– ARTICLE –

The Power of Paradigms: Examining the Evidential Basis for Early to Mid-Holocene Pigs and Pottery in Melanesia

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ABSTRACT

The origin and timing of the introduction of pigs and pottery into New Guinea are contentious topics. Arguments have centred on whether domestic pigs and pottery technology entered New Guinea following the 'Austronesian expansion' from Southeast Asia into Island Melanesia, *c.* 3,300 calBP, or in the early to mid-Holocene. We review the history of the debate and present new dates on pig bone and pottery contexts from archaeological sites, including Taora and Lachitu, on the north coast of mainland Papua New Guinea (PNG), where earlier data supported claims for early pig and pottery. We argue that theoretical positions about 'Neolithic' origins in PNG influenced the relative willingness to accept early dates *prima facie* and conclude that current evidence shows neither pig nor pottery arrived before 3,000 calBP in mainland PNG.

Keywords: Papua New Guinea archaeology, Neolithic, animal domestication, pottery

INTRODUCTION

In the 1970s, archaeological researchers in PNG found pig bones and teeth in cave sediments radiocarbon-dated to between 12,000 and 6,000 calBP (Bulmer 1975, 1982: 188; White 1972: 92). One site, Wanelek, also yielded pottery sherds from levels dated to > 5,000 calBP (Bulmer 1977: 68, 1985). As pigs (*Sus scrofa*) are not native to New Guinea and no pottery of this age occurred in adjacent islands, the claims were controversial. The orthodox view was that pigs and pottery arrived in the mid to late Holocene with the Neolithic expansion of Austronesian-speaking farmers, notably of Lapita culture, through the western Pacific (Bellwood 1985: 219–241; Spriggs 1989: 605). Nevertheless, the claim for early pig was accepted widely (Bellwood 1979: 16; Golson 1991: 51; Groube 1989: 302; Yen 1990: 264), albeit with qualifications. For example, some archaeologists allowed the possibility that translocation of wild pigs preceded the introduction of domestic pigs 'in much the same way as cuscus, cassowary and other wild animals are transported between islands today' (White & O'Connell 1982: 187). The claim for early pottery was less readily embraced (White & O'Connell 1982: 190). Even Bulmer (1985: 130) conceded that an absence of pottery in neighbouring regions presented a problem of origins for the Wanelek finds and she proposed a possible connection with the Jomon pottery tradition of Japan.

Subsequently, advocates of early pigs and pottery cited new finds from early to mid-Holocene contexts in the north coastal lowlands (Gorecki *et al.* 1991; Swadling 1997; Swadling *et al.* 1989) and the Bismarck Archipelago (Allen 2000), as well as evidence of indigenous early Holocene agriculture in wider Melanesia (Golson 1977, 1991; Golson & Hughes 1980). Skeptics pointed to the absence of early to mid-Holocene Neolithic evidence in islands to the west of New Guinea, and emphasised the danger of associating radiocarbon dates from large chronostratigraphic units with small numbers of sherds or bone fragments that might have been vertically displaced by undetected bioturbation (Kirch 2000: 82, 125; O'Connor *et al.* 2002; Spriggs 1996a: 43–44, 1999: 17–18, 2001a: 238–240, 2001b). In addition, linguistic evidence linked the introduction of pigs to the dispersal of Austronesian-speakers in the late Holocene (Blust 1976, 2002; Haberland & Seyfarth 1974), and some supposedly ancient pig teeth were AMS dated as

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modern (Hedges *et al.* 1995).

So why were the early claims so readily accepted? We suggest that it was in part a consequence of the pioneering stage of West Pacific archaeology, in which many new excavations produced finds and dates that challenged the existing knowledge base. A more important reason, however, was that the debate about early pigs and pottery mirrored wider theoretical uncertainty about the relationship of the Island Southeast Asian Neolithic to the appearance of Lapita culture in the Bismarck Archipelago (see Allen 2000: 163; Spriggs 1997 for an outline of the debate). Some scholars favoured migration and intrusion to explain Lapita phenomena, arguing that the arrival of Lapita pottery, domesticated animals, and some crops and shell decorative items was linked to Neolithic developments in Island Southeast Asia (Green 1991; Spriggs 1989, 1996b, 1997), and that pigs and pottery could hardly have appeared in New Guinea before their arrival, via Lapita, in the Bismarcks. Other scholars favoured innovation and independent development to account for most aspects of Lapita culture in the 'Lapita homeland' of the Bismarck Archipelago (e.g. Allen 2000; Terrell 2004: 606). As Spriggs (2001a: 236) remarked, the 'supporters of an indigenous origin for the Lapita culture of the Bismarck Archipelago were happy to see an indigenous origin in New Guinea for this cultural complex rather than a derivation from Southeast Asian neolithic', and thus were predisposed to accept *prima facie* the case for early to mid Holocene pigs and pottery.

Recent comment has noted the way in which the concept of a Neolithic cultural 'package' (including pottery, sedentism, land clearance, 'new lithics', domestication and agriculture) influenced the thinking of many researchers steeped in historical interpretations of agricultural development in Europe and Southwest Asia (Bulbeck 2008; Denham 2004; Denham 2006: 170–174; Denham & Ballard 2003: 132; Donohue & Denham 2010; Gosden 1995: 816, O'Connor 2006; Szabó & O'Connor 2004; Terrell 2003; Terrell & Welsch 1997: 567–569). We argue that the concept of a 'Neolithic package' underpinned interpretations of all sides of the debate concerning New Guinea, and we pursue that theme, with reference to the particular debate about early pigs and pottery, in the light of new data from three sites on the mainland north coast, an area of critical significance for the entire debate.

BACKGROUND: THE EVIDENTIAL BASIS FOR EARLY PIGS AND POTTERY IN NEW GUINEA

A central pillar of the willingness of researchers to accept early dates for pigs and pottery was the evidence from Kuk Swamp in the Western Highlands (see Figure 1 for all localities), where various drainage features dating between 10,000 and 6000 calBP were argued to constitute firm evidence for agriculture (Golson 1977; Golson & Hughes 1980). Oval hollows of the same age were seen as 'resembling those commonly made by contemporary pigs to lie in' (Golson 2007: 113; Golson & Hughes 1980: 299). These propositions were made in the light of radiocarbon dates of mid-Holocene age on levels containing pig bone in highland rockshelter sites at Kafiavana, Kiowa and Yuku

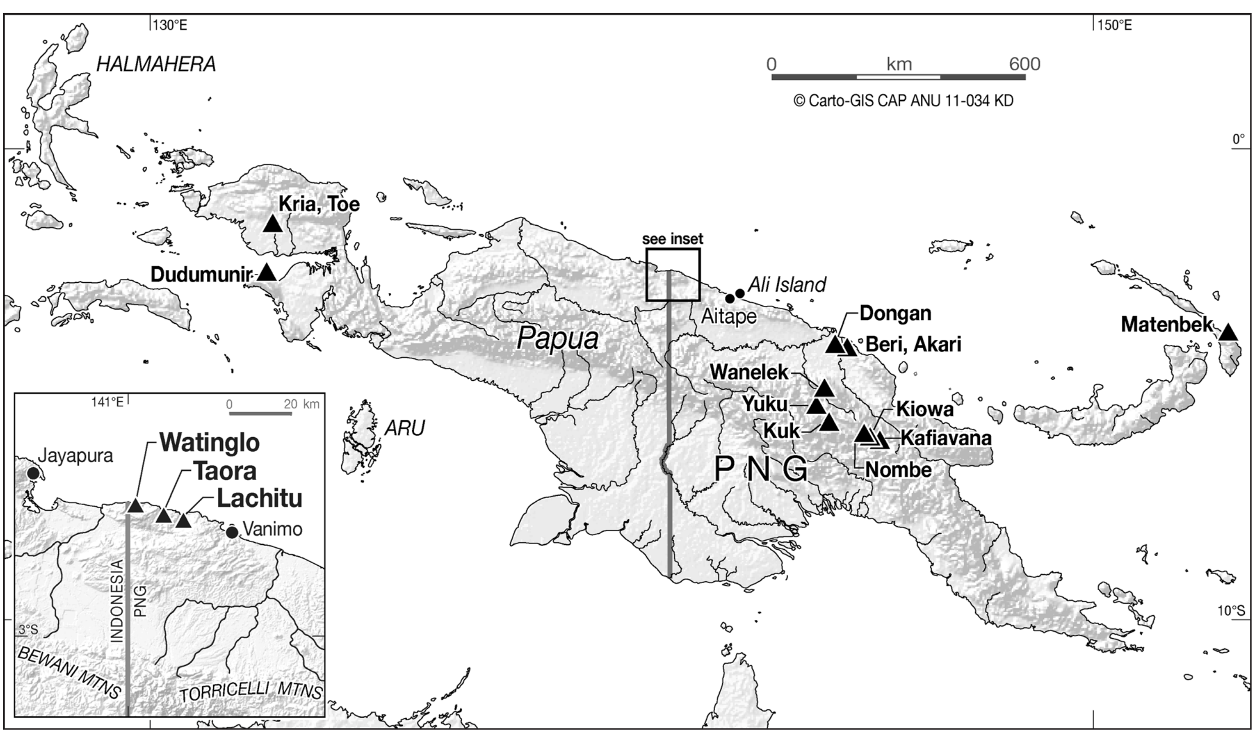

Figure 1. Map of New Guinea and region showing Lachitu, Taora and Watinglo and sites discussed in the text.

(Bulmer 1966; White 1972) and the report of a pig incisor from the lower levels of Kiowa with an associated radiocarbon date of 12,598–11,619 calBP[6] (Y-1366) (Bulmer 1975: 18–19, 36). Golson and Hughes (1980: 300) considered that the latter single date should not be ruled out as evidence, and indeed within a few years Bulmer (1982: 188) reported another pig incisor of the same age from the Yuku site.

Considering the tropical plants likely to have been cultivated at Kuk, Golson (e.g. 1991: 89) suggested that agriculture first emerged in lowland New Guinea during the terminal Pleistocene and expanded into the Highlands during early Holocene warming. His views appeared to be corroborated by other finds from Highlands and lowland sites. Evidence for domestication of tree crops was reported from Dongan, a lowland shell midden in the Sepik-Ramu Basin (Swadling *et al.* 1991). Here waterlogged anaerobic sediments preserved nuts and fruits of food species including galip nut (*Canarium* sp.), coconut (*Cocos nucifera*), screwpine (*Pandanus* sp.), possibly sago (*Metroxylon sagu*), and the stimulant betelnut (*Areca catechu*). Radiocarbon dates on charcoal indicated a mid-Holocene age. As betelnut was known to derive from Southeast Asia its presence seemed to represent exchange between Asia and PNG by 6,000 years ago. Dongan was seen, thus, as providing strong support for the cultivation or management of endemic tree crops *as well as* the surprisingly early introduction of economic plants from Southeast Asia. Together, these discoveries in PNG challenged the existing paradigm in which arboriculture was introduced to Melanesia from Southeast Asia only with the arrival of Lapita colonists (e.g. Kirch 1989: 228).

Early pottery and pig were also claimed for the Beri and Akari middens located on former open coast shorelines east of the Ramu River. Both were reported to have pottery to a depth of 50 to 70 cm in levels dated to 6,755–6,379 calBP (ANU 6087) and 6,436–6,060 calBP (ANU 6084) respectively (Swadling *et al.* 1989). It was argued that the pottery was not intrusive and that, with a marine reservoir correction of 400 years, 'pottery-making began in the area about 5600 BP' (Swadling *et al.* 1989: 109). The pottery in these middens bore no resemblance to Lapita ware and the ceramics were unchanged from the mid- to late Holocene. The excavators noted that the Dongan midden, dated 6,455–5,991 calBP (Beta 19707), contained no pottery or pig bone (Swadling *et al.* 1989: 108–109) but interpreted this as demonstrating that pottery making began in Ramu region just after occupation at Dongan had ceased, or alternatively, that the Dongan site preserved only a restricted range of activities as the 'the occupants had their main settlement elsewhere' (Swadling 1997: 7; see also Swadling *et al.* 1989).

