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The Radiocarbon Chronology of the Norfolk Island Archaeological Sites

ATHOLL ANDERSON[1], TOM HIGHAM[2] AND ROD WALLACE[3]

[1] Department of Archaeology & Natural History, Research School of Pacific and Asian Studies, Australian National University, Canberra ACT 0200, Australia
aja@coombs.anu.edu.au

[2] Waikato Radiocarbon Laboratory, University of Waikato, Hamilton, New Zealand.
Current address: Oxford Radiocarbon Accelaration Unit, University of Oxford, United Kingdom
thomas.higham@archaeology-research.oxford.ac.uk

[3] Department of Anthropology, University of Auckland, Private Bag 92019, Auckland, New Zealand
r.wallace@auckland.ac.nz

ABSTRACT. Radiocarbon determinations were obtained for archaeological sites at Cemetery Bay and Emily Bay, Norfolk Island. Sample materials were rat bone gelatin, marine shell and wood charcoal. Ages on bone gelatin are contradictory and suggest a laboratory problem, while ages on marine shell appear to include an old-carbon offset of 500–600 years: dates on these samples are consistent with those on charcoal when appropriate corrections are made. Ages on charcoal were divided according to the expected inbuilt age of the sample taxa. The samples with lowest inbuilt age were subjected to Bayesian analysis which concluded that the main archaeological site, at Emily Bay, had been occupied from the early thirteenth to the early fifteenth centuries A.D. The Norfolk Island settlement occurs within the same age range as other Polynesian settlements of southern islands.

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Radiocarbon determinations have been obtained from two archaeological sites on Norfolk Island: Cemetery Bay and Emily Bay. In both cases, multiple sample types were dated. Each type of sample is associated with different issues of processing and interpretation so we consider them first in these categories. Following that, we discuss the chronologies in their stratigraphic and spatial contexts and then consider the age of prehistoric settlement on Norfolk Island generally and in relation to the prehistoric chronologies of archipelagos which might have contributed colonists.

Charcoal identification

The first results from Norfolk Island (Rich *et al*., 1983: 17) were on unidentified charcoal (I-11019, I-11303, Table 6) from excavations at Cemetery Bay. Additional excavations there by Meredith (1985: 22) added two samples (Beta-6821, Beta-6822) comprising pieces from “small branches” (3–4 cm diameter) of gymnosperm, almost certainly Norfolk pine (*Araucaria heterophylla*). It is not clear how branchwood was identified (deduction from the curvature of growth rings is open to alternative interpretations), and there are other reasons (below) that recommend caution, so the assumption that these results are good estimates of the age of the Cemetery Bay deposit remains open to question, for reasons outlined below.

The first four samples from the Norfolk Island Prehistory Project (NIPP) 1995 excavations (ANU-10157 to ANU-10160, Table 6) were identified no more certainly. Two were of *Araucaria* sp., and two of other but unidentified wood. From the NIPP 1996 season, it was possible to isolate material which was entirely of broadleaf taxa. In the NIPP 1997 season, Wallace (1998) made a collection of comparative material from all 33 indigenous woody plants on Norfolk Island (Orchard and Thompson, 1999) from which he was able to identify charcoal samples to species.

The wood samples were made into thin sections showing each of the three planes of each sample, and from those were made photomicrographs which allowed identification to the species level. Charcoal samples were snapped across the grain and cloven along it, and the faces observed under incident illumination using a compound microscope at magnifications of 50–500 diameters. Identifications were made by comparing the cell patterns with the samples from the comparative collection.

Wallace (1998) examined 99 bags of charcoal (about 2.5 kg) from the 1997 trenches, two from EB97:21, one from EB97:22, 78 from EB97:23 and 18 from EB97:24. In general, about 75% of the charcoal in each bag could be identified, the remainder being of pieces too small to process. The objective was to obtain samples of identified broadleaf material weighing a minimum of 6 g to enable high precision Liquid Scintillation radiocarbon dating. This was achieved relatively rarely. Broadleaf charcoal samples of 6 g or more were found once in EB97:21, in 38 of the 78 bags from EB97:23 and in none of the EB97:21 or EB97:24 bags. In the latter trench, only 12.5 g of broadleaf charcoal was obtained from the entire collection.

The most striking aspect of the assemblage is that 95% of the charcoal by weight was from Norfolk pine. Even if that was the dominant emergent tree, as it was historically in the Kingston area, it probably would not have provided 95% of the available firewood, except if the inhabitants chose to ignore material from other kinds of trees, which seems improbable. It is more likely that much of the charcoal in the site is from burnt-down structures, such as houses or cooking sheds, which had been built from the long, straight branches of Norfolk pine. Certainly, the postbutts left in EB97:23 were all of Norfolk pine branches (Wallace 1998).

Unfortunately, this is a poor material for accurate radiocarbon dating because its mode of growth presents a high probability of significant inbuilt age (i.e. the wood was dead, and stored in the trunk or branches, for a long time before it was used as firewood—McFadgen, 1982). Norfolk pine grows quickly to form massive, cylindrical trunks with regular radial outgrowths of branches which persist during the life of the tree and expand only very slowly in diameter. Consequently, not only is trunkwood likely to be several hundred years old or more, but so is branchwood. Measurements on carbonized branchwood disclose up to two annual growth rings per mm, so that even quite small branches can have significant inbuilt age.

