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Liang Lemdubu: A Pleistocene Cave Site in the Aru Islands

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Introduction

Liang Lemdubu is located in the western interior of Pulau Kobroor in an area of karstic limestone (Fig. 9.1). This large, double-entranced cave was formed when an ancient subterranean river cut a passage through the limestone. It runs in length for 30m, is up to eight metres wide and has an average height of three metres (Figs 9.2, 9.3). To reach it one has to boat to the upper reaches of Sungai Papakulah, followed by a two hour walk inland through rainforest. This is the same *sungai* where Alfred Russell Wallace spent six weeks collecting skins and other specimens in 1857, at the hamlet he called 'Wanumbai'.

Lemdubu is regarded locally as a sacred cave and despite its relative inaccessibility, it is known outside of the Wanumbai area. We first heard of it from people at the village of Ujir whilst surveying the northwest coast during our 1995 field season. Excavation did not begin until the following field season in 1996, after consultation had been carried out with the owner of the land and the *adat* (customary law) leader for the cave, a resident of Papakulah Besar.

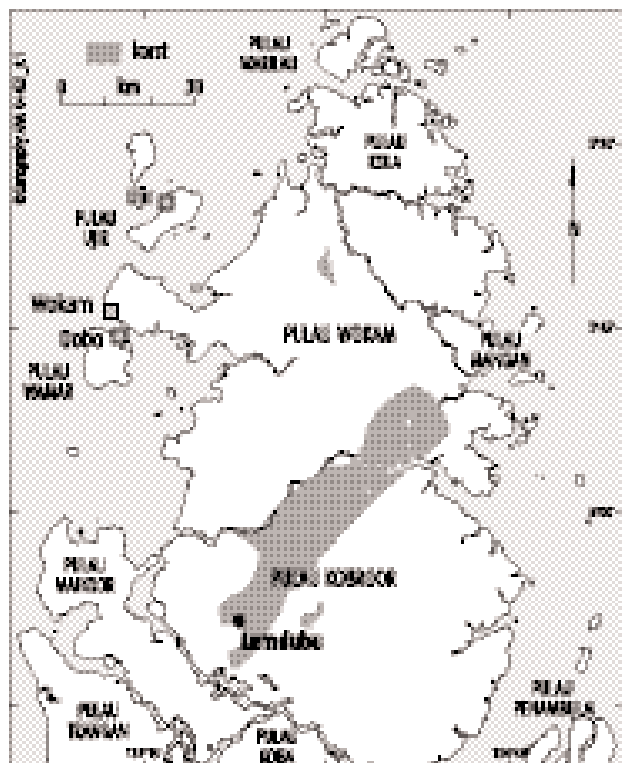


Figure 9.1 Liang Lemdubu: map showing location of the cave and the area of karst limestone in which the cave is located

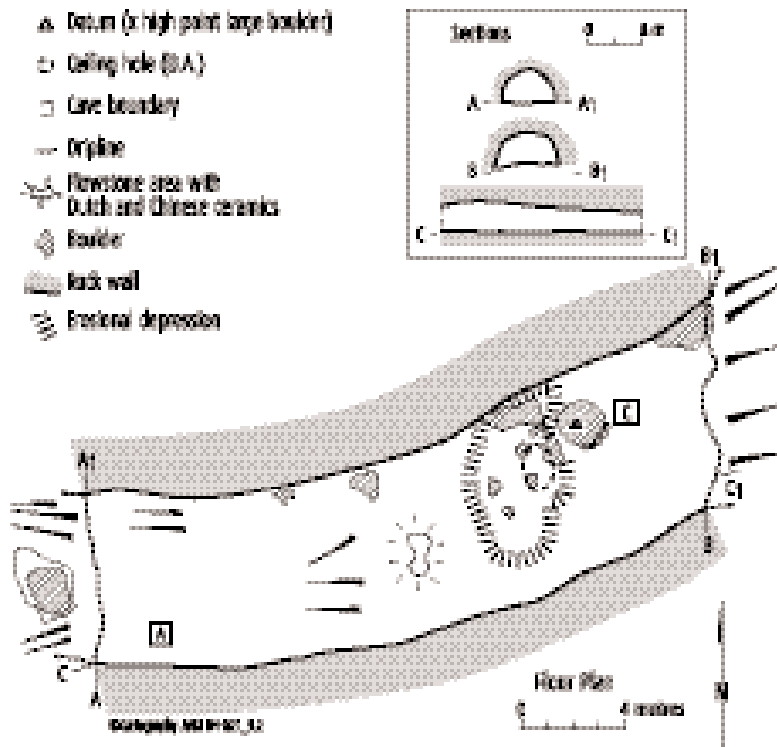


Figure 9.2 Liang Lemdubu: plan of the cave showing location of features discussed in the text and locations of Test Pits A and C