Later, Swadling *et al.* (1991: 104–105) provided further dates and site description for Akari which shows that the site had been extensively disturbed by quarrying shell for lime manufacture. The midden was pockmarked with pits of 1–2 m in diameter, at such a density that it was difficult to find undisturbed areas to place the test pits. Site stratigraphy was poorly defined and the excavator's assessment that the areas selected for excavation were undisturbed was apparently based on the fact that the shell species that were prime targets for quarrying were still present in some number. The new radiocarbon dates also demonstrated that a mid-Holocene association for the pottery was problematic. Samples from Spit 5 at Akari A, at least 10 cm above the lowest pottery, dated 1,813–1,310 calBP (ANU-7081) on charcoal, and 7,015–6,553 calBP (ANU-7082) on shell (Swadling *et al.* 1991: 106). As the authors admit, this raises 'serious problems about the antiquity of the pottery and other artifacts, as well as the pig and dog remains, recovered in spit 6 upwards' (Swadling *et al.* 1991: 106).

However, in later works Swadling (1996, 1997) overlooks these concerns:

> By 5,000 years ago the people living on the north coast of New Guinea had pigs. These pig finds are the oldest known from coastal and lowland areas of New Guinea. They also made pottery and had shell ornaments and tools. Their pottery technology came from Southeast Asia...In summary the almost simultaneous introduction of pottery making from Southeast Asia to New Guinea 5,000 years ago indicates that trade networks linked the coastal communities of this region (Swadling 1996: 51–53).

Swadling's case for a ceramic connection linking mainland New Guinea with Southeast Asia rests in large part on the incised and appliqué ware from Dudumunir cave on Arguni Island in West Papua. While undated, this pottery was said to be similar to decorated ware from sites in East Timor which at the time was believe to date to *c.* 5,000 years BP (Ellen & Glover 1974: 373). Swadling argued that pottery and economically important plants such as betelnut were moving from Southeast Asia east into Melanesia in exchange for valued goods such as bird of paradise feathers from New Guinea and spices from the eastern Moluccas (Swadling 1996: 52).

Extending this argument, and in the total absence of evidence, Swadling proposed that the incised and appliqué ware at the Akari midden was earlier than, and provided a stylistic antecedent for, some of the pottery (also incised and appliqué) found in low frequencies in Lapita sites. Lapita pottery could therefore be seen not as a Southeast Asian derivative, but rather as a local innovation in New Guinea which built on earlier pottery styles introduced thousands of years earlier through the Moluccas. Swadling (1997: 10) further argued that the corollary of this situation, the 'absence of birds of paradise in the New Guinea Islands (the Bismarck Archipelago) may explain the lack of early

6 Unless they appear in quotations all dates herein are presented as calibrated ages 2σ using OxCal 4.1 with DeltaR set at '0' for marine shell dates.

applied and appliqué pottery in these islands', hence the absence of a pre-Lapita pottery tradition.

Evidence for early pig domestication bolstered Swadling's (1997) case for a pre-Lapita pottery tradition. However, rather than coming from the middens, the critical evidence was derived from excavations in limestone caves near Vanimo, also in the north coast lowlands of mainland PNG. Gorecki (*et al*. 1991) and colleagues dug two trenches in Taora shelter, a 2 x 1 m trench (X2 and X3) and a 1 x 1 m pit (F4). The lowest date obtained on charcoal from the base of X2 was 7,034–6,170 calBP (ANU 7605). They reported that 'pig remains (*Sus scrofa*) were found throughout the deposit' (Gorecki *et al*. 1991: 120). Thirty-five pottery sherds were said to derive from mid-Holocene levels. In X2 and X3 pottery was reported as absent below a level dated to 6,135–5,583 (ANU 7604), but present above the level dated to 5,927–5,568 calBP (ANU 7702), while in F4 pottery was said to be absent in the level dated to 6,270–5,814 (ANU 7612), but present in the overlying level dated to 5,968–5,587 calBP (ANU 7611), (Gorecki *et al*. 1991: 120–121). The excavators were 'aware of the importance of these dates and of possible vertical displacement of artefacts, yet…are confident that pottery first appears at Taora about 5400 years ago. Taora…supports strongly the claim for the presence on mainland New Guinea of a pottery tradition that substantially pre-dates the Lapita tradition' (Gorecki *et al*. 1991: 120–21).

At Lachitu cave nearby, a 1 x 1 m pit (X1) a lower unit produced a Pleistocene date of 17,035–15,680 calBP (ANU 7603), but the excavators (Gorecki *et al*. 1991) noted several phases of non-occupation or cultural hiatus, including one dated between 6,642–6,289 calBP (ANU 7602) and 892–625 calBP (ANU 7698) from adjoining units. Gorecki et al. (1991: 121) reported 112 stone artefacts as derived from the excavation along with a total of 80 pot sherds 'most of which were in the upper 5 cm of the deposit'. Gorecki's unpublished notes on the finds from X1 show 3 sherds occurring in the unit dated to 6,642–6,289 calBP (Table 1). The faunal assemblage included 'a great variety of shellfish' but 'few and fragmented' faunal remains including fish and various marsupials. Pig remains were not mentioned. In 1991 Gorecki returned to Lachitu and excavated a further 3 m^2. Details of the recovered finds and sections were not published but Gorecki's unpublished notes on Square Y1 show that a few sherds were recovered from mid-Holocene contexts (Table 1). Again, the notes make no reference to pig bones or teeth in the Lachitu deposit although 'rather large bones' are noted from a depth of 5–10 cm.

At Matenbek Cave on New Ireland, two isolated pig teeth were found in an early Holocene layer (Allen & Gos-

Table 1. *Distribution of pottery and radiocarbon dates in Lachitu pits X1 and Y1, excavated by P. Gorecki in 1990 (compiled by SO from Gorecki's unpublished notes). Radiocarbon dates were calibrated using OxCal 4.1. For calibrations on marine shellfish DeltaR was set to '0'.*

LACHITU	Spit	Depth cm	Material	Lab No.	Age (BP)	Age 2σ calBP	Pottery weight (g/N)
SQUARE X1	1	0–5	charcoal	ANU-7697	260 ± 60	489–260 (70.4%)	292/68
						222–140 (18.9%)	
						27 to −4 (6.0%)	
	2	5–10	marine shell	ANU-7698	1,180 ± 70	892–625	31/9
	3	10–20	marine shell	ANU-7602	6,040 ± 80	6,642–6,289	5/3
	4	20–30	marine shell	ANU-7609	6,010 ± 90	6,643–6,260	
	6	40–50	marine shell	ANU-7699	12,700 ± 110	14,935–13,901	
	9	85–115	marine shell	ANU-7700	13,970 ± 200	17,110–15,829 (92.5%)	
						15,805–15,620 (2.9%)	
	10–11	115–130	marine shell	ANU-7603	14,340 ± 160	17,494–16,747	
	12	130–140	marine shell	ANU-7610	35,410 ± 1400	42,706–36,978	
SQUARE Y1							**Pottery Excavator's comments:**
	1–2	0–10					finding rather large bones and pot sherds
	3	10–15					sharp reduction in pottery
	4	15–20	marine shell	ANU-7928	5,850 ± 60	6,404–6,148	a few pot sherds
	5	20–25					one tiny pot sherd
	6	25–30					one tiny sherd
	10	45–50	marine shell	ANU-7927	8,880 ± 70	9,739–9,409	
	15	70–75	marine shell	ANU-7926	14,910 ± 90	17,944–17,223	
	23	110–115	marine shell	ANU-7925	13,360 ± 90	16,314–15,080	
	25	130–140	marine shell	ANU-7924	13,270 ± 120	16,309–14,913	

den 1996: 190–191). Allen (2000) argued that the teeth were firmly *in situ*, based on an absence of apparent disturbance or of finds such as Lou Island obsidian, Pacific rat (*Rattus exulans*), dog, chicken or pottery which would indicate displacement of Lapita-aged materials into the early to mid-Holocene layer. He also stated that the physical condition of the pig teeth was consistent with other bone in the early Holocene layer, as opposed to the more weathered bone in the younger overlying inwashed deposits (Allen 2000: 158). His claim was not supported by subsequent direct dating of one of the teeth.

DIRECT DATING OF 'EARLY' PIG REMAINS

The first direct radiocarbon dates on pig bones were reported by Hedges et al. (1995: 428). Six teeth from the Eastern Highlands caves at Nombe (n=4) and Kafiavana (n=2) were dated by AMS; all specimens 'yielded particularly high, i.e. almost modern, levels of collagen' and returned age estimates of less than 500 years old. One of the Nombe pig teeth (Nombe J71, 534–4 calBP OxA-2541) was recovered from an occupation layer dated *c.* 11,000–5,000 calBP and another (Nombe R79, 282–5 calBP OxA-2536) from the 'red brown clay' unit which contained remains of extinct Pleistocene megafauna and was bracketed by dates of *c.* 30,000–19,000 calBP (Mountain in Hedges *et al.* 1995: 248). The two specimens from Kafiavana came from 60 cm and 100 cm below the surface, stratigraphically below a date of 5,745–4,877 calBP (ANU-42) (White 1972: 91–92).

Comments appended to Hedges *et al.* (1995: 428) by J.P. White and M-J. Mountain acknowledged the possibility that all of the pig teeth might be intrusive from younger units. However, they also noted evidence of early pigs reported by Bulmer and Gorecki, and concluded that 'even if we accept all this series of dates this does not thereby definitively dismiss the possibility of pigs in Papua New Guinea by 6000 BP' (Hedges *et al.* 1995: 428).

The apparently older of two pig teeth from the early to mid-Holocene layer at Matenbek was AMS dated. No details of the results have been published except the comment that a 'modern' age determination was returned (Allen 2000: 158). Allen (2000: 158) questioned the veracity of the modern date obtained for Matenbek as well as the dates produced by Hedges *et al.* (1995) on the basis that the excavators believed the finds were *in situ* and that accepting the dating results challenges 'the basic methodology of archaeological excavation'. Allen (2000: 158) explains the results by raising the possibility that pig bone may be prone to contamination and the dates therefore unreliable. The circularity of such arguments should be obvious.

Pasveer (2004) reported a direct date of 1,876–1,638 calBP (OZE 542) on pig bone from the upper 15 cm of the deposit, which also contained small amounts of pottery, at Kria Cave on the low elevation Ayamaru Plateau in West Papua. The date was considered a minimum age based on the chemical signature of the bone. A non-pottery bearing unit approximately 40 cm below the pig bone returned an age of 5,261–4,840 calBP (GRA9100) (Pasveer 2004: 54, 56). To this day, the Kria Cave specimen remains the earliest directly dated pig bone from Melanesia.

As part of this study, we obtained direct dates on pig elements from the newly excavated site of Watinglo in north coastal mainland PNG (Figure 1)(three bones, a metapodial, an occipital and a humeral fragment). All returned dates of less than 500 calBP (Table 2), although one was from a mid-Holocene context. The dates and context of the pig remains from Watinglo are discussed below.