The identification of *Metrosideros* sp. (pohutukawa) is interesting, because it is not native to Norfolk Island (Wallace, 1998). It is possible that some charcoal from recently-introduced *Metrosideros excelsa* has managed to get into the site, but it was found in two excavation areas and it may indicate either the former existence of a native *Metrosideros* sp. on Norfolk Island (it is a prominent native on Raoul Island and Lord Howe Island), or the prehistoric introduction of the genus. The charcoal could have come as *Metrosideros* timber in prehistoric artefacts, such as canoe components, or *Metrosideros* sp. may have been brought as seeds. Wallace (1998) points out that *Metrosideros kermadecensis* is dominant on Raoul Island, existing as an almost pure forest over the Low Flat site (Anderson, 1980); any soil around plants carried from Raoul would probably contain *Metrosideros* seed, which is highly abundant, and seed would have ended up in any canoe pulled up on the Low Flat foreshore. *Metrosideros* might have grown at Kingston around the Polynesian settlement, perhaps then dying out as the Norfolk pine forest reclaimed the abandoned site.

The distribution of the charcoal samples amongst broadleaved taxa (Table 1) shows that 20 of the 33 woody plants native to Norfolk Island occur in the Emily Bay charcoals. These indicate the existence of a mixed coastal forest of trees and shrubs. The main species in the charcoals (with common name and maximum height) were *Nestegis apetala* (Ironwood, 6 m), *Rapanea ralstoniae* (Beech, 6 m), *Elaeodendron curtipendulum* (Maple, 13 m), *Ungeria floribunda* (Bastard oak, 15 m) and *Baloghia inophylla* (Bloodwood, 7 m). Bastard oak is quite rare today, whereas white oak (*Lagunaria patersonia*) which is common today and grows under the Norfolk pine forest at Emily Bay, is fairly rare in the charcoal samples.

On the basis of the taxonomic identifications it is possible to divide the charcoal samples used for radiocarbon determination into three groups. Group A comprises samples

Table 1. Distribution of charcoal samples and pieces by identified broadleaf taxa at Emily Bay.

broadleaf taxa	number of charcoal samples	number of charcoal pieces
Rapanea ralstoniae	18	87
Elaeodendron curtipendulum	15	78
Ungeria floribunda	14	50
Baloghia inophylla	14	49
Nestegis apetala	13	123
Dodonaea viscosa	7	18
Myoporum obscurum	6	29
Lagunaria patersonia	5	13
Melicytus ramiflorus	4	16
Dysoxylum bijugum	3	28
Pennantia endlicheri	2	2
Excoecaria agallocha	2	3
Streblus pendulinus	2	3
Sarcomelicope simplicifolia	2	2
Celtis paniculata	1	3
Melicytus latifolius	1	1
Pittosporum bracteolatum	1	2
Melicope littoralis	1	1
Coprosma pilosa	1	1
Rhopalostylis baueri	1	1
Metrosideros sp.	4	20

in which the charcoal is all from broadleaved taxa and derived predominantly from small tree or shrub species, plus shoots of Norfolk pine twigs (Table 2). Group B samples are of broadleaved taxa which are either unidentified to genera or are identified as being from larger tree species (Table 2). Group C samples are of Norfolk pine or unidentified charcoal.

Radiocarbon determinations on charcoal samples

Over the past decade there have been significant developments in radiocarbon age calibration, culminating in the publication of the 1998 INTCAL calibration curves (Stuiver *et al.*, 1998) which enable calibration from 0–24,000 cal B.P. In addition, there has been a growing awareness of the importance of careful sample selection in archaeological dating and the combination of radiocarbon determinations with prior archaeological knowledge, in the form of stratigraphic and contextual information (Buck *et al.*, 1996). In the dating of the Norfolk Island contexts, we were interested particularly in issues of occupation span and the evidence for earliest human occupation at the excavated site at Emily Bay.

We used the BCal calibration programme (Buck *et al.*, 1999) to help us to answer these questions of chronology in more detail. BCal enables relative archaeological *a priori* information (relative stratigraphy and archaeological provenance) to be used in association with radiocarbon determinations, within a Bayesian statistical paradigm (Buck *et al.*, 1996).

We developed a calibration model (see Figs. 1, 5) in BCal to evaluate the chronology at the Emily Bay EB97:23 and EB97:24 trenches. These two trenches yielded the majority of the Group A samples. In the model, certain mathematical symbols are used to describe the stratigraphic phases and boundaries at the site. α_n and β_n represent the beginning and ending dates of phase *n*. α_1 therefore represents the period preceding human occupation, while the late phase boundary of Spit 2 is represented by β_4 (Fig. 1).

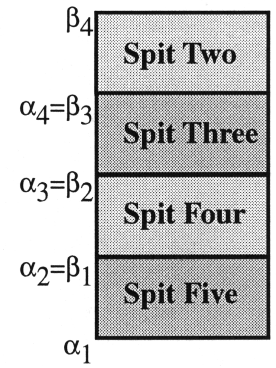

Figure 1. Calibration model for Trench EB97:23 at Emily Bay, Norfolk Island.

The calendar dates associated with individual radiocarbon determinations (termed $\theta_1 \ldots \theta_n$) (Table 3) from Trench EB97:23 were modelled within the constraints imposed by four stratigraphic phases, or spits. Spits 2, 3, 4 and 5 were modelled in BCal as abutting phases of shallow depth. Within each single spit, the radiocarbon determinations were assumed to be contemporary. The calibration model was run three times with a Markhov Chain Monte Carlo (MCMC) sampler of 50,000 iterations collected at a sampling interval of 50 (Buck *et al.*, 1996).

