deposits (above 220cm) came from different excavations and was the only *Anadara*-specific ΔR pair obtained, while different ΔR values for the *Conus* sp. shell (Wk-23771; Unit 4) from deposits below 220cm varied according to which unidentified charcoal sample was selected as the associated ΔR pair (Wk-23767 or Wk-23766 from Units 1 and 5 respectively, or Wk-23768 from Unit 4). It was therefore critical that a new and ΔR-specific study was carried out on the Bapot-1 material to test whether the older *A. antiquata* ages were the result of ^{14}C-depleted hardwaters or a true reflection of early settlement age.

Equally problematic to the determination of the settlement age of Bapot-1 and the calculation of ΔR is the possibility of displacement of small samples through the sediment matrix, or the unlikely mislabelling of multiple samples as suggested by Carson (2014:40). The Block A, 2008 excavation was undertaken in 10 cm spits following the natural layers which were clearly defined (Figure 3). All sediment was screened through 2 mm mesh and subsamples from each 10 cm layer were screened through 0.5 mm mesh to check that small elements were not being lost in the 2 mm sieve fraction. Using this methodology charcoal was found to be relatively common in the oldest cultural deposits (Layer VI and VII) albeit often as dispersed flecks and fragments. Moreover, chunks and concentrations of charcoal were found beneath accumulations of early red-ware sherds from a single vessel and from the base of small depressions with fire-hardened and reddened sediment interpreted as shallow hearths/fire pits.

The stratigraphic distribution of bone from the extirpated rail (*Gallirallus* cf. *philippensis*) in the Block A excavation can be used as an analogue for understanding the movement of small and light materials through the sediment. Around 80% of rail bones (n=72) came from the lowest layer with the remainder in upper levels consistent with minor upward mixing in keeping with the effects of continued use of the site. Stratigraphic integrity of the lower layers is also supported by Winter's (2015) comparison of the Bapot-1 artefacts with material culture remains from sites regarded as the oldest in the Marianas. The basal Bapot-1 ceramics consist of a predominantly thin (most 4-6 mm thick) red-slipped and calcareous tempered sherds representing a relatively small set of vessels (small-to-medium jars/bowls, some carinated with everted rims) that are similar – in form, manufacture, surface treatment and temper – to ceramics from Achugao, Unai Chulu, House of Taga, and Mangilao. Early styles of vessel decoration locally known as Achugao Incised and San Roque occur in Layers VI and VII at Bapot-1. The two decorative types appear to be contemporaneous, but Achugao sherds (n=2) were only found at the base of the deposit in Layer VII (Figure 4) while San Roque sherds were found in Layers VI and VII (n=17). The shell artefacts (n=228) recovered from the 2008 excavation contain two forms of early *Cypraea* sp. shell ornament/artefact. The first was made from the dorsum of *Cypraea* cf. *tigris* which had been edge abraded to make an circular-oval shape with two perforations bilaterally drilled in the middle or toward a flattened/worked edge. The second artefact was made by grinding dorsal and ventral surfaces of small *Cypraea* sp. shells (Figure 4). These artefacts were exclusive to Layer VII, and one or both types occur in other early Marianas sites such as Achugao (Butler 1995:249), House of Taga (Carson 2014: 130 and Fig. 10.14), Chalan Piao – where some deposit reworking is likely – (Moore et al. 1992:81) and Unai Chulu (Haun et al. 1999:263). The lower layers of the Bapot-1 site also have a varied lithic assemblage compared to upper layers, similar to Achugao and Unai Chulu. Notable is the number of adzes/adze fragments made in a fine-grained amorphous rock/altered sandstone (11 out of 15 of the adzes/adze fragments) recovered from Layers VI and VII.

Based on this combined evidence we favour Carson's (Carson & Welch 2005:26; Carson 2008:119) original assessment that the lower Bapot-1 stratigraphy indicates: "a gradual change in sedimentation and minimal apparent disturbance". Consequently, Carson (2014:40) subsequent suggestion to the contrary must reflect an attempt to explain the disparity between shell and charcoal radiocarbon ages rather than any observed displacement.

B. Radiocarbon and stable isotope sampling

To investigate both the earliest date for settlement of Bapot-1, and the magnitude of marine reservoir offset required to enable accurate calendar ages to be calculated, an additional 23 radiocarbon dates were measured. This brings the total number of dates from the lowest cultural layers of the Block A excavation to 36. The total includes short-lived charcoal (n=4), charcoal of unknown species (n=8), bird bone (n=1) and marine shell (n=23). The 23 new shell samples were selected from archived catalogued samples. The selection strategy was, first, to examine whether *A. antiquata* (n=11) produced consistent ages by sampling shell from different parts of the lowest Block A cultural deposit (Units 2-5 [U2, U3, U4 and U5]) and valves from a stratified sample (U4: 230-240cm, 240-250cm and 250-260cm). Second, the accuracy of the *A. antiquata* results was examined by dating associated samples of charcoal (n=3) and bird bone (n=1) with minimal inbuilt age and a secure context; samples SANU-11619 (nut endocarp) and SANU-11625 (*Gallirallus* cf. *philippensis*), both from U4:250-260cm depth, were found beneath a compact accumulation of early red slipped calcareous-tempered pottery (n=270) including large sherds from a carinated vessel and a sherd of incised and stamped Achugao ware, which is recognised as the oldest pottery in the Marianas. Sample SANU-11623 on nut endocarp from U3:240-250cm was recorded as a 'good' sample in the field as it came from the base of a small fire-reddened depression close to a pit feature (Feature K:230-285cm), and SANU-11621 (twig) from U2:250-260cm was found below a small accumulation of bivalves. It is highly unlikely that all of these samples were displaced from 140-160cm levels and consistent field catalogue numbers are evidence that the samples were not mislabelled as suggested by Carson (2014:40). Third, dates were obtained on worked shell from four marine taxa (*Conus* sp., echinoids, *Cypraea* sp., Pteriidae sp.; n=8) to compare results on different marine organisms.