NEW RESULTS FROM THE NORTH COAST LOWLANDS SITES OF TAORA, LACHITU AND WATINGLO

As one of the strongest claims for early pig and pottery in New Guinea was made by Gorecki *et al.* (1991) examining its evidential basis was a key aim of new research that commenced in 2004. Before undertaking new excavations, we sought to relocate Gorecki's excavated materials in the Museum and University of Papua New Guinea (UPNG).

Table 2. *Direct dates obtained on pig bones and teeth from Watinglo. Determinations were made at The Leibniz Laboratory for Radiometric Dating and Stable Isotope Research, Christian-Albrechts-University of Kiel, Germany. Sample preparation was carried out at the Max Planck Institute by Michael Richards.*

	Spit No.	Material	Lab No.	Age (BP)	$\delta^{13}C$ (‰, PDB)	Age 2σ calBP
	A/6	bone	KIA 35648	265 ± 25	−22.80 ± 0.14	429–376 (27.5%)
						367–360 (0.8%)
						325–281 (59.1%)
						169–152 (7.9%)
	A/8	bone	KIA 35649	220 ± 20	−20.26 ± 0.09	305–271 (39.9%)
						187–150 (42.9%)
						12 to −4 (12.6%)
	A/10	bone	KIA 35650	290 ± 25	−18.57 ± 0.09	437–350 (63.0%)
						334–290 (32.4%)

We found the faunal remains from 3 of the 4 excavation squares at Lachitu in the Natural Science Resource Centre in the Biology Department, UPNG, and Aplin's re-examination identified no pig bone. Subsequently, Jack Golson found a bag of Lachitu bones given to him by Gorecki. It was labeled 'piggish bones' but Aplin identified the bones as remains of cassowary and a large macropodid, probably a tree kangaroo. Some bone fragments could not be identified but none was judged likely to represent pig. No bone samples could be found for Taora, the cave where pig bone was said 'to occur throughout', potentially including levels dated to earlier than 6,000 calBP. Section drawings from the sites were never published so the dates and excavation units could not be matched to stratigraphy, nor could claims for lack of disturbance or bioturbation be evaluated. To tackle the problem, the best strategy was to excavate afresh.

PRELIMINARY RESULTS OF THE 2004 AND 2005 EXCAVATIONS

New excavations were carried out at Lachitu and Taora in 2004, and again at Lachitu and a newly discovered cave site called Watinglo in 2005. Excavation units averaged between 2 and 5 cm in depth. Samples of shell and charcoal were collected for dating from *in situ* locations within excavation units and from the sections so that excavated units could be correlated with any stratigraphic changes in the section undetected during excavation. All marine shell samples submitted for dating were tested for recrystallisation. All pottery visible in the plans or sections was recorded. All excavated deposit was sieved through a 1 mm mesh in combination with flotation to the <0.25 mm level which eliminated any possibility that tiny sherds, bones or teeth could have been overlooked, and also ensured maximum recovery of charcoal and other macrobotanic material.

Lachitu and Taora lie within 5km of each other in karstic limestone terrain at the foot of the Oenake Range, between the coast and the Bewani-Torricelli mountain chain (Klootwijk *et al.* 2003). The area is tectonically active with net uplift rates > 1.2 m/1000 years and likely movement associated with Holocene seismic events (see Tudhope *et al.* 2000). Taora is at *c.* 9–12 m a.s.l. and both the erosional notch and aspects of the sediment sequence and chronology of this site indicate the main phase of human occupation coincides with an active shoreline and back-beach abutting the limestone cliff around 7,000 years ago. Subsequently relative sea level fall has left the site 450 m inland. Lachitu lies only 150 m inland but at 22–24 m a.s.l. A steep scree slope seaward and immediately below the mouth of the cave might be a product of cliffline retreat and roof collapse, perhaps during the 7,000 calBP marine relative high stand. However, the cave floor area was never less than 12 m above the shoreline during the Holocene. Watinglo is further to the west, near the border with the Indonesian Province of Papua. It is approximately 1 km inland and at a height of 102 m a.s.l.

LACHITU

Three test pits (Squares A–C) were excavated, each of 1 m², and dug to a point where large rubble and local breccia-tion of infilling sediments hindered further removal (Figure 2). Only Squares A and C have thus far been dated. All radiocarbon dates obtained are shown in Table 3. Square A at Lachitu shows initial sediment infill into steep-sided hollows and clefts in underlying flowstone and bedrock (spits 31–23), dated to between *c.* 17,500 and 13,000 calBP (Figure 3). Artefacts in the infill include a waisted cobble in shell-dated horizons dating prior to 13,000 calBP. Episodic deposition of poorly sorted shelly deposits and shelly gravels continued through a phase of leveling-up with accumulation averaging >20 cm/1000 years. Elevated shelly breccias cemented onto the cave wall and the sides of two speleothem columns demonstrates that an infilling phase continued to higher than the present floor; a date of 7,400–6,995 calBP (OZI 282) was obtained from the

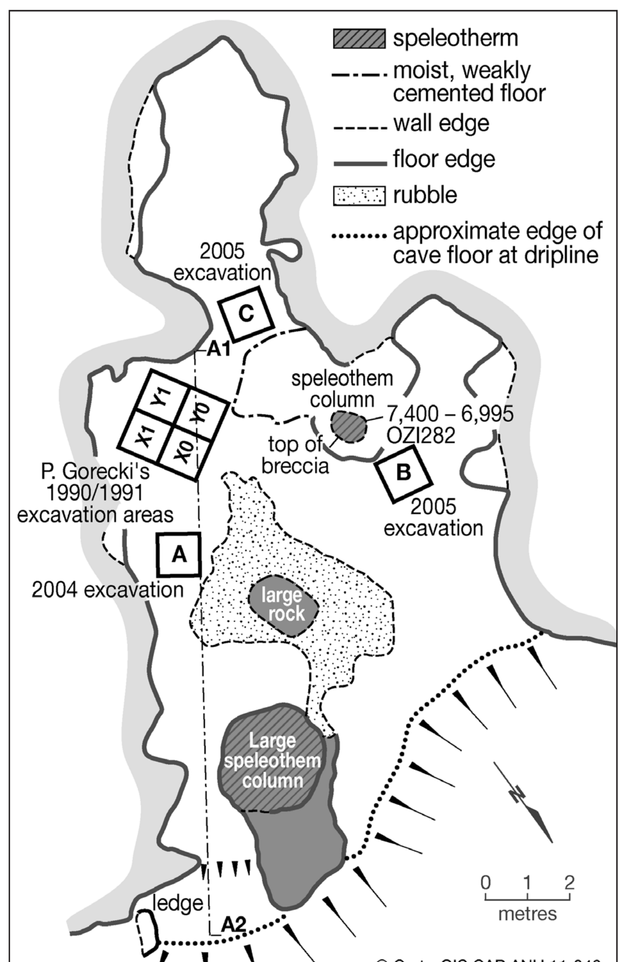

Figure 2. Plan of Lachitu showing location of all excavation pits, speleothem columns and a dated breccia deposit

Table 3. *Radiocarbon dates obtained after the 2004–2005 excavations in Lachitu, Taora and Watinglo. Radiocarbon dates were calibrated using OxCal 4.1. For calibrations on marine shellfish DeltaR was set to '0'. This table does not include the direct dates on pig from Watinglo which are presented in Table 2.*

Site	Spit No.	Material	Lab No.	Age (BP)	$\delta^{13}C$ (‰, PDB)	Age 2σ calBP
LACHITU						
SQUARE A	A/2 unit I	charcoal	Wk-16532	132 ± 34	−31.6 ± 0.2	280–171 (39.9%)
						152–57 (40.4%)
						45–7 (15.1%)
	A/4 unit I	charcoal	Wk-16533	160 ± 34	−28.7 ± 0.2	287–243 (16.9%)
						231–124 (46.4%)
						119–65 (14.6%)
						38 to −2 (17.6%)
	A/7	*Turbo* sp.	Wk-16524	6,399 ± 45	2.8 ± 0.2	7,000–6,741
	A/10 unit I	*Turbo* sp.	Wk-16523	6,519 ± 46	2.8 ± 0.2	7,155–6,901
	A/10 unit II	*Turbo* sp.	Wk-16525	6,842 ± 48	1.4 ± 0.2	7,446–7,260
	A/14	*Turbo* sp.	Wk-16526	9,695 ± 69	1.7 ± 0.2	10,735–10,392
	A/18	*Turbo* sp.	Wk-16527	24,140 ± 155	2.9 ± 0.2	29,065–28,000
	A/20 unit I	*Trochus* sp.	Wk-16528	25,436 ± 282	2.4 ± 0.2	30,444–29,380
	A/24	*Turbo* sp.	Wk-16529	11,753 ± 62	2.0 ± 0.2	13,353–13,108
	A/28	*Turbo* sp.	Wk-16530	10,825 ± 59	1.3 ± 0.2	12,553–12,436 (17.4%)
						12,418–12,060 (78.0%)
	A/31	*Turbo* sp.	Wk-16531	14,464 ± 92	3.6 ± 0.2	17,485–16,850
SQUARE C	C/6	*Turbo* sp.	Wk-17536	6,062 ± 46	3.2 ± 0.2	6,622–6,376
	C/8	*Turbo* sp.	Wk-17535	6,013 ± 50	2.8 ± 0.2	6,555–6,300
	C/14	*Turbo* sp.	Wk-17534	5,932 ± 45	2.6 ± 0.2	6,449–6,260
	C/24	*Turbo* sp.	Wk-17537	9,897 ± 78	0.9 ± 0.2	11,085–10,599
	C/38	*Turbo* sp.	Wk-17538	15,053 ± 167	3.2 ± 0.2	18,497–18,256 (12.3%)
						18,123–17,226 (83.1%)
LACHITU BRECCIA	Breccia C	*Turbo* sp.	Wk-17978	15,357 ± 109	3.6 ± 0.2	18,557–17,893
	Breccia D	*Turbo* sp.	Wk-17979	15,325 ± 97	3.6 ± 0.2	18,544–17,868
	Breccia	*Turbo* sp.	OZI282	6,680 ± 90	1.4 ± 0.2	7,400–6,995
TAORA	**SAMPLES from NORTH and WEST SECTIONS**					
	Spit 17	*Canarium* sp.	Wk-17902	5,655 ± 41	−26.0 ± 0.2	6,533–6,316
	West 1	*Turbo* sp.	Wk-15548	6,03834	3.3 ± 0.2	6,563–6,354
	West 2	*Turbo* sp.	Wk-15549	5,988 ± 31	3.4 ± 0.2	6,480–6,305
	West 3	*Turbo* sp.	Wk-15255	5,955 ± 51	2.3 ± 0.2	6,484–6,267
	West 7	charcoal	Wk-15256	5,853 ± 41	−25.6 ± 0.2	6,779–6,763 (2.0%)
						6,755–6,551 (93.4%)
	North 1	*Turbo* sp.	Wk-15547	6,067 ± 32	3.3 ± 0.2	6,594–6,397
	North 2	*Turbo* sp.	Wk-15254	6,122 ± 41	3.2 ± 0.2	6,658–6,437
WATINGLO						
SQUARE A	A/West section	charcoal	ANU-9419	445 ± 30	−24 ± 1.0	535–464
	A/6	*Turbo* sp.	ANU-9418	865 ± 25	2.0 ± 0.2	530–445
	A/9	*Turbo* sp.	Wk-17254	2,178 ± 38	2.6 ± 0.2	1,880–1,671
	A/10	*Turbo* sp.	Wk-17255	5,248 ± 51	2.6 ± 0.2	5,722–5,485
	A/14	*Turbo* sp.	Wk-17253	6,932 ± 65	2.4 ± 0.2	7,559–7,314
	A/East section	*Canarium*	Wk-17259	9,892 ± 65	−25.8 ± 0.2	11,605–11,526 (8.1%)
						11,501–11,199 (87.3%)
	A/71	*Canarium*	Wk-17260	9,990 ± 51	−25.9 ± 0.2	11,707–11,664 (4.4%)
						11,648–11,261 (91.0%)
	A/North section	*Turbo* sp.	Wk-17257	10,143 ± 53	2.1 ± 0.2	11,236–11,063
	A/86	*Terebralia* sp.	ANU-9420	10,445 ± 45	−2.0 ± 1.0	11,830–11,805 (1.0%)
						11,747–11,291 (94.4%)