Table 2. Charcoal composition of Group A and Group B samples from Emily Bay.

laboratory number	ANU-11037	ANU-11041	ANU-11042	ANU-11043	ANU-11046	ANU-11047	ANU-11050	ANU-11051	WK-6901	WK-6902	WK-6903	WK-6904	ANU-11035	ANU-11036	WK-6905
charcoal Group	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B
broadleaf taxa															
Ungeria floribunda	—	—	2	—	—	—	3	6	—	5	3	3	2	2	7
Lagunaria patersonia	—	—	—	3	2	—	—	—	3	—	3	—	2	—	—
Elaeodendron curtipendulum	—	—	3	2	9	4	—	—	2	6	4	—	12	11	—
Pennantia endlicheri	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Celtis paniculata	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—
Metrosideros sp.	—	—	—	—	—	—	—	—	—	—	—	—	6	5	3
Baloghia inophylla	6	—	5	1	2	7	—	6	—	—	3	2	7	1	—
Nestegis apetala	3	1	—	20	—	—	—	—	30	25	12	—	3	—	3
Dodonaea viscosa	—	—	—	—	—	—	—	—	—	7	1	—	2	—	—
Myoporum obscurum	—	15	—	2	5	—	2	3	—	—	—	—	—	—	—
Rapanea ralstoniae	1	4	10	3	15	6	—	—	—	—	3	—	—	—	3
Melicytus latifolius	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Dysoxylum bijugum	—	—	—	—	—	—	—	—	—	—	—	25	—	—	—
Streblus pendulinus	—	—	—	—	—	—	—	3	—	—	—	—	—	—	1
Pittosporum bracteolatum	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—
Coprosma pilosa	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Melicope littoralis	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Rhopalostylis baueri (seed)	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Norfolk pine twig	—	—	—	—	—	—	—	4	—	—	—	3	—	—	—

Table 3. Individual posterior date calendar distributions for each determination from EB97:23, as simulated in BCal. The HPD regions given are at 95% probability and are rounded to five years.

calendar date	laboratory number	HPD region
θ_1	ANU-11043	A.D. 1065–1080,1125–1135,1160–1295
θ_2	Wk-6902	A.D. 1240–1315
θ_3	Wk-6903	A.D. 1245–1320
θ_4	ANU-11037	A.D. 1275–1335, A.D. 1340–1380
θ_5	Wk-6901	A.D. 1275–1330, A.D. 1345–1385
θ_6	ANU-11042	A.D. 1295–1330, A.D. 1340–1400
θ_7	ANU-11041	A.D. 1300–1415
θ_8	ANU-11051	A.D. 1300–1435
θ_9	ANU-11046	A.D. 1300–1445

Prior to the analysis of the radiocarbon determinations, we hypothesized that the variation in Norfolk Island radiocarbon determinations upon charcoal samples might be related to inbuilt age. We therefore applied an outlier analysis to the Group A radiocarbon dataset at EB97:23 at Emily Bay to consider whether there were grounds for considering some determinations as affected by inbuilt age. We ascribed a prior outlier probability of 10% to each radiocarbon determination. With the exception of ANU-11042 (780±70 B.P.) which produced an posterior probability of 12%, the determinations were less than the 10% prior outlier applied. We concluded therefore that there are no outliers of significance.

The Group A results for EB97:23 span 790–530 B.P. (Table 4). We examined the group boundary parameters (early and late) for the determinations from each of the four stratigraphic components in this trench. These parameters represent the calibrated ages for the start and end of the groups. The posterior probability density for the earliest date of human occupation at this area of the site is represented by α_1. The most likely calendar date range (or ranges) for each parameter outlined in Fig. 1 are represented by highest posterior density (HPD) regions. The HPD region for α_1 at 95% is 1520 B.C. to A.D. 1295, with a modal value of A.D. 1220 (see Fig. 2). The modal value is the calendar age associated with the highest probability value. The terminus of occupation at the site is represented by β_4. The range for this parameter is A.D. 1300–1540 with a modal value of A.D. 1410 (Fig. 3). The overall range for occupation inferred for the EB97:23 area at 95% is 55–3,000 years, with 200 years yielding the highest probability (Fig. 4).

There are four Group A radiocarbon determinations from Trench EB97:24 (Table 4). The calibration model for these is shown in Fig. 5. The individual conventional radiocarbon ages support an occupation dating to the late thirteenth to fourteenth centuries A.D. A Bayesian analysis suggests a total elapsed occupation span of 10–2,740 years, with the highest probability (modal value) at 100 years (Fig. 6). The range for α_1 was 1350 B.C. to A.D. 1390 with a modal value of A.D. 1300. This represents the earliest likely date for human occupation given the present data. Taken together, the analysis supports an occupation which began after A.D. 1300 and lasted for about a century. Confidence in this interpretation is reduced by the small number of dated samples from this area.

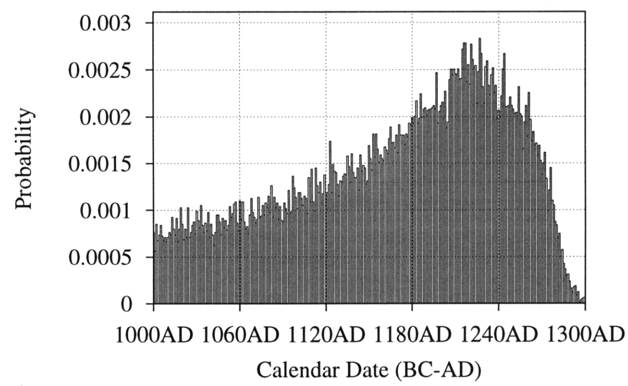

Figure 2. Posterior probability distribution for α_1 at EB97:23.