Each sample type has a particular set of issues that need to be considered before the age of the site can be ascertained. These are discussed below.

Charcoal: It is well established that most wood charcoal determinations will date earlier than the associated human activity by an unknown amount. This could be by a few years, or several hundred years depending on inbuilt age (Spriggs & Anderson, 1993; Allen & Wallace, 2007; Allen & Huebert 2014). Therefore, short-lived nut charcoal samples with only one year of growth are considered to be one of the best dating materials assuming minimum stratigraphic displacement. Only one charcoal date reported by Clark et al. (2010) was identified as short-lived (Wk-23763) and therefore, inbuilt age is a possibility for the remaining eight. To provide a check on previous unidentified charcoals, and conform with the ΔR protocol, a further three charcoal samples, identified as nut endocarp/twig using the ANU charcoal reference collection, were dated by AMS. Radiocarbon results on unidentified charcoal results from layer VII displayed more statistical variability across the site (i.e., $\chi^2_{5:0.05} = 20.52 < 11.07$) than short-lived charcoal remains ($\chi^2_{3:0.05} = 5.93 < 7.81$), but were not significantly older at the level of precision encountered. These results indicate that there has been negligible displacement of charcoal across the identified Layer VII deposit within units 2, 3 and 4, and no intermingling of younger charcoals from the layers above.

Faunal Remains: The dating of faunal remains (bone and shell) can have a significant impact on dating accuracy where there is an identifiable and direct chronological relationship between sample (the animal) and target event (e.g., hunting activity). Moreover, inbuilt age is typically minimal because of the fairly rapid rate of collagen turnover and the short-lived nature of most animals. The interpretation of these ^{14}C results is, however, often complicated by diet.

Rail bone: It was initially assumed that the rail (*Gallirallus* cf. *philippensis*) was a terrestrial scavenger eating small invertebrates, vertebrates and vegetable matter (Marchant and Higgins 1993), but the stable isotope values ($\delta^{13}C$; -16.9 ± 0.2‰, and $\delta^{15}N$; 9 ± 0.2‰) obtained for SANU-11625 indicate that either marine or C_4 foods were also included in the diet (Schoeninger & DeNiro 1984). Isotopic measurements on New Zealand duck and swan produced very similar values to the Bapot-1 rail (-15.0 ± 3.6‰ and 8.2 ± 1.8‰ for $\delta^{13}C$ and $\delta^{15}N$ respectively). Kinaston et al. (2013:5) interpreted these values as reflecting a diet of low trophic level fish, invertebrates and aquatic plants from marine, freshwater and brackish environments. The slightly older CRA for the Bapot-1 rail sample (SANU-11625; 3085 ± 30 BP) compared to associated charcoals (both short-lived and unidentified)(Table 2) supports the likelihood that a partial marine correction is needed to bring this date into congruence.

Few attempts have been made to calibrate radiocarbon dates on such animals (see Beavan-Athfield & Sparks 2001; Higham et al. 2005). Petchey et al. (2015), however, found that a diet correction using linear extrapolation between terrestrial and marine $\delta^{13}C$ endpoints, in a similar manner to established protocol for human bone dietary corrections (e.g., Arneborg et al. 1999; Dewar & Pfeiffer 2010; Petchey et al. 2011, 2014), could be used to determine the appropriate mix between terrestrial and marine ^{14}C calibration curves for chicken bone (*Gallus gallus*) from Teouma, Vanuatu. For the Bapot-1 rail bone sample (SANU-11625) we have therefore applied a linear extrapolation methodology using −21‰ and −12‰ $\delta^{13}C$ endpoints (see Petchey et al. [2014] for methodology). This calculation indicates a marine dietary correction of 46±10 per cent marine carbon is needed. This diet correction shifts the calibrated radiocarbon result from 3360-3240 cal. BP to 3150-3000 cal. BP (68% prob.); a value more in keeping with the closely associated charcoal dates from this unit (U4, 230-240cm depth; SANU-11619: 3220-3070 cal. BP; Wk-23768: 3140-2980 cal. BP) (Figure 5).