Table 3. *Continued*

Site	Spit No.	Material	Lab No.	Age (BP)	$\delta^{13}C$ (‰, PDB)	Age 2σ calBP
WATINGLO						
SQUARE C	C/4	*Turbo* sp.	ANU-9423	800 ± 35	2.0 ± 2.0	502–334
	C/4	*Turbo* sp.	ANU-9424	895 ± 35	2.0 ± 3.0	593–583 (1.0%)
						567–447 (94.4%)
	C/4	charcoal	ANU-9425	270 ± 25	−26.0 ± 0.0	430–374 (35.3%)
						369–359 (1.7%)
						329–283 (53.7%)
						168–153 (4.7%)
	C/7	*Turbo* sp.	ANU-9426	6,755 ± 40	3.0 ± 2.0	7,390–7,190
	C/10	*Turbo* sp.	ANU-9427	880 ± 35	2.0 ± 3.0	551–439
	C/13	*Turbo* sp.	ANU-9430	6,810 ± 45	2.0 ± 2.0	7,419–7,246
	C/14	*Turbo* sp.	ANU-9432	6,295 ± 40	1.0 ± 2.0	6,868–6,648
	C/21	*Turbo* sp.	ANU-9433	7,400 ± 40	1.0 ± 2.0	7,953–7,768
	C/41	*Terebralia* sp.	ANU-9435	8,720 ± 50	5.0 ± 1.0	9,495–9,272
	C/48	*Terebralia* sp.	ANU-9436	8,590 ± 50	−2.0 ± 3.0	9,399–9,089
	C/53	*Turbo* sp.	ANU-9437	10,735 ± 45	−3.0 ± 2.0	12,329–11,960
WATINGLO BRECCIA	rear wall	charcoal	OZI 283	6,350 ± 110	−25.0 ± 0.2	7,469–6998

highest level of a breccia attached to a column near the centre of the cave (Figure 4). Acetic acid treatment of breccia samples produced cultural assemblages of broken and burnt marine shell and animal bones, plus charcoal and stone artefacts, i.e. they are comparable in cultural content with the non-brecciated lower unit. Detached breccia fragments occurred around the elevated remnants indicating episodic fretting of derived cultural material into the accumulating deposit.

The top 20 cm (spits 1–4) in Square A consist of fine sandy grits or sandy calcareous earths, typically less clastic and with discrete sandy-silty lenses. Ashy layers, interpreted as the remains of hearths, occur within shallow depressions unconformably over lower shelly units. Shell, especially large intact shells, forms less of the sediment by volume. This unit is a visibly active biozone, with evidence of mixing by invertebrates and burrowing by land crabs. A date of 287–modern calBP (Wk-16533) was obtained on charcoal in spit 5, directly overlying the shell-rich deposits of mid-Holocene age. Accordingly, there is little evidence

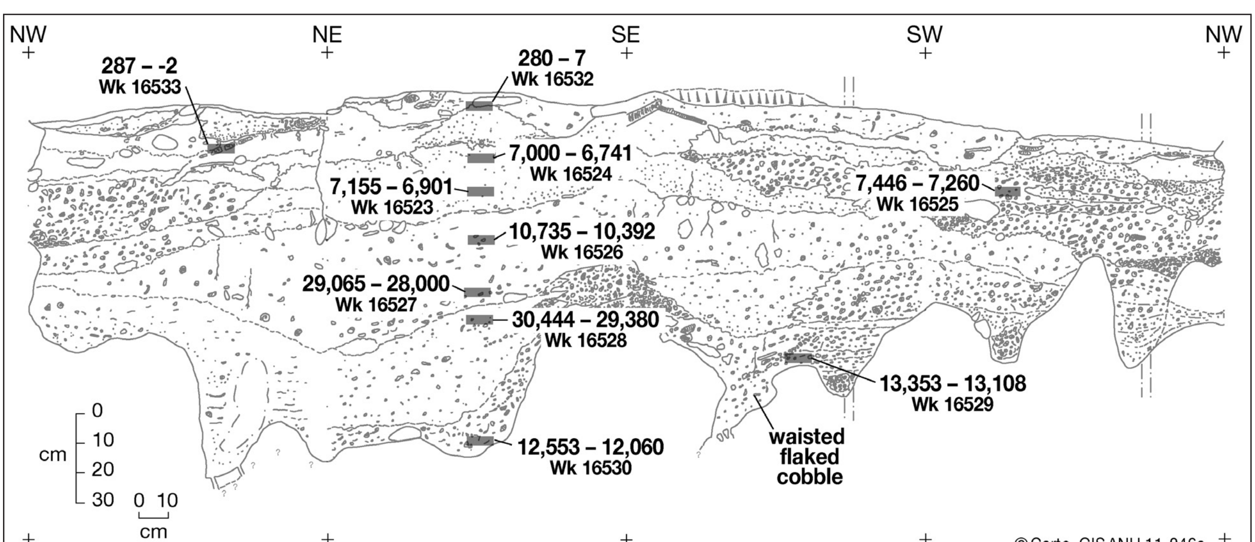

Figure 3. Section diagram for Square A, 2004 excavation at Lachitu, showing complex nature of stratigraphy and position of dated samples.

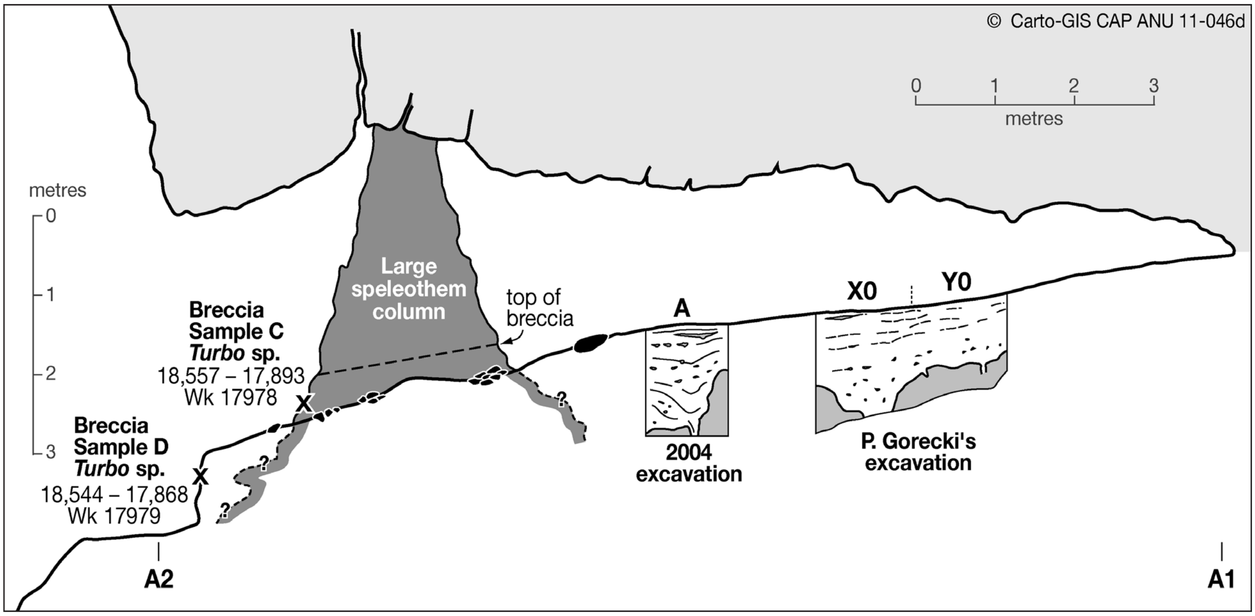

Figure 4. Profile of Lachitu showing the location of dated breccia deposits in relation to the excavation squares.

for net sediment accumulation in Square A between *c.* 6,000 and 300 calBP.

We obtained two shell dates of 30,444–29,380 and 29,065–28,000 calBP from within the early Holocene age unit and note that Gorecki obtained one standout date of 42,706–36,978 calBP (ANU 7610) from spit 12 of X1 (130–140 cm below surface), directly overlain by one of 17,494–16,747 calBP (ANU 7603) from 115–130 cm below surface. These early dates alert us to a much longer history of occupation as well as the probability of at least one major erosional episode prior to that which occurred subsequent to 6,600 calBP; whether any remnant of these earlier deposits remains *in situ* is currently unknown. Potentially, Gorecki's very early date from the base of Square X1 might represent an *in situ* brecciated unit separated by an erosional hiatus from the terminal Pleistocene deposits.

The stratigraphy and dating of Squares B and C represent minor variants on that reported above, with C producing a near basal date of 18,497–17,226 calBP (Wk 17538). In Square C an infilled rat hole was traced down from surficial layers to a depth of 85 cm and produced a partial skeleton of a native rat (*Rattus praetor*) from within the lowermost infill. Other bioturbation in the form of open or infilled crab burrows was noted during excavation of all squares. Contrary to Gorecki's claims, there is abundant evidence of bioturbation at Lachitu.

A moderate quantity of thoroughly fragmented but well-preserved bone was obtained, with an average in Square A of around 100 gm per spit (Table 4, Figure 5). A diverse suite of taxa is represented but all derive from rainforest habitats. In the lower levels are some taxa that are restricted today to higher elevation forests in the Bewani and Torricelli Ranges – a finding that parallels that documented for latest Pleistocene levels in Toé Cave on the Ayamaru Plateau of the Bird's Head (Aplin *et al.* 1999; Pasveer 2004; Pasveer & Aplin 1998). In contrast, the mid-Holocene levels contain a fauna typical of lowland rainforest habitats such as occur in the region today. A wide size range of prey items are represented, including tree kangaroos and cassowaries.

Fragments of pig bone and tooth were recovered from two of the three excavated squares. None were found in Square A. In Square B two fragments were recovered in spit 5, while Square C produced a single fragment of a molar in spit 2. The pig specimens all have a fresh appearance consistent with a portion of the associated faunal remains. Other bone from the same levels has undergone significant diagenesis and is partially encrusted in carbonate. These remains may be derived by lateral input from elevated breccia deposits, from other areas of cave floor subject to scour, or from older material vertically displaced upwards. What is very clear, however, is that the assemblage from the transition zone between the upper and lower units is a palimpsest of material of very different ages. A total of 202 sherds of pottery was recovered from Square A in Lachitu and ten of these were from spits dated at, or older than, 7,000–6,741 calBP Wk-16524 (Table 4).