Small stalactite formations occur in the central third of the cave, beneath which a platform of flowstone has accumulated (Fig. 9.3a). The water which drips through the roof at this point is believed to have sacred properties and to imbue the drinker with strength, health and long life; we were told that the cave was still visited periodically to collect the water in times of crisis or ill health. In historic times, Dutch and Chinese ceramics were placed on the flowstone platform and these are now cemented to it (Fig. 9.3a). There is a small hole in the roof in this area through which water and limited sediments enter the cave; this minor collapse appears quite recent.



Figure 9.3a Liang Lemdubu: view to west inside the cave with natural flowstone platform with ceramics at mid-centre



Figure 9.3b Liang Lemdubu: view to east entrance

Lemdubu lies about 25m above sea level and represents a high point in the low-lying local landscape. While other caves were located during our field survey in the surrounding karstic formations, most were low-lying, wet, and unsuitable for human habitation. Lemdubu was the only cave of its size and elevation located during three field seasons, which no doubt accounts for its notoriety.

The cave is surrounded by evergreen rainforest which has a fairly simple structure (Monk et al. 1997:198, 203). Immediately around the cave the rainforest is uncleared but within a few hundred metres to the east it is interrupted by sago swamps and small mixed garden clearings, planted to meet subsistence requirements (Fig. 9.4). At the time of our last visit in 1997 the area was being more intensively cleared for cash crop coffee plantings.

The densest concentrations of cultural material on the extensive sediment floor of Lemdubu are located in the better lit areas at the east and west entrances, near the driplines. Shellfish (*Geloina* sp. and *Terebralia* sp.), pottery and animal bone were noted on the surface, along with pieces of matting and bamboo indicating the contemporary use of the cave by



Figure 9.4 Liang Lemdubu: cleared garden area where our base camp was located, approximately 1.5km from the cave

villagers while on hunting trips or to collect the sacred water. Our initial judgment was that the deposits immediately inside the dripline at each end of the cave were likely to be the deepest and the least disturbed by water action, roots, and major roof fall events. These areas were also more likely to have been the focus of daily occupation than the darker interior of the cave.

The Excavations and Stratigraphy

Two test pits (A and C) were excavated at either end of the cave (Fig. 9.2). Excavation units (spits) averaged approximately five centimetres unless sediment changes were apparent, in which case depths varied to accommodate changes in the stratigraphy. All material was wet sieved through fine mesh (<2mm). Volumes of excavated sediment were recorded prior to wet sieving and an initial sort of cultural residues was carried out at the cave to remove large non-cultural limestone fragments. The remaining material from each excavated unit or 'spit' was then bagged for secondary sorting back at base camp where it was rewashed, thoroughly dried and re-sorted. We found that this method led to the recovery of even small pieces of micro-debitage and bone.

Prior to excavation, it was agreed that the excavated material from Lemdubu would be divided between ourselves and our Indonesian co-workers. All the material and records from Test Pit A were deposited in Puslit Arkenas in Jakarta; to our knowledge, these have not yet been analyzed. The cultural material from Test Pit C was returned to Canberra for analysis. It is this material that forms the basis of this report.