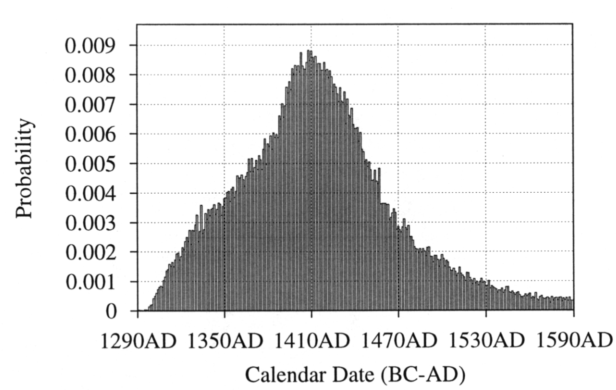

Figure 3. Posterior probability distribution region for β_4.

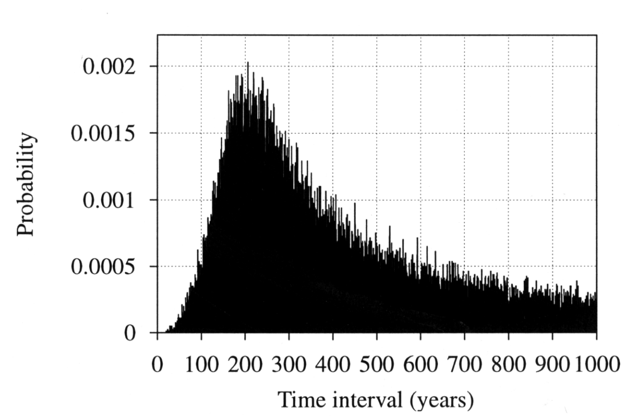

Figure 4. Total elapsed occupation span for cultural horizons at EB97:23, α_1–β_4.

Group B results from several trenches at the Emily Bay site are on material which could contain a higher inbuilt age. They are more variable, with the conventional radiocarbon ages spanning 400 radiocarbon years, three of them older than 800 B.P. (Table 5). Group C results are on material from Cemetery Bay and Emily Bay which, at least where it is identified as Norfolk pine, is likely to be significantly in error by reason of inbuilt age. They are the most variable of results, with conventional ages spanning 650 radiocarbon years, six of them older than 800 B.P. and three younger than 500 B.P. (Table 6). The young determinations remain enigmatic. They are too old to be

Table 4. Group A radiocarbon determinations from Emily Bay.

lab number	trench	square/spit	CRA (B.P.)	$\delta^{13}C$	calibrated 1SD (A.D.)
ANU-11037	EB97:23	Square B7 Spit 3	790±120	-24±2	1162–1300
ANU-11042	EB97:23	Square C7 Spit 2	780±70	-24±2	1217–1290
ANU-11041	EB97:23	Square D6 Spit 2	670±80	-24±2	1281–1398
ANU-11046	EB97:23	Square E7 Spit 2	530±70	-24±2	1327–1333, 1395–1441
ANU-11043	EB97:23	Square E10 Spit 5	760±70	-24±2	1225–1295
WK-6902	EB97:23	Square E12 Spit 4	750±45	-26.0±0.2	1255–1292
WK-6901	EB97:23	Square F10 Spit 3	720±45	-26.2±0.2	1277–1299
WK-6903	EB97:23	Square F10 Spit 4	710±45	-24.6±0.2	1280–1301
ANU-11051	EB97:23	Square A1 Spit 2	570±70	-24±2	1307–1361, 1378–1431
OxA-9629	EB97:24	Square A5 Spit 2	621±31	-26.6±0.3	1304–1370, 1370–1398
ANU-11050	EB97:24	Square A6 firepit/posthole	540±90	-24±2	1310–1354, 1385–1444
ANU-11047	EB97:24	Squares B1 & B2 Spit 3	590±110	-24±2	1293–1436
WK-6904	EB97:24	Square B4 Spit 2	740±55	-24.3±0.2	1256–1297

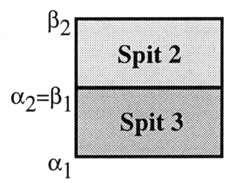

Figure 5. Calibration model for Trench EB97:24 at Emily Bay, Norfolk Island.

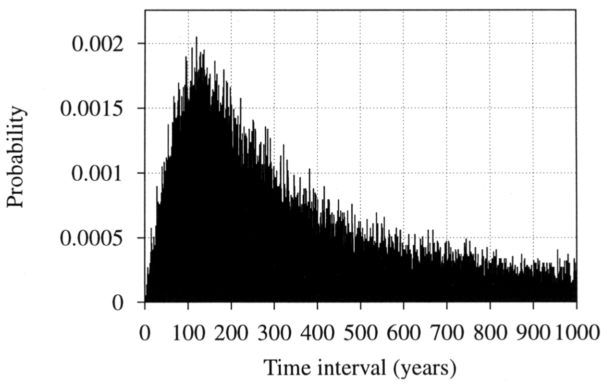

Figure 6. Total elapsed occupation span for cultural horizons at EB97:24; α_1–β_2.