ii. Shell: Carbon in the shells of marine invertebrates is mainly derived from metabolic sources (Tanaka et al. 1986). Because suspension-feeding shellfish predominantly consume suspended phytoplankton and dissolved inorganic carbon (DIC) from seawater the isotopic composition should primarily reflect surface ocean reservoir conditions (Hogg et al.1998). It is, however, possible that carbon from sources other than ocean DIC can become incorporated into shells (cf. Dye 1994; Keith et al. 1964). The most problematic shells for radiocarbon analysis are those that live in and/or feed on either particulate carbonate or dissolved bicarbonate ions. Large offsets have been identified for herbivorous shells (*Turbo* and *Trochus* sp.) from Teouma, Vanuatu, a site bordered by limestone cliffs (Petchey et al. 2015); for estuarine filter feeding shellfish *Gafrarium* sp. and *Anadara* sp. from the limestone bounded lagoon of Tongatapu (Petchey & Clark 2011, Spennemann & Head 1998); and smaller offsets have been recorded for *T. granosa* from Caution Bay, south coast of Papua New Guinea where minor amounts of limestone bedrock are found in the hinterland (Petchey et al. 2013, 2012).

The shellfish selected for dating from Bapot-1 include *A. antiquata* food shells and artefact remnants made from *Conus* sp., echinoids (sea urchins), *Cypraea* sp. and Pteriidae shells. These shellfish occupy a diverse range of environments and have different feeding strategies. *Anadara* are filter-feeding bivalves, and are highly adaptive occupying many different niches from fully marine to estuarine environments (Broom 1985:9-10). *A. antiquata* however, prefer sandy-gravels and are poor burrowers – often favouring seagrass beds, mangroves and shallow-lagoon bottoms (Tebano & Paulay 2000:13). Echinoids are found from the low intertidal region and below, and although they are scavengers (Follo & Fautin 2001), previous investigations of ^{14}C by Petchey et al. (2013) support an isotopic character that is primarily marine, though this may be species specific. Pteriidae shellfish prefer full-strength, clear seawater and will quickly die if exposed to brackish or freshwater for long periods (Beesley et al.,1998:262), minimalizing any potential impact from hardwaters and therefore supporting the use of a marine correction in-keeping with the global marine reservoir value (i.e., a ΔR of ~0; Reimer et al. 2013). *Conus* spp. are carnivorous and also occupy a wide range of marine environments, though most Australian species occupy coral reef habitats (Beesley et al., 1998:852-853). A few anomalous ΔR values have been reported, but again insufficient work has been undertaken to confirm a problem and again, issues may be species specific (Dye 1994; Petchey et al. 2008). *Cypraea* are usually associated with live coral colonies (Poutiers 1998:493-500) but can be herbivorous, carnivorous and/or omnivorous depending on species and age group (Beesley et al. 1998:780). Grazing on algae can be problematic where fossil coral (limestone) is present, and anomalous ΔR values have been obtained for *Cypraea* shells recovered from limestone coastlines around Hawai'i (Dye 1994). Cypraeids are therefore theoretically the most problematic of the Bapot-1 shellfish.

Petchey & Clark (2011:547) suggested that it may be possible to predict the presence of hardwater offsets in *Anadara* and other shellfish by using δ^{18}O and δ^{13}C values (see also Culleton et al., 2006; Petchey et al., 2008). In particular, δ^{18}O is a sensitive indicator of change in water temperature and salinity, while the δ^{13}C value of marine shells predominantly reflects water source and overall marine productivity since most shellfish precipitate their shells in equilibrium with stable isotopes in the local environment (Keith et al., 1964; Swart et al., 1983; Romanek & Grossman, 1989; Kennett et al., 1997; Goewert et al., 2007). Estimates vary, but the δ^{13}C value of shell should be ~2‰ heavier than DIC as the result of equilibrium partitioning of the isotopes (Tanaka et al. 1986:523). Input of freshwater within a lagoon environment should result in the depletion of shell ^{13}C and ^{18}O (Keith et al. 1964:1781; Gat 1996:241, 255; Culleton et al. 2006:390), while increased productivity and CO_2 atmospheric absorption in reef locations may result in an enrichment in ^{13}C (Weber & Woodhead, 1971;Watanabe et al. 2006) and ^{14}C (Guilderson et al. 2000).

Analysis

Sample isotopes were measured at either the Waikato Radiocarbon AMS facility (Wk-) or the Australian National University (SANU-). Where possible a ~5-mm cross-section was sampled across multiple increments of growth to avoid intra-shell variations in ^{14}C caused by seasonal fluctuations and variable age of the shellfish (this was not possible for artefacts). This method provided an average isotopic value over a maximum period of ~5 year of growth (i.e., one increment in the Marine13 data set (Reimer et al. 2013). Radiocarbon dates were prepared following standard accelerator mass spectrometry (AMS) protocols, whereby the shells were washed in dilute HCl to remove surface contamination and tested for recrystallization (Friedman 1959)(Waikato only), charcoal was treated with a series of dilute HCl, multiple NaOH and HCl washes (UCI KCCAMS Faculty 2011; pers. com. R Wood 2015), and bone was gelatinized (cf., Brock et al. 2010) prior to CO_2 collection and conversion to graphite. $\delta^{13}C$ and $\delta^{18}O$ were measured using a Europa Scientific Penta 20–20 isotope ratio mass spectrometer on gas split taken during preparation of ^{14}C samples at the University of Waikato, and on a separate sample using a Sercon 20-22 at ANU.