Initially a 1 × 1m pit, Test Pit A, was dug at the western end of the cave (Fig. 9.2). This pit revealed a homogeneous, loose grey-brown to yellowish brown sediment, which changed to a dark yellowish brown mottled clay immediately above the sterile, basal deposit. The upper spits of the grey-brown sediment contained charcoal, terrestrial fauna, earthenware pottery, marine shellfish, stone artefacts, and a fragment of metal. Deeper spits lacked shellfish and pottery and produced fewer stone artefacts, but yielded abundant terrestrial fauna. The basal mottled clay was

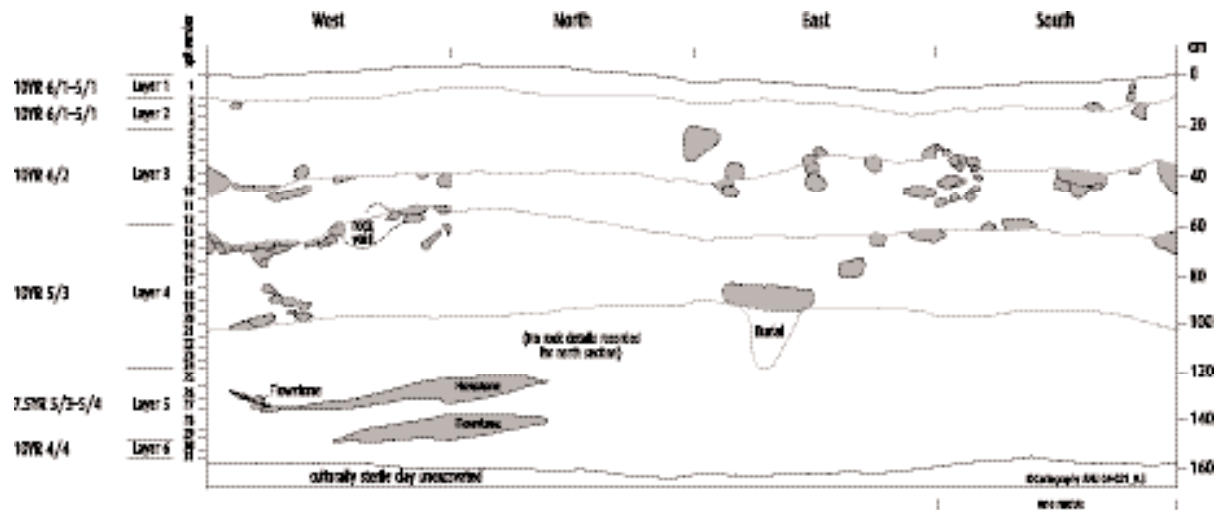


Figure 9.5 Liang Lemdubu: sections of Test Pit C showing spit depths



Figure 9.6 Liang Lemdubu: east section of Test Pit C, showing stone placed over burial



Figure 9.7 Liang Lemdubu: north section of Test Pit C, showing flowstone near base of pit

reached at approximately 50cm below the surface in Test Pit A. This yielded a small quantity of bone but otherwise appeared culturally sterile.

Test Pit C was located near a massive boulder at the eastern end of the shelter (Figs 9.2, 9.3b). This 1 x 1m pit revealed a similar but extended sequence to Test Pit A (Fig. 9.2). Six layers were recognised on the basis of variation in the sediment and cultural materials down the profile. These included: sediment colour; the degree of consolidation of the deposit; differences in texture and/or changes in clay and sand content, and quantities or size of clastic material; as well as changes in the cultural materials, such as presence or absence of shell and degree of cementation of bone. Bulk samples were collected from most spits during excavation of Test Pit C and averaged approximately 200g. Larger samples were not practical for transportation from the field. The sequence described below is based on an examination of the bulk samples and on information recorded on the excavation field sheets. The layers do not always have a one to one correspondence with the divisions as drawn on the sections at completion of the excavation. Figure 9.5 shows Layers 1–6 as well as the unmodified section drawing as it was reproduced in O'Connor et al. (2002). The sediments from the bulk samples are logged in Appendix 9.1. As would be anticipated in a limestone cave, the sediments were alkaline throughout the sequence (pH 8.0–9.0), and bone and shell were well preserved throughout.

Culturally sterile deposits were reached at approximately 150cm below the surface and excavation was discontinued without reaching bedrock at approximately 160cm (Figs 9.5–9.7).

Layer 1 comprises the top spit only: Spit 1. This layer is composed of a grey to greyish brown sediment (Munsell hue 10YR 6/1–5/1). The deposit was unconsolidated and contained large lumps of charcoal. This layer is differentiated from Layer 2 primarily because it was loose and powdery, probably as a result of ongoing disturbance of the surface.