Our re-excavation of Lachitu demonstrates that the site has undergone a major erosional phase and a depositional hiatus of unknown duration. Whether sediments from the period *c.* 6,700 to 300 calBP have been lost from the cave system or whether the cave was little occupied during this time cannot be ascertained at present but the former scenario is supported by dates on cultural material cemented in the breccias. Moreover, it is clear that any assemblage that relates to the critical period after 6,700 calBP

Table 4. *Stratigraphic distribution of major classes of cultural remains in Lachitu Square A. Excavated sediment weight does not include large pieces of limestone roof fall which were weighed separately.*

Spit no.	Bone (gm)	Lithics (g)	Pottery (g)	Pottery no.	Sediment (kg)	Age 2σ calBP & Lab. codes
1	9	8	22	8	32	
2	20	18	31	11	28	280–Modern, Wk-16532
3	9	365	–	–	45	
4	54	83	756	111	50	287–Modern, Wk-16533
5	31	28	271	54	33	
6	34	41	9	8	16	
7	49	43	12	9	58	7,000–6,741, Wk-16524
8	21	69	–	–	52	
9	17	158	1	1	52	
10	7	562	–	–	55	7,155–6,901, Wk-16523
11	34	1571	–	–	43	
12	14	314	–	–	43	10,735–10,392, Wk-16526
13	103	233	–	–	59	
14	59	215	–	–	80	
15	29	106	–	–	41	
16	123	429	–	–	58	
17	106	250	–	–	57	
18	204	287	–	–	62	29,065–28,000, Wk-16527
19	169	656	–	–	60	
20	65	484	–	–	44	30,444–29,380, Wk-16528
21	133	163	–	–	43	
22	100	367	–	–	43	
23	51	62	–	–	25	
24	129	239	–	–	29	13,353–13,108, Wk-16529
25	175	92	–	–	12	
26	156	254	–	–	21	
27	118	416	–	–	15	
28	82	273	–	–	17	12,553–12,060, Wk-16530
29	31	267	–	–	9	
30	17	–	–	–	8	
31	19	–	–	–	2	17,485–16,850, Wk-16531

is a palimpsest that could only be disarticulated through an extensive program of direct dating of its individual elements.

TAORA

A 1 m^2 excavation was conducted close to Gorecki's square F1 (Figure 6) in order to sample the same stratigraphy and activity areas. Excavation occurred to 100–178 cm below the surface where sterile beach sands or cemented sands were encountered (Figure 7). The stratigraphy and dating are broadly consistent with that reported by Gorecki *et al.* (1991).

The cultural deposit in Taora began to accumulate shortly after sea level stabilization and built up over a very short period (Figure 7). The site has wave-sorted cobble deposits northwards beyond the drip-line and >2 m below the present floor level. Stratigraphy in the 2004 excavation features shelly well-sorted beach sands in lower levels, indicating over-wash on a narrow cliff-base berm. Cultural material is present in the beach sand units, co-associated with coral blocks, suggesting initial occupation coincident with the maximum Holocene transgression on this uplifting slope. Subsequent relative sea level fall has left the site separated from the modern shoreline by forest. Upper units are more clastic and shelly throughout and had accumulated through cultural and natural deposition including sediment from rock-fall and inwash. A total of seven AMS dates, six on marine shell and one *Canarium* nut, all fall into the narrow time range between *c.* 6,800 and 6,300 calBP (Table 3). Small scale bioturbation involving crabs and other animals was noted during excavation, and there

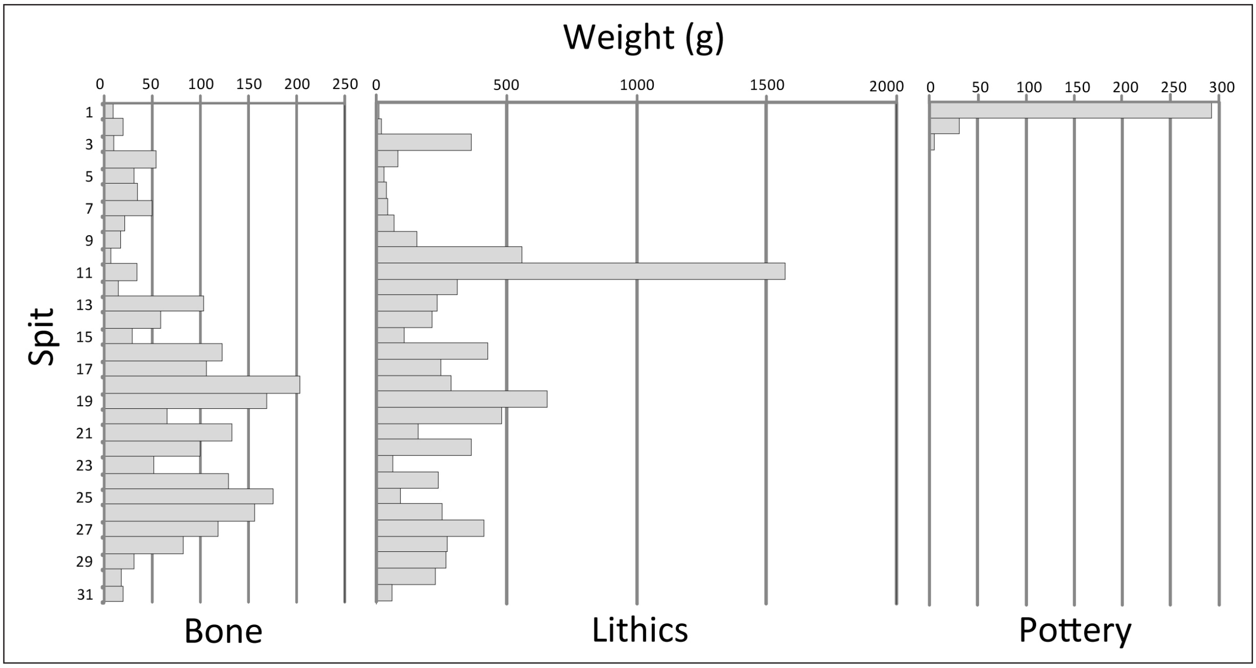

Figure 5. Graphical summary of vertical distribution of major classes of cultural remains in Lachitu Square A.

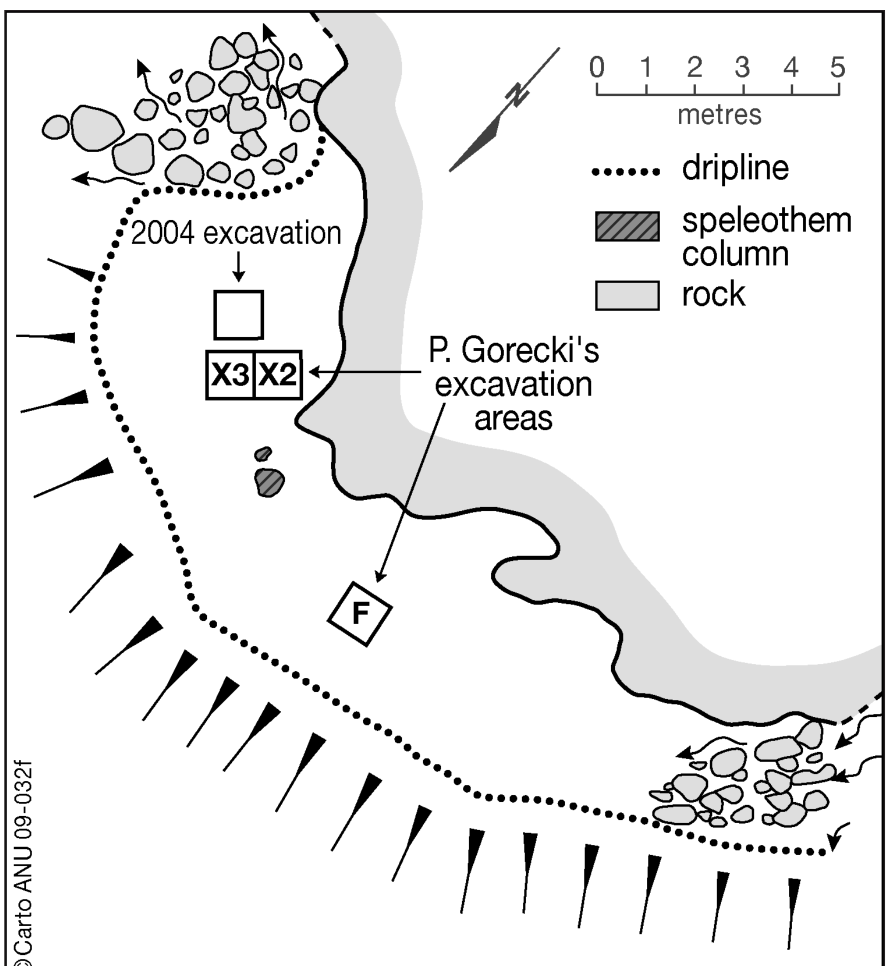

Figure 6. Plan of Taora showing the location of all excavation squares.

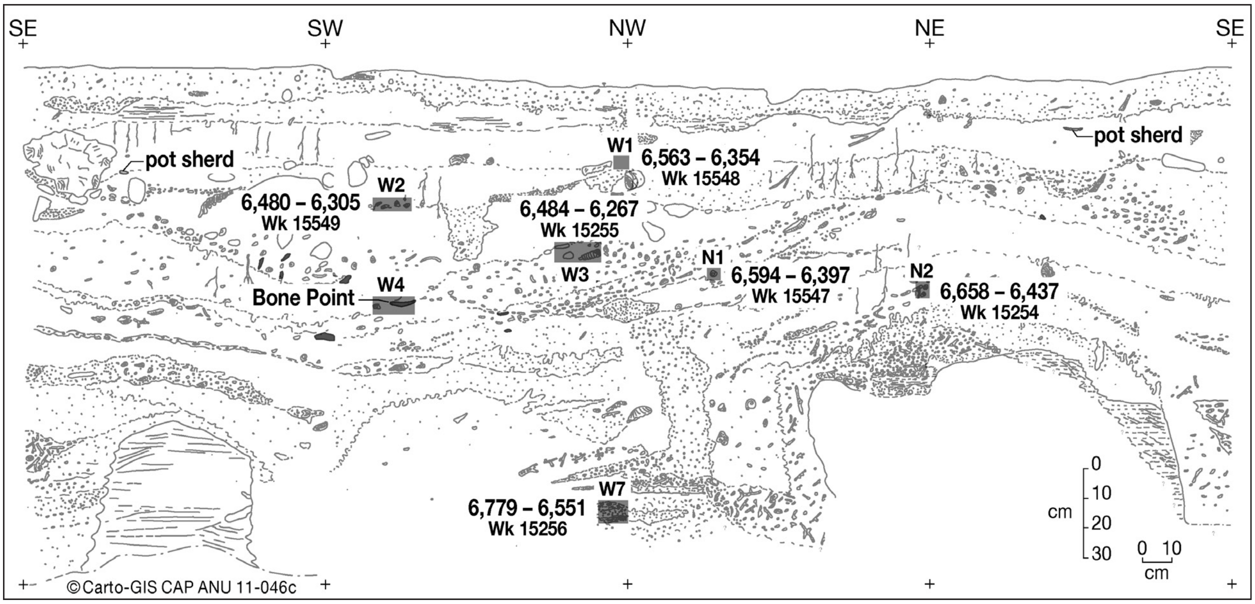

Figure 7. Section diagram for the 2004 excavation in Taora, showing details of stratigraphy and position of dated samples. All C^{14} determinations are presented as calibrated at two sigma.

was bioturbation where tree and vine roots had reached several metres into the deposit, but such deep bioturbation is uncommon and localised.

Shellfish are abundant throughout the deposit. Vertebrate remains are most abundant in the upper half of the deposit, with an average of 110 gm per spit (Figure 8). Below spit 17, this falls to an average of 16 gm per spit (Table 5). Fish bone is dominant but there is also crab and urchin, and a significant quantity of well preserved terrestrial mammal bone. While Gorecki *et al.* (1991:120) claimed that 'pig remains (*Sus scrofa*) were found throughout the deposit' we found no pig bone at all. Fragments of human bone were present in most spits down to 10, remains of tree kangaroo in spit 25, and turtle bone in spits 24 and 28. In the absence of Gorecki's collection it is not possible to refute his claim but our results suggest that the remains of other vertebrates had been mistaken for those of pigs.