RESULTS

A. Stable isotopes

Available stable isotope values for marine shells from Bapot-1, including samples not used for ΔR calculation, are shown in Figure 6 and Table 2. The *A. antiquata* shells all have depleted ^{13}C relative to the average ocean dissolved inorganic carbon (DIC) for this region. Similar values were recorded for *Gafrarium* sp. and some *Anadara* sp. shells from archaeological sites that border the Fanga 'Uta Lagoon, Tongatapu (Petchey and Clark 2011)(Figure 6). At this site reservoir correction (ΔR) values as high as 329 ± 90 ^{14}C years for *Anadara* and 380 ± 69 ^{14}C years for *Gafrarium* were recorded for those individuals with depleted $\delta^{13}C$. Based on the Tongatapu research it is highly probable that a hardwater effect is present in the Bapot-1 *Anadara* shells from lower levels, including those collected during previous excavations that have negative $\delta^{13}C$ values (i.e., ANU-4767, ANU-4772, ANU-4768, Beta-202722 and Beta-216616) (Table 1). Those animals that preferred reef or more open marine habitats generally had $\delta^{13}C$ values closer to the global ocean DIC (e.g., *Conus*, Echinoidea, Pteriidae and *Cypraea*).

B. Radiocarbon

All radiocarbon dates were calibrated in OxCal v4.2 (Bronk Ramsey, 2014) using the Marine13 and Intcal13 curves (Reimer et al., 2013) initially, with <u>no</u> marine reservoir correction applied to the shellfish. These results, when grouped into Layer VI and VII designations as determined by Winter (2015) and ordered by material type, clearly display the offset in *A. antiquata* values compared to associated materials (Figure 7).

Marine reservoir calculation

In order to correct for this offset it is necessary to calculate a ΔR value for each of the shell species. The marine ΔR can be calculated from shell/charcoal samples (pairs) found in direct association (Petchey & Clark 2011; Jones et al. 2007). There are strict guidelines for these types of calculation (see Petchey 2009), which can seem overly restrictive, but failure to meet these guidelines can result in significant errors, as was the case for the initial Bapot-1 marine reservoir calculations. It is essential that the age of shellfish death be known. This is determined by dating charcoal from short-lived, associated materials. Following these guidelines we identified four pairs (Table 3). Based on these pairs we have calculated an average location-specific, species-specific reservoir correction value (ΔR) of 218 ± 57 ^{14}C years for *A. antiquata*, and 23 ± 37 ^{14}C years for *Conus* sp.. We were unable to obtain identified charcoal from the same depths as the remaining shellfish types but a ΔR of 23 ± 37 ^{14}C years is in keeping with open ocean values (i.e., a ΔR of ~0; Reimer et al. 2013; Petchey and Clark 2010) and these remaining shellfish have preferences for reef/open marine environments as indicated by ^{18}O and ^{13}C isotopes (Figure 6).

Bayesian model building

To further refine the chronological interpretation of Bapot-1 we have used the programme OxCal which applies Bayesian statistical methods whereby ^{14}C ages are constrained by prior information such as stratigraphic order and context. All radiocarbon dates, including those from previous excavations at Bapot-1, are presented in Tables 1 and 2, but only those from the 2008 excavations (Table 2) are considered in the Bayesian model (Oxcal specific commands are given as bold). The radiocarbon dates from Layers VI and VII are modelled as two discrete **phases** arranged in a **contiguous sequence**. Between each **phase** is a **uniform boundary** that provides an estimate for the date of transition between each **phase** (Bronk Ramsey 2009). The overall model is assessed by the calculation of an agreement index (A_{model}) that tells us how well the model agrees with the observations. If "A" falls below 60% (equivalent to the 5% level of a χ^2 test), the model should be re-evaluated (Bronk Ramsey 1995, 2009). All dates discussed in the text are reported at 68.2% probability unless otherwise noted.

The two-phase model produced a good agreement (A_{model}=107%) with ages for "top" (layer VI) falling between 3060 and 2970 cal. BP (1110-1020 BC), and dates for the "base" (layer VII) of between 3200 and 3080 cal. BP (1250-1140 BC) (Figure 8 and Table 4).

DISCUSSION AND CONCLUSION

The displacement of archaeological charcoal below 140-160cm in the Bapot-1 Block A excavation has been used to explain the disparity between charcoal and *Anadara* sp. radiocarbon ages (Carson 2014:40). Here we have, however, demonstrated that identified and unidentified charcoal, bone from an extirpated rail, and four other marine shell genera from comparable contexts all date younger than *Anadara*. Moreover, we have demonstrated using a combination of stable isotope ($\delta^{13}C$ and $\delta^{18}O$) and ^{14}C information that *A. antiquata* from the lowest layers of Bapot-1 is affected by hardwaters. Therefore, radiocarbon determinations on *Anadara* sp. do not support the existence of an older cultural assemblage at Bapot-1 dating to 3562-3508 cal. BP (1612-1558 BC) as suggested by Carson (2008), Carson & Kurashina (2012) and Carson (2014). Instead, our Bayesian ^{14}C model suggests human arrival at Bapot-1 around 3200-3080 cal. BP (1250-1140 BC). Regardless of any deficiencies in the Bapot-1 radiocarbon corpus it is currently the best dated and chronologically investigated site in the Marianas.