Layer 2 includes Spits 2 through to the base of Spit 4. It is essentially the same as Layer 1 (Munsell 10YR 6/1–5/1), but has been consolidated following burial. It has slightly more fine silts than Layer 1, and the sands are well sorted. It contains less charcoal and the charcoal pieces are much smaller in size.

Layer 3 was recognized as beginning at Spit 5 and continuing down to the base of Spit 12. Although the sediment colour was close in hue to Layer 2 (Munsell 10YR 6/2), this layer was differentiated because it contained significantly less shellfish than the layers above, no visible charcoal, and significantly more bone and small clasts. A particular concentration of rounded, cobble-sized limestone clasts was observed in Spits 8, 9 and 10. The appearance of bone breccia in Spit 10 indicates a zone of carbonate mobilization and it is possible that some clasts are carbonate nodules formed *in situ* as a result of water percolation through the profile. Alternatively, the clasts may represent degraded pieces of roof fall. The field notes indicate that many of the cobbles in Spit 12 were particularly chalky ‘as if weathered’. It is possible that they represent a roof fall event following which they lay exposed for some time prior to being covered by sediment.

Layer 4 comprises Spits 13 to 24. It was recognized on the basis of a slight change in sediment colour (Munsell 10YR 5/3) and texture. The sediment is recorded as moister, ‘stickier’ and slightly lighter or more orange in colour, with a major increase in clay content. The finds from the spits in this layer had to be wet sieved twice as so much fine clay adhered to them. A major decrease in roof fall or nodules was noted as occurring in Spit 21. The human burial occurred in this level under the large rock in Spits 17 and 18.

Layer 5 comprises Spits 25 to 29, and was recognized on the basis of a slight change in sediment colour (Munsell 7.5YR 5/3–5/4) and texture. The sediment becomes much stickier with coarser gritty inclusions. In the northern and northwestern area of the square, two travertine flowstone floors were recorded in Spits 25, 26, and 28 (Fig. 9.7). These formed a partial seal over the underlying deposit which in places was over five centimetres thick and had to be broken up with a crowbar.

Layer 6 begins at approximately 150cm below the surface and comprises Spits 30 and 31. The sediments in this layer are more yellowish in hue (Munsell 10YR 4/4) than those in Layer 5, and have an even higher clay content. This layer contained small bones but no definite cultural material. The fauna in Layer 6 is presumed to predate the first human occupation of the site. Excavation was discontinued in this layer at a maximum depth of 160cm, as the sediments were deemed to be culturally sterile.

Dating the Lemdubu Sequence

Little charcoal was preserved below the upper three spits and we have therefore dated a variety of different materials, using a range of techniques, in an attempt to obtain a chronology for the cave sequence (Table 9.1). Radiocarbon age estimates were obtained on charcoal, marine shellfish, *Celtis* seeds, *Casuarinus* eggshell, and a human tooth. All radiocarbon values were calibrated using CALIB 3.4. No ocean reservoir correction has been applied to the marine samples as no standards are available for this equatorial region. ESR was used to estimate the antiquity of the human burial distributed between Spits 18 to 23, and Uranium-Thorium dates were obtained on the travertine

TABLE 9.1 LIANG LEMDUBU: TEST PIT C, RADIOMETRIC DATES^{a, b}

Lab. code	Spit	Depth (cm)	Sample type	$\delta^{13}\text{C}$	Conventional age (YEARS BP, $\pm 1\sigma$)	Calibrated age (CAL YEARS BP) ^c
ANU-10782	2	5–10	Charcoal	-24.0	1830 \pm 60	1574–1916
OZF247	2	5–10	<i>Casuarium</i> eggshell	-13.5	2150 \pm 50	2000–2308
ANU-10794	3	10–15	Charcoal	-24.0	1100 \pm 160	708–1295
ANU-10792	5	25–30	<i>Geloina</i> shell	-10.7	11,700 \pm 130	13,183–14,057
OZF356	5	20–25	<i>Celtis</i> seed	-16.2	9400 \pm 50	10,432–11,055
OZF358	7	30–35	<i>Celtis</i> seed	-12.4	9280 \pm 50	10,242–10,635
OZD701	8	35–40	<i>Celtis</i> seed	-16.9	8170 \pm 60	9006–9397
OZF357	10	45–50	<i>Celtis</i> seed	-15.3	9250 \pm 60	10,242–10,577
OZD460	17	85–90	<i>Geloina</i> shell	-5.8	16,570 \pm 510	18,391–21,019
AA-32848	19	95–100	<i>Casuarium</i> eggshell	-10.0	16,770 \pm 110	19,321–20,658
OZF248	19	95–100	<i>Casuarium</i> eggshell	-11.7	16,850 \pm 120	19,402–20,760
OZC776	19	95–100	<i>Geloina</i> shell	-5.0	17,750 \pm 450	19,835–22,287
OZC777	26	130–135	Charcoal	-24.0 ^d	13,300 \pm 300	14,539–16,794
—	26	130–135	Flowstone			25,700 \pm 460
—	28	140–145	Flowstone			27,020 \pm 290