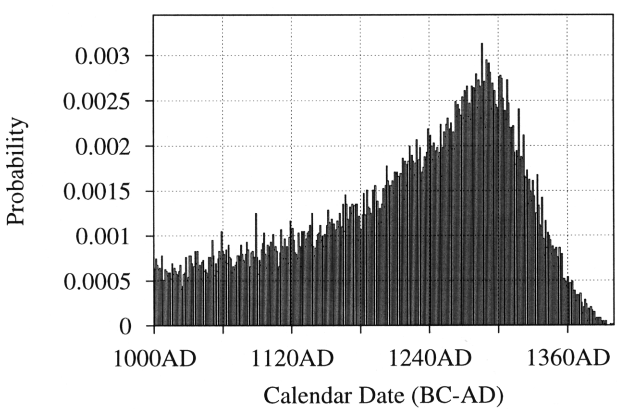

Figure 7. Posterior probability distribution of α_1 from EB97:24.

from European settlement and inbuilt age cannot be a significant variable in their measured ages since this influences radiocarbon determinations to be older, rather than younger. Whether they represent the last flickerings of the main prehistoric occupation, some later-arrived settlers, or are derived naturally from post-occupational forest fires, cannot be determined with confidence.

Neither Group B nor Group C samples were calibrated with BCal because of the sample constituent problems and the small numbers of dated samples from stratigraphically defined features. We conclude that the radiocarbon results for Group A samples from Trench EB97:23 are the most reliable since they are the largest and best identified assemblages of radiocarbon determinations for the excavation at Emily Bay. They provide support for an occupation which began in the thirteenth century A.D. The nature of the site suggests a brief period of occupancy, but this is not supported by the radiocarbon determinations which span 790–530 B.P., and suggest the highest probability associated with a period of c. 200 years of occupation from first settlement. This may imply that inbuilt age, even amongst the Group A samples, is still a significant influence in spreading the ages determined. Alternatively, it may suggest a more extensive span of occupation in prehistory than expected.

Radiocarbon determinations on marine shell

Determinations on marine shell samples are listed in Table 7. All of the determinations were from *Nerita atramentosa*, the most common shell species in the Emily Bay site. *Nerita* is an herbivorous grazing gastropod of the upper tidal zone, probably taken in largest numbers from the calcreted sandstone shore rock and tidal reef at Emily Bay. One question which arises regarding the marine shell series from Norfolk Island is the size of the marine reservoir offset. Radiocarbon assays of marine shell may be calibrated using the marine calibration curve which uses a box diffusion model based on the atmospheric ^{14}C record to determine an average world ocean curve (which incorporates a 400 year reservoir), from which local offsets (ΔR) can then be applied (Stuiver *et al*., 1998). In the absence of samples of known-age shell from Norfolk Island, the value for ΔR must be set to 0±0 yr, which assumes that the reservoir of surface ocean

Table 5. Group B radiocarbon determinations from Emily Bay.

lab number	trench	Square/Spit	CRA (B.P.)	$\delta^{13}C$	calibrated 1 SD (A.D.)
ANU-10701	EB96:10	Square A5 Spit 1	830±60	-24±2	1168–1278
ANU-10702	EB96:10	Square A5 Spit 2	730±70	-24±2	1251–1303
ANU-10703	EB96:10	Square B1 Spit 1	710±70	-24±2	1276–1377
ANU-10704	EB96:11	Square A1 Spit 1	1,010±110	-24±2	898–907, 961–1165
ANU-10705	EB96:11	Square A1 Spit 2	610±70	-24±2	1298–1409
ANU-11035	EB97:21	Square Z2 Spit 1	800±70	-24±2	1192–1286
ANU-11036	EB97:21	Square Z2 Spit 2	760±70	-24±2	1225–1295
WK-6905	EB97:24	Square C3 Spit 2	830±75	-25.6±0.2	1163–1281

waters in this region is typical of the average world ocean. Calibrating marine shell under these circumstances might involve a degree of error, because the local reservoir may be significantly different from the average world ocean value due to upwelling effects, for instance. One means of testing this is to radiocarbon date samples of known-age shell from the pre-bomb (earlier than A.D. 1950) reservoir and ascertain the size of the offset. In the absence of known-age shell, an alternative is to date stratigraphically identical marine and terrestrial samples, and determine the offset between them. In this instance, radiocarbon determinations of charcoal and *Nerita* shell from similar contexts produced ages at odds with that expected, with *Nerita* older by up to about 600 years. Why?

Marine and estuarine shellfish construct calcium carbonate within a small gap between the shell mantle and the body of the organism. Calcium and bicarbonate (HCO_3) are taken up by the organism from external sources, with the HCO_3 usually dominated by dissolved inorganic carbon (DIC) in the ocean water, as well as metabolic carbon from ingested marine microorganisms or algae. $CaCO_3$ is deposited from within the extrapillial fluid in the inner shell mantle. Determining the source, or sources, of carbon for shell carbonate precipitation is important in determining whether a marine shell is likely to prove reliable for routine radiocarbon assay.

One source of uncertainty in the dating of shell from Norfolk Island is the presence of calcareous rock substrates (that are radioactively dead), which may be an influence on shell radiocarbon concentrations if there is dissolution of the rock in the spray zone into a form which could be taken up by a living shellfish, such as the bicarbonate ion.