There is currently insufficient stable isotope information from upper layers at Bapot-1, but it appears that *Anadara* from deposits above 100cm (ANU-4771, ANU-4770) do not display the same environmental indicators of a hardwater effect (Table 1; $\delta^{13}C$ values of 0.9 and 0.3 ± 0.4‰ respectively), though this needs to be tested further. Dickinson (2000, 2006) suggested that coastlines on Saipan expanded after a post-mid-Holocene drawdown in sea level estimated at 1.75m. This sea level fall and progradation would have caused the loss of quiet intertidal settings where the impact of hardwaters may have been significant resulting in reef flats being covered by shallow sands and habitats more suited to *Strombus* sp. shellfish (see Amesbury 2007). Human predation on *Anadara* sp. may have also exacerbated this by the collection of marine shellfish from different areas with reduced exposure to hardwaters. This also means that the use of modern shellfish to assess possible environmental conditions and reservoir offsets in the past is problematic.

Other shellfish at Bapot-1 appear to be unaffected by hardwaters, but we have insufficient information to properly evaluate this, though available dietary/habitat information for Pteriidae, Echinoidea, and *Conus* shells suggest reef/open marine environments are preferred, reducing the likelihood of a hardwater influence. Previous research into different shellfish species (Dye 1994) indicated that herbivorous/grazing animals may be affected by the ingestion of limestone. Variation in the ^{14}C ages of *Cypraea* sp. shells from U1:230-240cm depth may support this conclusion, but Wk-23769 (3355 ± 30 BP) is of weathered and probably beach rolled shell, while Wk-23770 (3192 ± 30 BP) had a fresh lustrous surface. It would therefore not be surprising if the older result were caused by some inbuilt age.

It is notable that several of the sites identified as the oldest in the Marianas are also dated by marine shell determinations. For example, the Ritidian site on Guam is argued to have a confirmed date range of 3500-3282 cal. BP (1550-1332 BC) from two determinations on *A. antiquata* and one on naturally deposited *Halimeda* sp. bioclast. The House of Taga site on Tinian is dated by five *Anadara* sp. dates and two charcoal (twig) results that "redundantly overlapped" at 3363-3321 cal. BP (1413-1371 BC; Carson 2014: 34). Both sites are located in limestone environments and hardwater must therefore be considered as a potential factor influencing the *Anadara* sp. ages. Because the uptake of hardwater *Anadara* sp. results can skew the interpretation of calibrated radiocarbon probability distributions toward an older range, the 'redundant overlap' method for determining site age will favour an older age for the site. Regardless, this method has no statistical validity when interpreting site chronologies. It is also clear that apparent association of materials in archaeological sites is often difficult to ascertain. Consequently, marine reservoir evaluation should not be based on a single marine shell/charcoal pair (cf., Russell et al. 2011) and should ideally be combined with a Bayesian evaluation of site age as well as stable isotopic evaluation of the likely marine habitat of the shells.

Unai Chulu (Tinian) and the Mangilao Golf Course (Guam) are dated using multiple charcoal (unidentified) samples to between ~3640 and 3000 cal. BP (1690-1050 BC). The material culture assemblage of the lowest deposits at Bapot-1 is similar to these sites, particularly Unai Chulu where the lowest layer (Stratum VII) has the highest proportion of rail bone (73%) – including remains from extirpated species – and a lithic assemblage made in a variety of materials (Haun et al. 1999:100, 111). It seems likely therefore that Bapot-1 and Unai Chulu are of similar age and we estimate that colonisation of the Marianas probably occurred not much before Bapot-1. Reinvestigation of these charcoal chronologies is also recommended

In the most recent review of the spread of Lapita people from Near Oceania into Remoter areas of the Pacific, Denham et al. (2012) suggest their arrival in Mussau and the Bismarck Archipelago at 3470-3240 cal. BP and 3360-3250 cal. BP respectively, followed by dispersal to Vanuatu by 3250-3100 cal. BP. However, Bayesian analysis of radiocarbon ages from sites in the Solomon Islands by Sheppard et al. (2015) – supported by research in Vanuatu by Petchey et al. (2015) – indicates that Lapita arrival in Remote Oceania is unlikely to be much earlier than 3000 cal. BP, and that sites in the Bismarck Archipelago could date as late as 3250 cal. BP. Thus, on current evidence the Mariana Islands remain the first archipelago in Remote Oceania to be colonised, and the timing of human arrival in Western Micronesia appears to coincide with the appearance of Lapita in the West Pacific. A connection between the two dispersals is therefore on chronological grounds feasible (e.g. Bellwood 2011; Carson et al. 2013) and can be further examined by a comparison of early ceramics, shell ornaments and stone tools from Lapita sites in the West Pacific with those in the Marianas (see Winter 2015). Nonetheless, the redating of Bapot-1 to 3200-3080 cal BP, and the likelihood that other early sites in the Marianas are of similar age places this colonisation relatively late in the ISEA Neolithic. This, and the recent discovery of dentate- and circle-stamped pottery in northern Sulawesi (Reepmeyer et al. 2015) suggests the immediate origins of the people who colonised the Marianas (and those of Lapita groups in the West Pacific) may be found south of the Philippines in Austronesian dispersals that reached Indonesia-Northern New Guinea.