a In addition to the dates reported here an ESR date of 18,800 \pm 2300 years (linear uptake model) was obtained on a tooth representing human remains distributed across excavation layers, Spits 18–23

b All analyses are radiocarbon dates with the exception of two flowstone U-series dates at the base of the sequence

c Minimum – maximum intercepts, $\pm 2\sigma$ range

d This sample was too small to measure the delta ^{13}C

flowstones in Spits 26 and 28. The dates on the human burial are not included in Table 9.1 as they are bone dates and therefore date the burial itself and not the age of the sediments that it was interred within.

Charcoal from Spit 2 returned an age-estimate of 1830 \pm 60 (ANU-10782), and from Spit 3 an estimate of 1100 \pm 160 (ANU-10794). Thus there is a minor inversion in the charcoal age estimates between Spit 2 and 3. An AMS radiocarbon determination was also obtained on *Casuarium* eggshell from Spit 2. This sample was assayed at 2150 \pm 50 BP (OZF247) and confirms the late Holocene age of Spit 2.

We conclude that the upper three spits are Late Holocene in age. The age estimates are consistent with the recovery of pottery and domestic animal remains only from these spits (Table 9.2). Insufficient charcoal was available below Spit 3 for conventional radiocarbon determinations, and small-sized charcoal samples were avoided due to a high risk of vertical displacement within the deposit and of contamination during the process of excavation. Spit 4 remains undated, but as it contains large quantities of shellfish and minimal quantities of Agile wallaby bone (a species that became locally extinct in the early Holocene; see Chapter 7, this volume, and below), we infer that it is likely to also be Late Holocene in age.

Although marine/estuarine molluscs are abundant only in Spits 1–4, they are present in smaller quantities in Spits 5 and 6 (Table 9.2). It was therefore anticipated that Spit 5 would date to the period of sea level stabilization approximately 6000 years ago. However, a single *Geloina coxans* valve (ANU-10792) from Spit 5 returned an age estimate of 11,700 \pm 130 BP, considerably older than predicted. A sample of *Celtis* seed from Spit 5 was also analyzed and returned an age estimate of 9400 \pm 50 BP (OZF356). The two dates for Spit 5 indicate that at least some of the cultural material in this unit was deposited during the terminal Pleistocene or earliest Holocene. Two *Celtis* samples from Spits 7 and 10 (OZF358 and OZF357, respectively) yielded similar age estimates to OZF356 from Spit 5. A fourth *Celtis* sample from Spit 8 (OZD701) gave a slightly younger estimate. If the *Celtis* dates provide a generally accurate indication of age, Spits 5–10 accumulated fairly rapidly in the terminal Pleistocene/early Holocene, between 9000 and 11,000 cal BP.

Table 9.2 Liang Lemdubu: Test Pit C, weights (g) of cultural material by spit (this table supersedes an earlier version published in O'Connor et al. 2002)