There is also the question of post-depositional contamination. The principal contaminant is likely to be dissolved carbonate which recrystallizes onto the surface of archaeological shell within a site. If that dissolved carbonate is of significantly different age then the radiocarbon age will be affected. One test for this contamination is to use powder X-Ray Diffractometry (XRD) to determine the crystallinity of the prehistoric samples. Since carbonate from post-depositional environments precipitates in the form of calcite, the presence of calcite in a naturally secreting aragonitic organism is a good test of recrystallization.

We collected modern samples of *Nerita atramentosa* and analysed their shell carbonate structures using XRD to determine their natural crystallinity. The samples were both calcite and aragonite, as were the prehistoric examples. This presents problems for determining isotopic exchange post-depositionally for the reasons outlined above.

There is some information in the literature regarding calcareous substrates and their influence on radiocarbon dating samples of archaeological marine and estuarine shell. Dye (1994), for instance, obtained radiocarbon determinations which yielded considerable variation between species of shell of known-age collected from the Hawaiian Islands. Some of the dated shells are of the same genus (*Nerita* sp.) as those from Norfolk Island, and just as common amongst

Table 6. Group C radiocarbon determinations from Emily Bay and Cemetery Bay.

lab number	Site/Trench	Square/Spit/Unit	CRA (B.P.)	$\delta^{13}C$	calibrated 1 SD (A.D.)
I-11019	Cemetery Bay	Unit C4	715±75	—	1261–1307, 1360–1379
I-11303	Cemetery Bay	Unit C4	840±160	—	1022–1298
Beta-6821	Cemetery Bay	Unit C4	850±50	—	1165–1255
Beta-6822	Cemetery Bay	Unit C4	800±50	—	1217–1282
ANU-10160	EB95:06	Square A2 Spit 1	390±70	-24±2	1443–1634
ANU-10159	EB95:06	Square A3 Spit 2	880±60	-24±2	1049–1228
ANU-10157	EB95:06	Square A4 Spit 2	480±70	-24±2	1396–1614
ANU-10158	EB95:06	Square A4 Spit 3	810±70	-24±2	1185–1284
WK-6900	EB97:23	Square E12 Spit 2	320±45	-21.5±0.2	1489–1605, 1613–1649
ANU-11195	EB97:24	Square A1 Spit 3	700±60	-24±2	1279–1307, 1360–1379
WK-7821	EB97:24	Square A5 Spit 3[a]	810±45	-24.3±0.2	1215–1280
ANU-11170	EB97:24	Square A5 Spit 2[b]	690±60	-24.2±2	1281–1310, 1353–1386
ANU-11171	EB97:24	Square B4 Spit 2[a]	970±60	-24±2	1013–1162

[a] under paving
[b] posthole in SE corner

Table 7. Radiocarbon determinations on shell samples from Emily Bay.

lab number	Site/Trench	location	CRA (B.P.)	$\delta^{13}C$	calibrated 1 SD (A.D.)
WK-7299	Pt Ross	basaltic substrate	112.8±0.6% M	1.2±0.2	
WK-7298	Cemetery Bay	calcareous substrate	105±0.5% M	3.4±0.2	
WK-6898	EB96:10	Square A2 Spit 1	1,380±50	3.5±0.2	640–677
WK-6897	EB96:10	Square A4 Spit 1	1,440±45	3.7±0.2	601–656
WK-6894	EB97:23	Square D10 Spit 5	1,510±45	3.9±0.2	539–616
WK-6899	EB97:23	Square F12 Spit 3	1,480±50	4.2±0.2	547–641
WK-6896	EB97:24	Square A3 Spit 1	1,420±45	4.1±0.2	612–662
WK-6895	EB97:24	Square A5 Spit 2	1,560±45	4.0±0.2	424–560

prehistoric midden contexts. Dated *Nerita* samples yielded apparent ages up to 1740 years older than paired charcoal samples. Dye (1994) suggested that the most important variable in determining apparent ages was the substrate of the shell samples because freshwater inputs were negligible in their influence. Older shell determinations were consistently from locations with limestone substrates and younger determinations were from sites with volcanic substrates. Dye (1994) concluded that old carbon from limestone sources was making its way either indirectly into the organism's carbonate through consuming algae which ingested the limestone, or directly by the molluscs scraping and dissolving the limestone as they browse.

Goodfriend and Hood (1983) have examined ^{14}C uptake in landsnails in Jamaica and the United States. They showed that limestone was a source for shell carbonate in these species and that limestone contributed to carbon building in this organism, along with terrestrial plant carbon and atmospheric CO_2. Inputs from limestone-derived carbon occur through dissolution by secretions in the foot of the organism and subsequent metabolic uptake. In addition, limestone nodules may be stored in landsnails in the digestive gland and foot, and dissolved in the gut with subsequent diffusion into the hemolymph where it may then be incorporated into the shell of the organism. The $\delta^{13}C$ value for land snail is c. 9–10‰, so the uptake of limestone-derived carbon may be identified from an analysis of the change in $\delta^{13}C$. Marine gastropods are very different organisms, but it seems reasonable to hypothesize that the mechanism for uptake in *Nerita* might involve the weathering of $CaCO_3$ from limestone into calcium bicarbonate under localized conditions through foot secretions, with subsequent incorporation into the shell.