The 2004 excavation at Taora recovered 693 pottery sherds (Table 5, Figure 8). Most were found in the top 6 spits, above sample W1 dated to 6,563–6,354 calBP. Not surprisingly, a few were found within the mid-Holocene levels. A notable addition to the Taora artefactual assemblage, not mentioned by Gorecki *et al.* (1991), is a large number of bone points in the assemblage (the majority between spits 9 and 16). The function of these items is presently unclear. Although no very recent dates were obtained from the Taora site, the fresh condition of much of the bone from the top 20–30 cm of the deposit is suggestive of late Holocene age. As at Lachitu, the period between *c.* 6,300 calBP and the recent past thus seems either to be missing from the Taora chronostratigrapy or incorporated into a palimpsest assemblage representing the last 6,000 years.

Figure 8. Graphical summary of vertical distribution of major classes of cultural remains in the 2004 excavation in Taora.

Table 5. *Stratigraphic distribution of major classes of cultural remains from the 2004 excavation in Taora. Excavated sediment weight does not include large pieces of limestone roof fall. With the exception of Wk-17902 the radiocarbon dates from Taora were obtained on samples of shell and charcoal removed from the sections at the completion of the excavation. They are shown in stratigraphic position on Figure 7.*

Spit no.	Bone (g)	Lithics (g)	Pottery weight (g)	Pottery sherds (N)	Excavated sediment (kg)
1	94	67	145	80	94
2	103	199	89	62	65
3	65	23	185	140	59
4	39	162	266	189	57
5	40	91	253	97	63
6	106	74	109	78	63.5
7	90	244	24	19	55.5
8	96	257	31	17	51
9	93	840	11	10	72
10	123	691	–	–	71
11	130	903	1	1	77
12	92	1524	–	–	77
13	56	1676	–	–	76
14	119	2026	–	–	70
15	232	2866	–	–	80
16	230	2429	–	–	79
17	184	1858	–	–	87
18	38	538	–	–	72
19	9	127	–	–	76
20	6	118	–	–	81
21	18	54	–	–	125
22	15	110	–	–	78
23	18	68	–	–	68
24	30	16	–	–	61
25	25	35	–	–	71
26	15	19	–	–	62
27	9	19	–	–	60
28	12	17	–	–	89
29	13	39	–	–	33
30	2	19	–	–	28

WATINGLO

In 2005 we excavated a newly-discovered, large, rockshelter known locally as Watinglo. It is within several hundred metres of the Papuan/PNG border, less than 1 km inland and *c.* 100 m a.s.l. Two 1 m² test pits were excavated, one metre apart (Figure 9). Square A reached *c.* 270 cm deep, terminating in deeply weathered limestone rubble that contained occasional mineralized bones but no shell or artefactual material (Figure 10). We cannot rule out the possibility that further cultural deposits underlie this weathered rubble, but it at least marks a significant hiatus in deposition. Excavation of Square C ceased at *c.* 205 cm depth before reaching the base of the cultural sequence, as large boulders covered most of the surface area of the square.

The stratigraphy at Watinglo mirrors that seen in Lachitu, with a principal division between surficial fine silts and sands containing small quantities of cultural material, and the main body of the deposit with much greater quantities of shell and other cultural remains (Figure 10). As in Lachitu, the lower part of the sequence in Watinglo accumulated as infilling of an irregular rubbly surface. However, the much greater depth of the Watinglo deposit means that the bulk of the deposit accumulated more or less horizontally and with little obvious indication of disturbance.

Radiocarbon dates from Square A (Table 3, Figure 10) are in correct stratigraphic order and indicate accumulation of the cultural sequence since the terminal Pleistocene, about 12,000 years ago. Relatively rapid sedi-

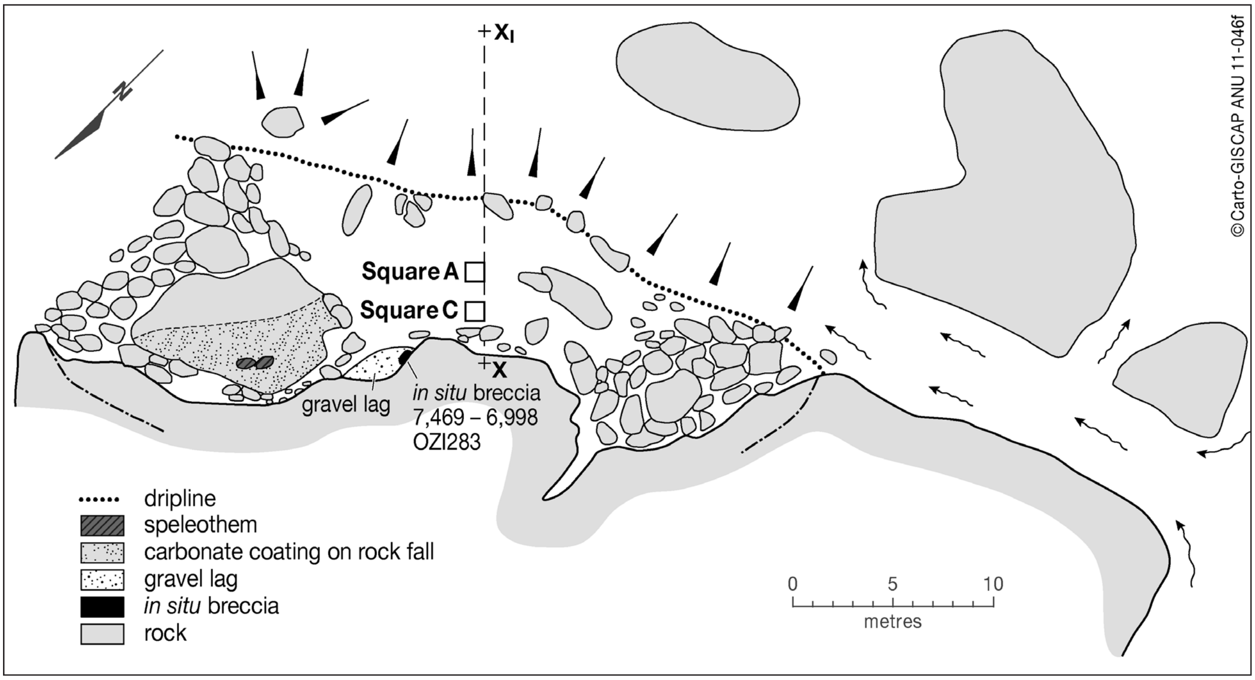

Figure 9. Plan of Watinglo showing 2005 excavation area and position of dated elevated breccia which included cultural materials.

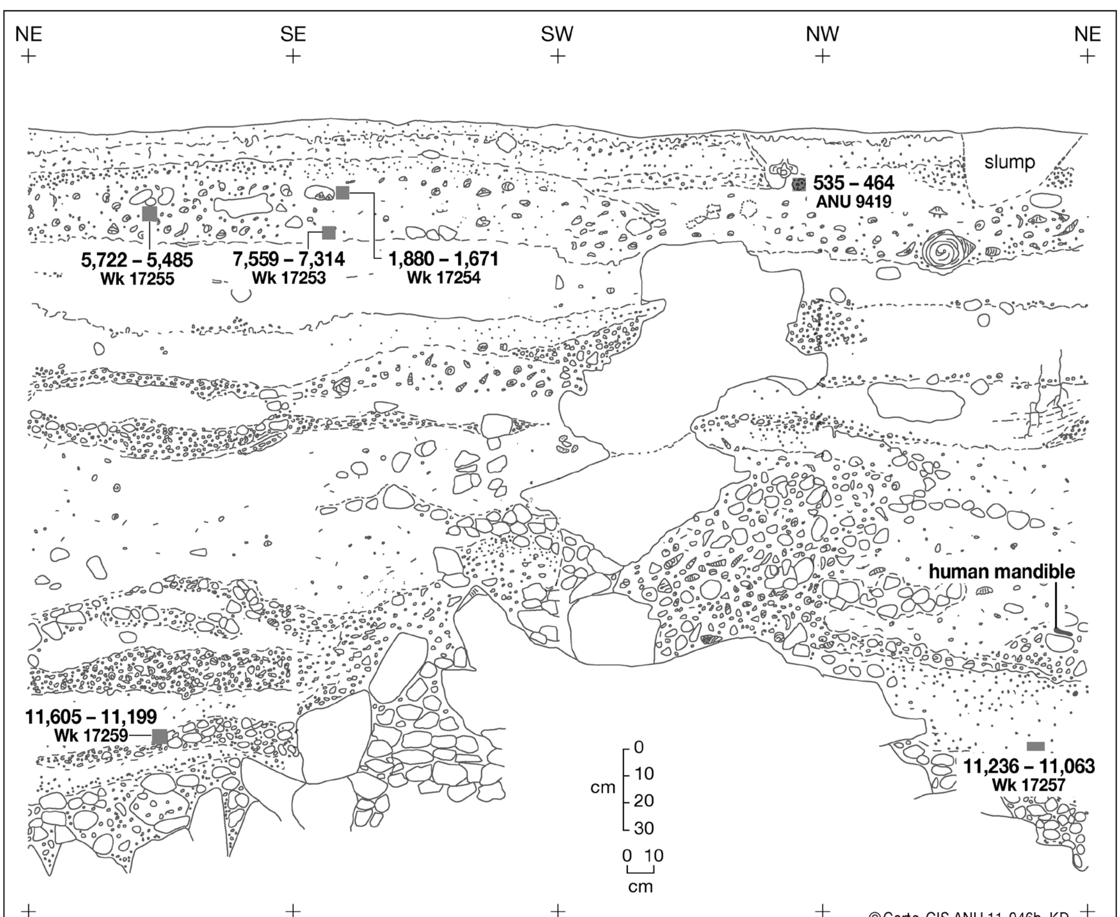

Figure 10. Section diagram for Watinglo Square A, showing details of stratigraphy and position of dated samples.

mentation occurred until *c.* 7,400 calBP but involved the deposition of a number of variably shell-rich zones. Bone and stone artefacts also show several distinct and correlated peaks (Table 6, Figure 11). A date of 5,722–5,485 calBP (Wk 17255) from Square A spit 10 is in correct sequence but suggests either a marked slowing of sedimentation rate, an erosional phase, or some local disturbance. Further dating is underway to clarify the explanation. However, it is

Table 6. *Stratigraphic distribution of major classes of cultural remains in Watinglo Square A. Excavated sediment weight does not include large pieces of limestone roof fall. Radiocarbon dates were calibrated using OxCal 4.1. For calibrations on marine shellfish DeltaR was set to '0'. Note: additional radiocarbon dates were obtained on samples taken from the sections at the completion of the excavation and are shown in stratigraphic position on Figure 10.*