CONV. AGE BP	SPIT	STONE ARTEFACTS	BONE	MARINE/ ESTUARINE SHELL	CELTIS SEEDS	CHARCOAL	CASSOWARY EGGSHELL
1830±60	1	54.1	1178.7	2227.9	11.3	57.6	4.4
	2	11.4	430.5	515.1	7.6	5.5	2.3
1100±60	3	22.0	361.0	526.2	5.3	0.8	0.2
	4	2.8	475.0	286.0	4.6	0.2	2.6
9400±50	5	5.9	617.4	52.6	3.9		0.3
	6	5.7	546.1	23.7	1.1	0.2	
9280±50	7	167.6	1085.2	2.2	0.8		
	8	89.2	1162.9	0.2	0.1		
	9	54.6	2062.1	2.7	0.2	0.8	
9250±60	10	216.7	3482.7	4.1	0.1	0.01	
	11	10.6	1352.6	2.0	0.1		
	12	53.7	1241.7	0.1			
	13	4.5	1168.8	2.4			
	14	26.3	1591.8	1.2			
16,570±510	15	32.7	1488.2	0.1			
	16	3.2	1658.4	1.7			
16,570±510	17	7.9	1566.3	9.5			0.1
	18	1.9	1421.3	1.5			0.1
16,850±120	19	6.3	2112.9	7.2			1.7
	20	0.5	2400.6				0.2
25,700±460	21		2433.8				
	22		1567.6				
	23	0.2	1531.9				
	24	2.6	3356.4				
	25	1.7	5665.8				
	26		1912.0				
	27		1004.2				
27,020±290	28		640.9				
	29	0.1	207.9				
	30		91.7				
	31		59.3				

The *Geloina* fragment from Spit 17 (OZD460) returned an estimated age of 16,570±520 BP. This value is broadly consistent with the results of two radiocarbon determinations on *Casuarinus* eggshell from Spit 19 of 16,770±110 (AA-32848) and 16,850±120 BP (OZF248), and one on *Geloina* shell from Spit 19 of 17,750±450 BP (OZC776). The two *Casuarinus* eggshell dates are statistically identical and although the A/I ratios for these samples are slightly different — 0.407±0.001 (AAL 8559C) and 0.390±0.005 (AAL 8559C) — the possibility must be considered that they derive from the same egg but have had slightly different thermal histories (see Chapter 13, this volume). However, even if the *Casuarinus* eggshell samples (AA-32848 and OZF248) are not independent ages, the production of close age estimates on the two valves of *Geloina* from Spits 17 and 19 with the *Casuarinus* from Spit 19 provides reason for confidence in the inference that Spits 17–19 accumulated between 18,400 and 22,200 cal BP.

As mentioned above, small-sized charcoal samples were not used for radiocarbon analyses as their provenance was uncertain. The exception to this was a small fleck of dark coloured material, tentatively identified as charcoal, which was found adhering to the flowstone from Spit 26. As this part of the sequence clearly had not been disturbed during the period after travertine deposition, and furthermore, the flowstone fragment had not been through the wet sieving

process, there seemed little possibility of modern or ancient contamination. However, the sample yielded an anomalously young age estimate of $13,300 \pm 300$ BP (OZC777), which is at odds with the suite of mutually supportive age estimates from Spits 17–19, and with age estimates obtained from Uranium-Thorium analysis of other pieces of flowstone from the same level (see below). In view of these radically different chronological estimates, we are now inclined to think that the sample was not charcoal but rather some kind of secondary carbonaceous deposit.

Attempts were made to directly date a human burial which occurs predominantly between Spits 18 and 23, using AMS radiocarbon dating of bone collagen and ESR dating of tooth enamel. The stratigraphic position of the burial is shown in Figures 9.5 and 9.6, and the morphological description and analyses are presented fully in Bulbeck (Chapter 12, this volume). The results of the analyses and dating of the burial are reported in some detail here as they are critical to the reliability of the assessment of the Lemdubu burial's age.