We tested this hypothesis by dating post-bomb samples of *Nerita* of known-age, collected in 1999 from two different substrates; calcareous sandstone and basalt. The results were 105±0.5 pMC[1] for the calcareous substrate sample (Wk-7298) and 112.8±0.6 pMC (Wk-7299) for the basalt substrate. The results are clearly different, with the calcareous substrate sample yielding a lower pMC result and a $\delta^{13}C$ which mirrors those of the prehistoric samples. It is difficult to determine precisely the size of the offset from "true" age if the pre-bomb *Nerita* samples are taking up dead carbon from the calcreted sandstone substrate. If we estimate that there is a 7% contribution from the ^{14}C-free source, as the modern determinations imply, and we assume that the reservoir effect for Norfolk Island is the same as the average for the world ocean, then as a first approximation the net reservoir effect locally could amount to 800–1000 years. We think there is a possibility, then, that the older than expected ages might be caused by uptake of carbon from the local ^{14}C-free source based on the evidence to hand. The shell determinations of *Nerita* therefore appear to represent apparent ages too old by between 500 and 600 years. These conclusions might have implications for dating this species in other Pacific contexts, particularly where there is evidence for calcareous rock formations within the environs of the site. The application of a correction to these determinations would be premature and will remain so until additional data are obtained which tests the reliability of our estimated age offset in the *Nerita* samples. The shell determinations in Table 7 are therefore shown as uncorrected conventional radiocarbon ages (CRA) B.P.

Radiocarbon determinations on bone samples

Radiocarbon determinations on bone samples are listed in Table 8. The human bone sample was reported by Specht (1993: 152). Two fractions were dated as follows: ANU-7651A (apatite) 460±160 B.P. and ANU-7651B (collagen) 380±60 B.P. This sample is from burial 608 at Emily Bay, one of several burials exposed by high seas in 1936 (Specht, 1984: 32). Bulbeck and Groves (1984: 62) concluded that the morphology of the remains "eludes a straight racial identification [and] may well suggest a European×Oceanic hybrid status" of which they thought Polynesian characters the more prominent. However, the radiocarbon determination, even at two sigma (cal A.D. 1430–1654) is still comfortably older than European discovery. Perhaps this was a Polynesian burial.

There is a degree of uncertainty as well about the interpretation of the AMS determination, OxA-8749, upon the dog mandible (Smith, Clark and White, this vol.), which crosses the prehistoric/historical boundary. The sample was recovered by workmen digging a toilet pit outside the site and although other material collected then appears to be midden, the provenance is insecure. However, since a dog carnassial tooth was found in Trench EB96:11 within the site, the existence of dog prehistorically is probable. The pig mandible (OxA-8750, Smith, Clark and White, this vol.) is certainly modern. It came from the surface spit (1) of the cultural layer of Trench EB97:23 and it suggests, as does

[1] pMC is percent modern carbon, a ratio of the activity of the modern standard and the unknown sample activity as a percentage. 0 pMC is A.D. 1950.

Table 8. Radiocarbon determinations on bone samples from Emily Bay.

lab number	Site/Trench	location	material	CRA (B.P.)	$\delta^{13}C$	calibrated 1SD (A.D.)
ANU-7651	Emily Bay	eroded shore	human bone	380±60		1446–1635
OxA-8749	West Emily Bay	0.8 m below surface	canine mandible	205±40	-12.7	1658–1682, 1747–1805, 1935–1954
OxA-8750	EB97:23	Spit 1	pig mandible	50±35	-20.9	1900–1900, 1955
OxA-5781	Cemetery Bay	Unit C4	rat mandible	495±55	-19.2	1320–1460
NZA-6635	CB95:01	Layer 7	rat femur	1,077±79	-19.1	883–1067
OZC-697	CB95:01	Layer 7	rat femur	795±50	-18.3	1219–1283
OZC-699	EB95:06	Square A4 Spit 3	rat tibia	540±50	-20	1398–1434
NZA-6634	EB95:06	Square A4 Spit 1	rat tibia	1,206±94	-19.8	716–957
NZA-6631	EB95:06	Square A4 Spit 3	rat femur	1,142±86	-19.3	812–992
NZA-6630	EB95:06	Square A4 Spit 4	rat mandible	874±84	-19.3	1047–1244
OZD-833	EB95:06	Square A3 Spit 2	rat femur	600±50	-20.5	1305–1408
OZD-834	EB95:06	Square A1 Spit 2	rat femur	605±45	-17.9	1305–1405
NZA-8039	EB96:10	Cultural layer Spit 1	rat bone powder	552±50	-18.5	1326–1430
OxA-7953	EB96:10	Cultural layer Spit 1	rat bone powder	565±45	-18.7	1321–1421
OZD-105	EB96:10	Cultural layer Spit 1	rat bone powder	990±60	-20	1004–1156
OZD-975	EB96:10	Cultural layer Spit 1	rat bone powder	560±60	-18.9	1315–1431
Ua-14267	EB97:23	Square F7 Spit 1	rat femur	485±60	-19.7	1408–1451
OxA-8331	EB97:23	Square H1 Spit 1	rat femur	790±35	-18.3	1227–1282
Ua-14268	EB97:24	Square B3 Spit 3	rat femur	485±60	-19.7	1408–1451

some other material, that parts of the site had been exposed in the historical period.