Spit no.	Bone (g)	Lithics (g)	Pottery weight (g)	Pottery (N)	Excavated sediment (kg)	Age 2σ calBP & Lab. Codes
1	–	–	–	–	41.5	
2	–	–	–	–	43	
3	8	5	2	4	53	
4	23	–	12	5	38.5	
5	56	67	155	46	30	
6	47	89	157	45	35	530–445, ANU 9418
7	64	122	121	74	38	
8	54	143	137	100	45	
9	71	198	32	32	53	1,880–1,671, Wk-17254
10	175	135	1	1	45	5,722–5,485, Wk-17255
11	332	251	–	–	46	
12	222	212	1	1	35	
13	98	363	–	–	42	
14	110	328	–	–	39	7,559–7,314, Wk-17253
15	124	438	–	–	42	
16	139	324	–	–	42	
17	167	307	–	–	45	
18	132	67	–	–	43	
19	56	79	–	–	44	
20	26	12	–	–	59	
21	18	1	–	–	28	
22	51	6	–	–	27	
23	34	5	–	–	31	
24	41	21	–	–	46	
25	7	4	–	–	42	
26	25	–	–	–	48	
27	68	97	–	–	40	
28	53	–	–	–	34.5	
29	38	10	–	–	28	
30	35	37	–	–	44	
31	43	22	–	–	45	
32	94	97	–	–	53	
33	109	24	–	–	51	
34	60	2	–	–	39	
35	37	27	–	–	43	
36	32	161	–	–	49	
37	31	67	–	–	39	
38	21	34	–	–	41	
39	15	30	–	–	42	
40	–	–	–	–	47	
41	21	23	–	–	43	
42	31	15	–	–	39	

Table 6. *Continued*

Spit no.	Bone (g)	Lithics (g)	Pottery weight (g)	Pottery (N)	Excavated sediment (kg)	Age 2σ calBP & Lab. Codes
43	11	165	–	–	37	
44	14	52	–	–	43	
45	13	27	–	–	57	
46	9	12	–	–	53	
47	9	17	–	–	47	
48	9	2	–	–	49	
49	22	10	–	–	57	
50	6	29	–	–	55	
51	2	34	–	–	42	
52	20	149	–	–	51	
53	5	385	–	–	59	
54	7	85	–	–	56	
55	10	140	–	–	51	
56	21	100	–	–	47.5	
57	6	290	–	–	52	
58	41	189	–	–	48	
59	23	94	–	–	50	
60	29	147	–	–	53	
61	34	80	–	–	47	
62	18	177	–	–	39	
63	39	522	–	–	58	
64	75	693	–	–	50	
65	97	16	–	–	57	
66	88	24	–	–	63	
67	176	504	–	–	60	
68	62	55	–	–	44	
69	103	15	–	–	47	
70	117	13	–	–	56	
71	93	370	–	–	42	11,707–11,261, Wk-17260
72	60	351	–	–	41	
73	38	366	–	–	25	
74	61	6	–	–	46	
75	40	118	–	–	31	
76	28	67	–	–	36	
77	66	111	–	–	41	
78	43	135	–	–	43	
79	42	117	–	–	38	
80	39	172	–	–	28	
81	19	24	–	–	28	
82	16	34	–	–	63	
83	2	9	–	–	39	
84	15	74	–	–	64	
85	13	62	–	–	65	
86	14	9	–	–	73	11,830–11,291, ANU 9420
87	10	5	–	–	33	
88	2	–	–	–	20	
89	–	–	–	–	14	
90	–	–	–	–	11	
91	3	1	–	–	8	

Figure 11. Graphical summary of vertical distribution of major classes of cultural remains in Watinglo Square A.

interesting to note that a small block of brecciated sediment containing shellfish and other cultural remains is adhered to the cave wall approximately 30 cm above the adjacent floor level. This produced a date of 7,469–6998 calBP (OZI 283) and is thus broadly contemporaneous with the elevated breccias that occur in Lachitu. Some local erosion and deflation is implied, though perhaps not on the scale evident at Lachitu.

The stratigraphic boundary between the upper and lower units is relatively sharp in both squares, but shows local bioturbation, and is generally suggestive of an erosional disconformity. The upper unit is deeper in Square C than Square A and its lower boundary is contoured to suggest either a deeper scour channel running downslope, parallel with the cave wall, or a shallow prehistoric pit. Within the upper unit in Square C, several smaller discrete features were noted. One had the appearance of a shallow hearth while another contained some dissociated human remains and probably represents a shallow secondary burial. The upper unit produced a basal date of *c.* 1,800 calBP (Wk 17254) in Square A (Spit 9). The period between *c.* 5,500 and 2,000 calBP thus appears to be missing from the Watinglo lithostratigraphic profile. While this is a shorter hiatus than found in each of Lachitu and Taora, it nonetheless adds to the growing sense of widespread abandonment of, or disruption to, the sedimentary sequences of, local cave sites across the study area, starting in the mid-Holocene and continuing until sometime after 2,000 calBP.

Despite being located further from late Pleistocene and Holocene shorelines, Watinglo contains abundant marine shell of edible taxa throughout late Pleistocene and Holocene levels. It also produced a very large faunal assemblage that shows excellent preservation throughout. A plot of bone weight by depth for Square A shows three peaks, one in spits 13–21 that probably represents the period from *c.* 7,000–8000 calBP, a smaller peak of undetermined age but centred on spit 32–33, and a third covering spits 63–72 that covers the terminal Pleistocene – early Holocene (Figure 11). In Square C, the upper peak is much larger, with quantities in excess of 1000 gm of bone from spits 13–14. The presence of significant numbers of bone fragments at this level showing a uniform high gloss suggests a phase of water transport or rolling.

All of the Watinglo bone appears to be from human discard and most is derived from terrestrial vertebrates. Fish bone is relatively scarce in the lower levels and shows marked increases in abundance around spit 45 and again at spit 12. At no point does fish bone attain the degree of prominence that it has in the Taora assemblage. As in Lachitu, the mammal assemblage from the earliest Holocene levels in Watinglo includes species normally associated with montane habitats. These taxa are absent from the upper levels where all identified taxa are representative of lowland rainforest habitats.

Pig remains are present at Watinglo in most spits between 3–10 in Square A, and in spits 9–14 in Square C. Direct dating was performed on three definite pig bones; all returned ages less than 450 calBP (see Table 2). One of these specimens came from Square A, spit 10, that features the uppermost peak in bone quantities and produced a radiocarbon date on marine shell of *c.* 5,600 calBP (Wk 17255). A key observation is that pig remains are not present below this level, despite the continuance of large quantities of bone dating to the mid-Holocene.

Just over 300 pottery sherds were recovered from each of Squares A and C. In Square A the majority came from spits 5–9, with single sherds only from spits 10 and 12. Spit 10 yielded a C^{14} date of *c.* 5,600 calBP (Wk 17255). In Square C pottery extends in quantity down to spit 13 but is abruptly absent below this.

DISCUSSION

The chronostratigrapy of each of Lachitu, Taora and Watinglo has three elements in common, albeit with slight differences in dating and expression. In each, a phase of rapid sedimentation and cultural accumulation during the first half of the Holocene is terminated either by an erosional disconformity and, or, a marked slowing of deposition rate or an hiatus beginning about 7,000–6,000 calBP, with recommencement of archaeologically visible cultural activity only within the last 2,000 years or more recently. The result in each case is a palimpsest assemblage of older and more recent material; e.g. dated pig teeth that are only a few centuries old lying directly alongside marine shell dating to between 7,000–6,000 calBP. In each site, pottery and pig remains are found only within the context of the palimpsests and are convincingly absent from underlying *in situ* contexts dating from the terminal Pleistocene through to *c.* 6,000 calBP.

While these new observations clearly refute one of the key evidential bases for the claims of mid-Holocene pigs and pottery in Melanesia, several important questions remain. One is whether the chronostratigraphic hiatus in all three sites is itself alerting us to significant changes in settlement pattern and socioeconomics in the mid-Holocene, perhaps even a local 'Neolithic' expansion, but one without pottery or domesticated animals? Another is whether our conclusions regarding the antiquity of pigs in the north coastal lowlands of New Guinea has any bearing on the date of arrival of pigs elsewhere in Melanesia e.g. in the New Guinea Highlands or in the Bismarck Archipelago?

WHAT HAPPENED IN THE MID-HOLOCENE?

The dramatic shift around 6,500 calBP is one of the most striking features of the archaeological record on the north coast of New Guinea. Interestingly enough, a similar pattern is observed in many other individual sites and even regional records within wider Melanesia. Allen (2000), for example, identified a similar pattern in the cave sites in the Bismarck Archipelago and Admiralty Islands. He notes that while the cave sites of Buang Merabak, Panakiwuk, Pamwak, Matenkupkum, Kilu and Matenbek may have had periods of abandonment in the Pleistocene, often coinciding with the Last Glacial Maximum, all have evidence of fairly dense, if spasmodic, occupation in the terminal Pleistocene and early Holocene. Yet these same caves show 'increasingly fragmentary patterns of occupation in the mid and late Holocene'. Allen (2000:156) suggests that the abandonment or declining use of caves at this time may 'reflect an increasing sedentism, increasing group size, and a move to village life predicated on increasing the intensity of food production systems which we can gloss here as 'agriculture'.

Writing specifically about the north coast of mainland PNG, Swadling and Hide (2005) suggested that sea level stabilisation created hitherto unprecedented rich marine and lacustrine environments adjacent to fertile land and that these new settlement foci formed, over time, the basis of a new subsistence strategy involving locally developed horticultural strategies and marine or estuarine resource use. However, comparable trends are also observed in locations remote from coastal resources. For example, at Kria Cave (above) detailed analysis and dating of a deep deposit disclosed a relatively rapid accumulation in the early to mid-Holocene, followed by a probable hiatus and a resumption of deposition spanning the last few thousand years (Pasveer 2004). The nearby site of Toé Cave shows no obvious hiatus and has a shallower and more complex stratigraphy, but it too features a very low rate of deposition over the last few thousand years (Pasveer 2004).

Most cave sites in the New Guinea Highlands require more intensive dating to establish detailed chronologies (Bulmer 1982, 1991; White 1972). However, even with the available coarse chronologies, it is clear that many sites show a similar reduction in deposition rates of cave sediment and cultural materials during the mid- to late Holocene (reviewed by Sutton *et al.* 2009). Sutton *et al.* (2009:55) remark on the paradox of 'decreasing use of rockshelter and cave sites during the mid- and late Holocene, at times of presumably increasing human populations and increasingly intensive and extensive forms of agriculture'. They further note that 'simple correlations between variables are inadequate to understand economic and social transformations through time and their variable manifestation across space' and conclude that 'investigations at multiple sites are essential to reconstruct the temporal and spatial variability of past human-environment interactions in the highlands of New Guinea, as elsewhere' (Sutton *et al.* 2009:55). Significantly, a regional study of open sites in the Eastern Highlands found that the majority were first occupied around 4,500 years ago (Watson & Cole 1977).

While Lachitu, and to a lesser extent Watinglo, has evidence to support a mid-Holocene erosional event, we do not think that this explains the changes in cultural discard and sedimentation rates seen in the north coastal sites satisfactorily. Those changes seem to be reflected in cave, shelter and open sites, of different altitude and aspect on the mainland and in the New Guinea islands. If, as it currently appears, this pattern reflects broad scale change across Melanesia, then it seems likely that it signals a change in human settlement and activities. Perhaps as Allen (2000) and others have suggested there was a transition from a predominantly hunting and gathering lifestyle, requiring a high level of mobility, to a socioeconomic system based substantially on food production with its corollaries of greater dependence on spatially fixed resources, increased sedentism, and more spatially restricted and stronger sense of territoriality (e.g. Denham & Haberle 2008). Historical sources suggest that other factors leading to local depopulation in New Guinea, could include resource depletion, disease, or intertribal aggression, but unless they were generated by underlying regional factors, such as population growth or increased connectivity among human populations, then it is improbable that they would display the synchronicity evident in the data. Therefore, it is pertinent to ask what, other than a shift to an agricultural economy might have been capable of driving change on a sufficiently large geographic scale.