Three independent radiocarbon analyses aimed at extracting collagen from the bone produced inconsistent results. Two laboratories were unable to extract any datable material from the bone, while a third laboratory, the Australian Nuclear Science and Technology Organisation (ANSTO), produced a late Holocene determination. A section was cut from the medial diaphysis fragment of the right femur (from Spit 18) for the purpose of getting an AMS radiometric analysis of the bone from ANSTO. This section of femoral bone was divided and the other half sent to Donald Pate's laboratory at Flinder's University, in an attempt to get a stable isotope ratio assay. The section sent to ANSTO (OZD577) was assayed at 3180 BP. However, the reliability of the ANSTO analysis on OZD577 must be evaluated in the light of the failure by Pate to extract any collagen from the bone. This raised the prospect that the ANSTO analysis was not carried out on collagen extant in the bone sample, but rather on some contaminant. A third sample of the same section of femoral bone was then submitted to the AMS dating facilities at Oxford as a further check on the ANSTO determination. The Oxford laboratory was also unable to extract datable material from the bone. On this basis alone — that the extraction of datable material could not be replicated by two high quality laboratories — we conclude that the ANSTO analysis must be regarded as an unreliable estimate of the age of the burial. Furthermore, the ANSTO radiocarbon determination is inconsistent with the stratigraphic context of the burial in relation to all other age estimates presented here, *and* with the ESR analysis obtained for the tooth from the burial, which was recovered from the same depth below surface in the excavation (Spit 18). When ANSTO was approached about the details of the collagen extraction for OZD577 their representative Ugo Zoppi (pers. comm.) stated that:

OZD577 was first pretreated in October 1998 ... the high C/N ratio and low value of $\delta^{13}\text{C}$ (-26 per mil) for the second attempt at extracting collagen indicated that the extracted collagen still consisted of some humic acid contamination and was not suitable for dating. As a result the age estimate of 3180 BP should be used as a minimum age.

Taking all of these lines of evidence together, OZD577 is regarded as unreliable and is not used in subsequent discussion of the chronology of Lemdubu burial.

The tooth used in the ESR analysis, also from Spit 18, is thought to belong to the same individual as the femur described above. The analyses and dating were undertaken by Rainer Grün at the Australian National University. The ESR analysis was carried out using a single aliquot technique (for experimental details see Grün 1995; for details on ESR age estimation see Grün 1989). The tooth yielded an age estimate of $15,800 \pm 1800$ years if a model of early Uranium-uptake is employed, and an age of $18,800 \pm 2300$ years if a model of linear Uranium-uptake is used. The sample has surprisingly high uranium concentrations. In view of the young age of the sample, it is unlikely that the early uptake model (which assumes that the uranium that is measured migrated into the sample in a very short time compared to its age) is applicable. Grün therefore considers an

ESR age of $18,800 \pm 2300$ years to be the best estimate for the human burial (Grün pers. comm., September 2001). This implies that the human remains are roughly contemporaneous with the deposition of Spit 17 or 18, and were not dug into the deposit from much higher in the profile. The ESR date accords well with the stratigraphic context of the burial which shows a large stone in Spits 17 and 18 capping the burial (Fig. 9.6), and no evidence of vertical displacement of cultural materials found in the Holocene levels into the Pleistocene levels of the deposit.

Uranium-Thorium (Th/U) age estimates were obtained for fragments of speleothems found in Spits 26 and 28. One flowstone formed a partial seal over the deposit beginning at 130cm below the surface in Spits 25 and 26, and a lower flowstone occurred at approximately 150cm below the surface, mostly in Spit 28 (Fig. 9.7). Analytical methods follow that of Ayliffe et al. (1998), and the results are reported in full by O'Connor et al. (2002). The Th/U ages indicate that the lower portion of the cultural deposit, represented by material in Spits 26–28, is approximately 25–28,000 years old.

The Liang Lemdubu Cultural Sequence

Several features of the assemblage were evident during excavation and the on-site sorting of material. The estuarine molluscs found on the surface were restricted to the upper few spits. These levels also produced occasional pottery sherds along with the remains of introduced species such as pig and dog. Other vertebrate faunal remains in these levels were noticeably burnt and fragmented. At greater depth, the vertebrate remains became more abundant and less fragmented, with remains of small to medium-sized wallabies particularly evident. Stone artefacts were present in fairly low numbers throughout the sequence. Most were small and not typologically distinctive. The abundant faunal remains held promise of a detailed record of environmental change and human exploitation of game around the site.

Raw weights for all cultural material are presented in Table 9.2, and weights adjusted for difference in volume of sediment removed in each excavation unit are presented in Table 9.3. The depth of spits as they correspond with the volume of sediment removed can be found in Appendix 9.2. Some shell and bone is cemented with calcium carbonate and sediment, and this will tend to inflate the weights slightly in most levels. In Spits 25 and 26 this problem is exacerbated by the presence of several fragments of bone breccia cemented by travertine.