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Figure 1. Map of Island South East Asia (ISEA), the Bismarck Archipelago and New Guinea showing the location of the Bapot-1 site, Saipan Island. Insert: archaeological excavations at Unai Bapot (after Carson 2014:108).

Figure 2. A. Carsons (2008) overview of the chronology at Unai Bapot (using a ΔR value of 75 ± 35 ^{14}C years) shown in BC/AD in line with original publications. Note: radiocarbon ages for the UCR- and ANU- dates presented by Carson (2008) were not conventional radiocarbon ages (CRAs) as defined by Stuiver & Polach [1977]). **B.** Calibrated CRAs for each of the three excavations using a ΔR of 75 ± 35 ^{14}C years. Probability distributions show in grey = *Anadara* sp.; black = charcoal.

Figure 3. Block A, Bapot-1, North profile (U1-U3) showing stratigraphy and presence of *in situ* charcoal in Layers VI and VII. Note that these are not charcoal collection points.

Figure 4. Early material culture in the Bapot-1 assemblage. 1-2. Achuago incised and punctate sherds (Layer VII); 3-4. San Roque incised sherds (Layer VII and VI); 5-6. *Cypraea* beads (dorsal and ventral grinding) (Layer VII); 7-8 *Cypraea* drilled ornaments made from the dorsum (Layer VII); 9-10. Adzes made from fine-grained amorphous rock/altered sandstone (Layer VII). Note: artefacts are not to scale.

Figure 5: Calibrated radiocarbon dates from Area 2, Unit 4 by increasing depth. Outline distributions are shell and rail bone results uncorrected for ΔR and diet. Medium grey = rail bone corrected for dietary offset. Black = charcoal. Figure 5 text: two dates start with 'A. antiquata:' the others start with 'Wk-' or 'SANU-'

Figure 6. Measured $\delta^{18}O$ and $\delta^{13}C$ values for mollusc shells from Bapot-1 and Tongatapu. Large circles demarcate high ΔR values. Around Saipan the modelled $\delta^{13}C$ isotopic composition of the modern surface ocean DIC falls between 1.3 and 1.7‰ (Tagliabue & Bopp 2008: Fig. 2) as indicated by grey bars. Around Tongatapu the modelled $\delta^{13}C$ isotopic composition of the modern surface ocean DIC falls between 1.3 and 1.4‰.

Figure 7. Radiocarbon dates from Bapot-1 grouped into Layer VI and VII and ordered by material type (charcoal, other shell, *Anadara*). All shell dates (*Cypraea*, Pteriidae, echinoid, *Conus* sp. and *A. antiquata*) are uncorrected for ΔR. Calibrated age for rail (*Gallirallus* cf. *philippensis)* corrected for diet as discussed in text.

Figure 8. A. Calibrated radiocarbon ages for Bapot-1. The outline date distributions show the unmodelled calibrated ages for each individual sample. The solid black distributions show the calculated ranges when applying the reservoir (ΔR) and dietary corrections and the Bayesian model outlined in the text (quoted agreement indices ["A"] vary slightly by run). **B.** Boundary ages for Bapot-1.

Table 1. Radiocarbon dates from pre-2008 excavations at Bapot-1.

Reference	Lab Code†	Provenance	Material	δ^{13}C (‰)	Conventional Radiocarbon Age (BP)
Marck (1978)	UCR-649	Upper sample	Charcoal	-	2890±100
	UCR-650	Lower Sample	Charcoal	-	2910±100
Bonhomme & Craib (1987)	ANU-4771	40-50cm	*Anadara antiquata* shells	0.9±0.4‡	1040±110
	ANU-4770	90-100cm	*Anadara antiquata* shells	0.3±0.4‡	2880±90
	ANU-4767	100-110cm	*Anadara antiquata* shells	-2.4±0.4‡	3040±110
	ANU-4772	135-155cm	*Anadara antiquata* shells	-2.5±0.4‡	3050±110
	ANU-4768	170-190cm	*Anadara antiquata* shells	-0.5±0.4‡	3210±80
	ANU-4769	310-330cm, beneath cultural layer	*Anadara antiquata* shells	-	3490±110
Carson (2008)	Beta 214761	TU-2, Layer III-A combustion feature.	Charcoal	-25.8	2840±40
	Beta 202722	Layer IV-1, localized discard pile.	*Anadara* sp. shell	-1.5	3590±40
	Beta 216616	Layer IV-1, localized discard pile.	*Anadara* sp. shell	-1.1	3710±50

†Beta – Beta Analytic, Inc. ANU = Australian National University. UCR = University of California, Riverside. ‡isotope data not previously reported.

Table 2: Radiocarbon dates from Bapot-1 2008 excavation.