All the remaining results are AMS determinations on whole or powdered bone from *Rattus exulans*. Radiocarbon dating of *Rattus exulans* bone, including of the Norfolk Island samples (Holdaway and Anderson, 1998) processed by the Rafter Laboratory in Lower Hutt, New Zealand (the NZA series), has been the subject of considerable debate (e.g., Anderson, 1996, 1997, 1998, 2000a; Smith and Anderson, 1998; Holdaway, 1996, 1999; Holdaway and Beavan, 1999) which need not be detailed here. Suffice it to say that the latest review of the data (Anderson, 2000a), argues that there is a strong correlation between unusually old radiocarbon determinations and the period of processing at the Rafter Laboratory. The Norfolk Island results (NZA-6630, 6631, 6634, 6635, Table 8) were processed in 1995–1996, during which all the anomalously old determinations on *Rattus exulans* samples from New Zealand were also produced. Consequently, they should not be regarded as reliable estimates of age.

Part of the process of testing radiocarbon ages on *Rattus exulans* samples involved inter-laboratory dating of aliquots from the same bone powder samples. The results NZA-8039, OxA-7953, OZD-105 and OZD-975 (all Table 8) are from this project. The first was processed at the Rafter Laboratory in 1997–1998 at a time when all rat bone samples produced ages consistent with archaeological expectations (Anderson, 2000a). Sample OZD-105 is one of several anomalously old results from early processing of *Rattus exulans* samples at the ANSTO Laboratory (Lucas Heights, NSW; series OZC, OZD). A second aliquot subsequently produced the result OZD-975 and the former result is regarded by ANSTO as unreliable. When the unreliable results are discarded it can be seen the remaining determinations from all laboratories are consistent with ages on other material types at about 600 years.

Distribution of radiocarbon determinations

The radiocarbon determinations do not indicate any differentiation in occupation age between trenches. The Bayesian analysis suggested that Trench EB97:23 area was most probably occupied A.D. 1220–1410 and EB97:24 area for about a century beginning soon after A.D. 1300. On Group B samples and other results, EB97:24 looks to be somewhat earlier, probably occupied in the thirteenth century A.D. Certainly, the distribution of Raoul Island obsidian through Trenches EB97:23 and EB97:24 indicates their general contemporaneity (Turner, Anderson and Fullagar, this vol.). The other main excavation, Trench EB96:10, produced determinations indicative of thirteenth century occupation, and while determinations are few and variable for other parts of the Emily Bay site, they do not contradict the proposition that habitation began in the thirteenth century A.D.

From the first results, referring to Trench EB95:06, it was apparent that there is no significant relationship of age determination with stratigraphy. The Emily Bay site is consistently shallow and disturbed, both by cultural activity at the time of occupation and by subsequent bioturbation, if not other factors as well. It is therefore impossible to test stratigraphically the occupation spans suggested by the Bayesian analyses, and alternative explanations cannot be ranked. Within the 100–200 year occupations suggested, sources of radiocarbon dating variability, not least in inbuilt age of materials, constitute a sufficient explanation, and certainly the low density and shallow depth of material everywhere in the site does not suggest that people were living at Emily Bay for more than a few decades at most. However, we must not lose sight of the fact that occupation on a similar scale to Emily Bay had probably once existed in Slaughter Bay, judging by the continuing recovery of adzes in the intertidal zone there, and that some occupation may have extended to, or occurred in, Cemetery Bay, not to mention other places where artefacts have been discovered on Norfolk Island. So, it is quite possible that Emily Bay, while not occupied continuously for 200 years, was frequently visited over a longer period than that in which it was inhabited most intensively.

The determinations from Cemetery Bay are fewer and none are on Group A or B charcoals, so they may have quite significant inbuilt age. Taking that possibility into account, an occupation span beginning in or about the thirteenth century A.D. (c. 800 years B.P.) seems probable. In summary, the prehistoric habitation of Norfolk Island probably began in the early thirteenth century A.D. and may have persisted until the fifteenth century (c. 600 years B.P.) or even later, as some results that are potentially of cultural origin suggest the sixteenth and early seventeenth centuries.

The Norfolk Island chronology in Pacific perspective

The Norfolk Island archaeological chronology is strikingly similar to that from elsewhere in the south Polynesian region (Anderson, 2000b). Assemblages of radiocarbon determinations have shown, contrary to some earlier evidence and conjecture, that the earliest-known archaeological sites in New Zealand were inhabited from the thirteenth century A.D., as notably at Papatowai (Anderson and Smith, 1992), Houhora (Anderson and Wallace, 1993) and Wairau Bar (Higham *et al*., 1999). Extensive radiocarbon databases compiled by the Rafter Radiocarbon Laboratory (Anderson, 1991) and the Waikato Radiocarbon Laboratory (Higham, 1993; Higham and Hogg, 1997), as well as a wide-ranging study of the calibrated ages (McFadgen *et al*., 1994), agree that there is no evidence of human habitation of New Zealand before 800–600 B.P.

An extensive colonization site on Raoul Island in the Kermadecs, discovered in 1979 (Anderson, 1980), has radiocarbon dates extending back to 1,000 B.P., but probably because the first set of charcoal samples were exclusively on charcoal from the long-lived pohutukawa tree, *Metrosideros* sp. Later research, using different sample materials, indicated that 650–600 B.P. was a better estimate of the advent of habitation (Higham and Johnson, 1996). A similar age, 800–600 B.P., is indicated on relatively short life span charcoals (*Phyllocladus* sp.) from a fireplace and associated midden at Sandy Bay, on Enderby Island in the New Zealand subantarctic region. In short, south Polynesia was settled at virtually the same time and very probably from within the same colonizing population out of central East Polynesia. The Norfolk Island chronology fits precisely into this pattern.

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