To establish what really happened in north coastal New Guinea and elsewhere in the region around 6,500 calBP, far more extensive, indeed landscape-scale, investigations are necessary. Studies by Gorecki and Swadling, with their emphasis on open and cave sites, respectively, laid the foundation upon which this work can progress. However, their conclusions, at least in regard to the antiquity of pottery and pigs, were flawed as a consequence of insufficient attention to stratigraphic detail and acceptance *a priori* of a theoretical model about 'Neolithic culture.' We turn to these issues.

WHEN DID PIGS AND POTTERY ARRIVE IN MELANESIA?

We have refuted claims that pigs were *in situ* in the mid-Holocene levels of cave sites in the Vanimo region of mainland New Guinea. But do these findings have wider application or significance? We argue that they do. The key issue concerns feral rather than domestic pigs. The elevational and habitat distribution of feral pigs today in New Guinea is not well documented but it is generally agreed that they are most abundant in lowland contexts, less so in montane forests, but common again in subalpine habitats (Hide 2003; Aplin pers. obs.). This is indicated by the relative socioeconomic importance of wild pigs in hunting returns from both the southern and northern lowlands compared with hunting in the hill forest or lower montane zone (Dwyer 1990; Dwyer & Minnegal 1991a, b; Gorecki & Pernetta 1989; Hyndman 1979; Kelly 1988; Morren 1986). It is also clear that feral pigs, once established, are not dependent on people and can attain high densities in lowland areas with low human population densities. For example, domestic pigs (*Sus scrofa*) were introduced to Australia by Europeans with the First Fleet in 1788 and within two hundred years had spread throughout all but the most arid and waterless regions of the continent (Feral.org.au).

Consequently, it is pertinent to consider how rapidly an introduced domestic pig population could lead to establishment of a feral population, and how rapidly feral pigs would spread from their source area. The question cannot be answered precisely but it is realistic to assume that feralisation was instantaneous on an archaeological time scale with pigs becoming established first in their preferred lowland habitats. If pigs had been present anywhere on the New Guinea mainland prior to 6,000 calBP then their remains should have been recovered in substantial quantities in mid-Holocene samples from Taora, Lachitu and Watinglo. Their bones and teeth should also have been found in large numbers in the lower units of Kria Cave. Their remains might also have turned up fairly frequently in contemporaneous assemblages from highland New Guinea. The fact that they are altogether absent from most of these assemblages, and return latest Holocene ages when dated by AMS, suggests strongly that pigs were not present on mainland New Guinea at that time.

Whether the same case can be made for the Bismarck Archipelago depends upon a detailed critique of the evidence but we suspect that claims for early pigs will be discredited and that, in further work, they will be associated earliest with Lapita culture in the Bismarck Archipelago, about 3,300 calBP (Summerhayes 2010:13, 24), or possibly even following this (Anderson 2009:1507). An important point in this regard, as Bellwood and White point out (2005:381), is that pigs are singularly lacking from sites in northern Moluccu prior to 3,500 calBP (Bellwood *et al.* 1998; Flannery *et al.* 1998). They are also absent before this time from excavated assemblages in the Aru Islands in south eastern Moluccu (O'Connor *et al.* 2005: 310). The Moluccas was the major gateway into New Guinea from the west, thus from the sources of pigs, so the absence of pigs in this region prior to 3,500 calBP has significant implications for the timing of their arrival in the east.

Recently published genetic data on pigs is also highly relevant to this issue. Using sequence analysis of mitochondrial DNA, Larson *et al.* (2005) initially identified a unique 'Pacific Clade' that included pigs from New Guinea, Hawaii, Vanuatu and Halmahera. Larson *et al.* (2005: 1621) found the isolation of this clade from all others 'intriguing' and suggestive of 'either the existence of indigenous *S. scrofa* in Wallacea or an early human-mediated introduction from elsewhere in ISEA (Island Southeast Asia) currently not sampled by our study'. Their conclusion that 'ISEA must be considered another independent center of pig domestication' might well have bolstered claims of early pigs in New Guinea. However, any support was short lived for in a subsequent publication, based on more intensive sampling of mainland and Island Southeast Asian pigs, Larson *et al.* (2007) reported 'Pacific Clade' haplotypes from multiple islands in the Lesser Sunda group, from Java and Sumatra, and from Vietnam. This new information 'clearly shows the ancestry of New Guinea pigs to be directly linked with the dispersal of Pacific Clade pigs … originally introduced by farmers to islands west of the Wallace Line' (Larson *et al.* 2007: 4836). The successful extraction of mtDNA sequences from archaeological pig remains from both western and eastern Polynesia in the same study also clearly linked the dispersal of this 'Pacific Clade' with both the Lapita and later Polynesian colonization of remote Oceania.

Our review also shows that evidence is lacking for the appearance of pottery in New Guinea predating the appearance of Lapita ware in the Bismarcks. Even during the Lapita phase evidence of cultural interaction between the PNG mainland and the Bismarck Archipelago is sparse. Despite intensive survey on the north coast of mainland PNG during this, and earlier projects (Terrell & Welsch 1990, 1997; Summerhayes pers. comm.), only two pieces of dentate-stamped pottery have been recovered. The first was an unprovenanced find from near Aitape, (Swadling *et al.* 1988) and the second a surface find from Ali Island (Terrell & Welsch 1997). Terrell and Schechter (2007: 66) have argued that the ceramic sequence of the mainland north coast near Aitape begins with Nyapin Ware thought to date to *c.* 2,000–1,400 calBP (Terrell & Schechter 2007). However they argue that the Aitape wares have affinities with Lapita ceramics, and that Lapita represents the most likely precursor for this series (Terrell & Schechter 2007: 66).

THE POWER OF PARADIGMS

The various scenarios for introduction of pig and pottery into New Guinea were advanced within the context of a wider debate about independent development versus diffusion. Agriculture, sedentism, pottery production and animal husbandry were often conceptualized as a 'package' driving a 'Neolithic expansion' akin to that documented in Europe and the Middle East. The presence of one element was seen to signal the likely presence of the others. Depending on their position in this debate, researchers were quick to accept or reject apparent evidence from the sites and to ignore or gloss over potential problems in the stratigraphic context.

While we show that there is no evidence for pig or pottery in mainland New Guinea in the early to mid-Holocene, and arguably none before 3,000 calBP, other elements of the early models have stood the test of time and, more pertinently, of direct dating. There is firm evidence for the local development of food production practices in the early to mid-Holocene, including quite specialized water management systems. Most convincingly, recent fine-scale work on the Highlands site at Kuk swamp has substantiated claims of early arboriculture and cultivation of indigenous crops such as banana by 7000 calBP (Denham 2004; Denham & Donohue 2009; Denham *et al.* 2003, Kennedy & Clarke 2004). However, our results in relation to the antiquity of pigs and pottery in northern New Guinea, coupled with our skepticism about other regional records, suggest to us that horticulture developed in Melanesia in the absence of pottery and domestic animals.

For lowland New Guinea the evidence for local development of food production practices in the mid-Holocene remains equivocal. Swadling *et al.* (2008) have argued that the widespread distribution of stone pestles and mortars, which includes the north coast lowlands, is evidence for taro cultivation by the early Holocene. Even if we accept a specialized function as taro processors for these tools, there are no direct dates on lowland finds. Pestle and mortars have been found in locations near the mid-Holocene Sepik-Ramu shorelines and Swadling *et al.* (2008: 272) surmise that taro cultivation must have begun by the mid Holocene. However, direct evidence for horticulture; that is garden-based food production, has not been identified at any of the sites.

New research has evaluated existing claims for food production (Gosden 1995: 815), and expanded the dataset for plant exploitation in lowland mainland New Guinea, especially relating to tree-exploitation (arboriculture) (see Yen 1990: 262). A program of AMS dating on specimens from Dongan showed the betelnut and sago to be modern intrusions (Fairbairn & Swadling 2005). In contrast, *Canarium* and other taxa were securely dated to the mid-Holocene, confirming the presence of complex tree-exploitation practices from *c.*7,000 calBP (Swadling *et al.* 1991). Macrobotanical analysis of floated charred-plant remains at Taora, Lachitu and Watinglo also provided new evidence for early to mid-Holocene exploitation of edible tree-fruits and nuts. *Canarium*, directly dated by AMS at all 3 sites, was used throughout the periods of occupation, complemented at Taora (Fairbairn 2005) and Watinglo in the mid- to late-Holocene (Bowman 2008) by *Aleurites, Pandanus*, *Cocos nucifera*, *Terminalia catappa* and *Syzygium*, among other species. Clearly, subsistence practices in northern New Guinea included the use of a range of highly ranked tree resources, including several species of contemporary economic significance, such as *Canarium* and coconut. While this evidence is consistent with claims for tree-cultivation, and is similar in character to that of recognized arboricultural assemblages such as Talepakemalai (Kirch 1989), we are unable, on the basis of current evidence, to exclude alternative scenarios involving the harvesting of wild tree stands in northern New Guinea. However, the repeated association of highly-ranked tree species in charcoal assemblages from a variety of sites certainly suggests regular and systematic arboricultural practice, and indeed similar reasoning has been used in other parts of the world (Denham *et al*. 2007; Pearsall 2007). Further research is required to make this more than speculation in lowland New Guinea.

Recent discussions suggest that tropical food production and procurement systems contain many possible combinations of food acquisition practices (Denham *et al*. 2007), but that detecting many practices and identifying agriculture in particular, can be analytically difficult if not impossible in some regions, including New Guinea (e.g. Denham 2004; Fairbairn 2005). For example, sago pith extraction is known ethnographically to have involved large semi-sedentary populations and surplus starch storage for trade (Allen 2005: 605; Roscoe 2005: 558–560). Sago pith extraction is demonstrated archaeologically by *c*. 1,500 calBP in some lowland areas of New Guinea by the presence of stone pounders with high silica gloss (Rhoads 1980: 127, 143–144). Elsewhere, on the lowland north coast, wooden or bamboo blades were substituted for stone tipped pounders (Crosby 1973: 233–236) and they may have rendered archaeologically invisible any major cultural shift toward intensive exploitation or 'management' of this endemic New Guinean plant, except through indirect changes in subsistence, settlement patterns or trading patterns.

CONCLUSION

Our research suggests that pigs and pottery are not part of lowland Melanesia's early to mid-Holocene archaeological record. Further research might reveal whether prehistoric north coastal New Guinea at that time, with an economic base in hunting, fishing and collecting of wild animal foods, also had practices of plant exploitation that went beyond the predictable collection of wild fruits and nuts into the conceptually more difficult realms of tree-management and beyond.

On a global scale, the evidence discussed here suggests that Melanesia joins other cases where the conceptual decoupling of the various classic components of the 'Neolithic' is desirable. We note, in particular, Jomon Japan where sedentism, villages, substantial houses and sophisticated pottery by 12,000 calBP or earlier, occurred within a socioeconomic context of hunting, fishing and plant foods, but in the absence of evidence for agriculture (Pearson 2007: 361). Conversely, ground stone technology and seed grinding technology both developed in Australia during late Pleistocene times in the context of hunter-collector economies (Gorecki *et al*. 1997; O'Connor 1999: 75, White 1967). Consequently, we join a growing number of researchers in the Asia-Pacific region in suggesting that the concept and use of the term 'Neolithic' as a shorthand for a package of traits which includes 'agriculture', 'domestic animals', 'ceramics' and 'new lithics', be abandoned. Instead, our attention should be directed to understanding and describing the development of local economic practices and the relationships, innovations and transformations they entail (e.g. Donohue & Denham 2010; Szabó & O'Connor 2004; O'Connor 2006).

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