Lab no.	**Identification**	**Context**	**Layer**	**Depth from string line (+20cm)**	**CRA ± error (BP)**	**$\delta^{13}C$† (‰)**	**$\delta^{18}O$† (‰)**	**cal BP (68% prob.) (unmodelled age)**	**cal BP (95% prob.) (unmodelled age)**
SANU-11634	*Anadara* cf. *antiquata*	A2: U4	VII	230-240 cm	3515 ± 25	-0.7	-1.32	3190-3020	3290-2940
SANU-11749	*Anadara* cf. *antiquata*	A2: U4	VII	240-250 cm	3565 ± 25	-0.8	-1.37	3250-3080	3350-3020
SANU-11902	*Anadara* cf. *antiquata* (duplicate of SANU-11750)	A2: U4	VII	240-250 cm	3530 ± 30	-	-	3210-3040	3310-2960
SANU-11750	*Anadara* cf. *antiquata*	A2: U4	VII	240-250 cm	3500 ± 30	-0.34	-1.35	3180-2990	3260-2910
SANU-11903	*Anadara* cf. *antiquata*	A2: U4	VII	240-250 cm	3485 ± 30	-1.2	-0.70	3160-2980	3240-2890
SANU-11637	*Anadara* cf. *antiquata*	A2: U4	VII	240-250 cm	3510 ± 25	-1.1	-1.11	3190-3010	3270-2930
Wk-23771	Conus sp. ring	A2: U4	VII	240-250 cm	3182 ± 30	0.6	-0.84	3010-2860	3090-2810
Wk-23768	Unidentified charcoal	A2: U4	VII base	250-260 cm	2908 ± 30	−24.9	-	3110-3090 3080-2980	3160-2950
SANU-11625	*Gallirallus* cf. *philippensis***	A2: U4	VII base	250-260 cm	3085 ± 30	-16.9	-	3150-3000	3210-2940
SANU-11619	Nut endocarp	A2: U4	VII base	250-260 cm	2985 ± 30	-24.8	-	3220-3140 3130-3110 3100-3070	3330-3300 3250-3060
SANU-11748	*Anadara* cf. *antiquata*	A2: U4	VII base	250-260 cm	3540 ± 30	-	-	3220-3050	3320-2990
SANU-11901	*Anadara* cf. *antiquata* (duplicate of SANU-11748)	A2: U4	VII base	250-260 cm	3485 ± 30	-1.70	-1.28	3160-2980	3240-2890
Wk-23764	Unidentified charcoal	A2: U2	VII	230-240 cm	2910 ± 30	−25.1	-	3140-3120 3110-3090 3080-2990	3160-2960
Wk-23765	Unidentified charcoal	A2: U2	VII	230-240 cm	2900 ± 30	−25.5	-	3080-2970	3160-2950
Wk-25210	*Anadara* cf. *antiquata*	A2: U2	VII base	250-260 cm	3484 ± 35	−0.7	-1.58	3150-2970	3240-2880
SANU-11900	*Anadara* cf. *antiquata*	A2: U2	VII base	250-260 cm	3460 ± 30	-1.5	-1.23	3130-2950	3200-2860
SANU-11621	Twig	A2: U2	VII base	250-260 cm	2960 ± 30	-23.6	-	3170-3070	3220-3000
Wk-41290	Conus sp. ring	A2: U3	VII	220-230 cm	3251 ± 17	2.9	-1.34[#]	3110-2970	3170-2910
Wk-23763	Nut endocarp	A2: U3	VII	220-230 cm	2904 ± 30	−21.8	-	3080-2970	3160-2950
Wk-41287	Echinoidea abrader	A2: U3	VII	230-240 cm	3265 ± 18	2.5	-1.44[#]	3130-2990	3180-2930
Wk-41288	Pteriidae worked shell	A2: U3	VII	230-240 cm	3289 ± 18	0.9	-1.78[#]	3160-3030	3210-2960
SANU-11633	*Anadara* cf. *antiquata*	A2: U3	VII	240-250 cm	3600 ± 25	-2.3	-0.97	3310-3150	3370-3060
SANU-11623	Nut endocarp	A2: U3	VII	240-250 cm	3000 ± 30	-25.1	-	3240-3140 3090-3080	3330-3300 3260-3070
Wk-23760	Unidentified charcoal	A2: U5	VI	200-210 cm	2866 ± 32	−25.3	-	3060-2940	3080-2870
Wk-41286	Echinoidea abrader	A2: U5	VI	210-220 cm	3257 ± 17	1.9	-1.07[#]	3120-2980	3180=2910
Wk-41289	Pteriidae worked	A2: U5	VII	240-250 cm	3288 ± 16	2.4	-1.79[#]	3160-3030	3210-2960
Wk-41291	*Conus* sp. ring	A2: U5	VII	240-250 cm	3237 ± 18	2.0	-1.47[#]	3080-2940	3150-2890
Wk-23766	Unidentified charcoal	A2: U5	VII	240-250 cm	3013 ± 30	−25.5	-	3320-3300 3250-3160	3340-3280 3270-3070
SANU-11630	*Anadara* cf. *antiquata*	A2: U5	VII base	250-260 cm	3485 ± 25	-0.7	-0.76	3150-2980	3240-2900
Wk-41293	*Cypraea* sp. ornament	A2: U6	VII	240-250 cm	3292 ± 17	3.8	-1.65[#]	3170-3040	3220-2970
Wk-41292	*Cypraea* sp. ornament	A2: U6	VII base	250-260 cm	3229 ± 18	2.5	-1.39[#]	3070-2940	3140-2880
Wk-23757	Unidentified charcoal	A2: U7	VI	170-180 cm	2907 ± 32	−25.1	-	3140-3130 3110-3090 3080-2970	3160-2950
Wk-23761	Unidentified charcoal	A2: U8	Transition V-VI	210-220 cm	2922 ± 30	−24.6	-	3150-3090 3080-3000	3170-2970
Wk-23769	*Cypraea* sp. disk pendant	A2: U1	VII	230-240 cm	3355 ± 30	1.9	-0.79	3260-3100	3330-3040

Wk-23770	*Cypraea tigris* disk pendant	A2: U1	VII	230-240 cm	3192 ± 30	2.1	-1.22	3030-2880	3110-2820
Wk-23767	Unidentified charcoal	A2: U1	VII base	250-260 cm	3010 ± 30	−28.1	-	3320-3300 3250-3150	3340-3280 3260-3070

†$\delta^{13}C$ and $\delta^{18}O$ were measured relative to VPDB, with precision of ±0.2‰ (Wk) and ±0.03‰ for $\delta^{13}C$ and ±0.10‰ for $\delta^{18}O$ (SANU).
#$\delta^{18}O$ measured on solid shell at the German Research Centre for Geosciences GFZ on a MAT253 ThermoScientific IRMS using 103% H_3PO_4. Precision of ±0.06‰

Table 3: ΔR results of shell/charcoal pairs from Bapot-1

Lab. No.	Material†	Location	Layer	CRA ± error (BP)	Marine modeled age ($R_g(t)$)	ΔR (years) $R_s(t)$-$R_g(t)$ ‡	Pooled ΔR (^{14}C years)
SANU-11619	Nut endocarp	A2: U4 250-260 cm	VII base	2985 ± 30			
SANU-11748	*Anadara antiquata*	A2: U4 250-260 cm	VII base	3540 ± 30			
SANU-11901	*Anadara antiquata*	A2: U4 250-260 cm	VII base	3485 ± 30			
SANU-11621	Twig	A2: U2 250-260 cm	VII base	2960 ± 30			
Wk-25210	*Anadara antiquata*	A2: U2 250-260 cm	VII base	3484 ± 35			
SANU-11900	*Anadara antiquata*	A2: U2 250-260 cm	VII base	3460 ± 30			
SANU-11623	Nut endocarp	A2: U3 240-250 cm	VII	3000 ± 30			
SANU-11633	*Anadara antiquata*	A2: U3 240-250 cm	VII	3600 ± 25			
Wk-23763	Nut endocarp	A2: U3 220-230 cm	VII	2904 ± 30			
Wk-41290	*Conus* sp.	A2: U3 220-230 cm	VII	3251 ± 17			

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†Available information suggests that *Anadara* spp. may live for up to 45 years (Stern-Pirlot & Wolff 2006). The limited information available for reef gastropods (c.f., *Conus* sp.) suggests that most live >5 years and some may reach 20 year of age (Frank 1969:247). This is unlikely to be truly reflective of animals collected from locations previously uninhabited by humans.

‡The ΔR for a specific location "(s)" is calculated from known-age shells collected prior to atmospheric bomb testing using the formula Rs(t) -Rg(t) =ΔR(s), where ΔR(s) is the difference between the actual ^{14}C activity of the surface ocean at a particular location [Rs(t)] at that time, and the global average [Rg(t)] (as represented by the modelled marine ^{14}C calibration curve Marine13 [Reimer et al. 2013]). To calculate ΔR values from archaeological terrestrial/marine pairs, an estimate of the Northern Hemisphere atmospheric calibration curve error (Reimer et al. 2013) over the 1σ span of the radiocarbon age is used to derive the calculated marine modelled age [Rg(t)], whereby atmospheric age $\sigma = \sqrt{(\sigma^{14}C\ age^2 + \text{average of calibration curve error}^2)}$. For detailed information on how to calculate this see Ulm (2002). The calculated average marine modelled age for the short-lived charcoal samples has been subtracted from each shell ^{14}C age [Rs(t)]. Each individual archaeological ΔR standard error is calculated by the formula $\Delta R\sigma = \sqrt{(\sigma_{Rg(t)}^2 + \sigma_{Rs(t)}^2)}$.

Table 4: OxCal modelled calibrated ages for Bapot-1 radiocarbon samples.

	68.2%	95.4%
	A_{model} (agreement index):107	
Top (VI)	1110-1020 BC 3060-2970 cal. BP	1130-950 BC 3080-2900 cal. BP
Transition	1140-1080 BC 3090-3030 cal. BP	1180-1050 BC 3120-3000 cal. BP
Base (VII)	1250-1160 & 1150-1140 BC 3200-3110 & 3100-3080 cal. BP	1270-1130 BC 3220-3080 cal. BP

[1] Radiocarbon results of wood charcoal samples may be influenced by inbuilt age if they originate from long-lived species (Allen and Huebert 2014), or by ''storage age'' if the species selected is resistant to weathering and decay, or if stored wood is burned (Schiffer 1987).

[2]Also known as *Anadara granosa*.