Organic Remains

Molluscs

Marine/estuarine shellfish

Marine/estuarine shellfish remains are relatively abundant in Spits 1–3. The quantity declines somewhat in Spit 4 and then falls dramatically below Spit 4 (at ca. 20cm below surface level; Table 9.2, Fig. 9.8a). Occasional fragments of marine/estuarine shell occur down to Spit 19.

Species represented include the gastropods *Terebralia* sp. and *Ellobium aurismidae*, which live intertidally amongst mangroves (Coleman 1981:19) and the bivalves *Geloina coaxans*, *Anadara* sp. and *Isognomon* sp. (see Table 9.4, Fig 9.8b). A few cowrie shells (Cypraeidae) were found in Spits 2 and 3. All shellfish found in the site, with the exception of the cowrie shells, probably could be obtained from the *sungai*, a few hours walk from the site.

Two morphologically similar bivalves, *Geloina coaxans* and *Batissa violacea*, are both represented in the samples. The primary way to distinguish between these bivalves is the nature of

Table 9.3 Liang Lemdubu: Test Pit C, distribution and weights (g) of cultural material through the sequence, adjusted for volume of deposit (m³) removed per spit

CONV. AGE BP	SPLIT	STONE ARTEFACTS	BONE	MARINE/ ESTUARINE SHELL	CELTIS SEEDS	CHARCOAL	CASSOWARY EGGSHELL	TOTAL VOLUME
1830±60	1	54.1	1178.7	2227.9	11.3	57.6	4.4	5.0
	2	14.3	538.1	643.9	9.5	6.9	2.8	4.0
1100±60	3	36.7	601.7	877.0	8.8	1.3	0.3	3.0
	4	4.7	791.7	476.7	7.6	0.3	4.4	3.0
9400±50	5	8.4	882.0	75.1	5.5		0.5	3.5
	6	9.5	910.2	39.5	1.8	0.3		3.0
9280±50	7	239.4	1550.3	3.1	1.2			3.5
	8	127.4	1661.3	0.3	0.1			3.5
9250±60	9	68.3	2577.7	3.4	0.2	1.0		4.0
	10	270.9	4353.4	5.1	0.1	0.01		4.0
	11	13.3	1690.8	2.5	0.1			4.0
	12	89.5	2069.5	0.2				3.0
	13	7.5	1948.0	4.0				3.0
16,570±510	14	37.6	2274.0	1.7				3.5
	15	54.5	2480.3	0.2				3.0
	16	5.3	2764.0	2.8				3.0
	17	13.2	2610.5	15.8			0.1	3.0
	18	3.2	2368.8	2.5			0.1	3.0
16,850±120	19	10.5	3521.5	12.0			2.8	3.0
	20	0.8	4001.0				0.3	3.0
	21		2897.4					4.2
	22		2612.7					3.0
	23	0.3	1914.9					4.0
25,700±460	24	3.3	4195.5					4.0
	25	2.0	6745.0					4.2
	26		2390.0					4.0
	27		1434.6					3.5
	28		712.1					4.5
27,020±290	29	0.1	231.0					4.5
	30		114.6					4.0
	31		74.1					4.0

the hinge; *Batissa violacea* has transversely serrated or grooved lateral teeth, whereas *Geloina* has smooth lateral teeth. Despite the broken and chalky condition of much of the shell, most of the hinge fragments examined were identified as *Geloina coxans*. However, positive identifications of *Batissa violacea* were made in Spits 4, 6 and 10. The majority of the valve fragments are probably also from *Geloina*, nevertheless the possibility remains that some *Batissa* has been conflated with the *Geloina*.

Isognomon sp. is an oyster that lives on the roots of mangroves in estuarine environments. It has a very distinctive hinge and was easy to separate from the other bivalves. The bivalves *Geloina* and *Isognomon* sp., and the gastropods *Terebralia* sp. and *Ellobium aurismidae*, would probably have been available in the upper reaches of the Sungai Papakulah, which is the point at which the *sungai* is closest to the cave.

Live specimens of *Geloina coxans*, *Terebralia* sp., and *Ellobium aurismidae* were collected in 1997 for comparison with those found in the deposit. The bivalve *Batissa violacea* is found in fresh to brackish water conditions and tolerates pools, creeks, and even fast flowing rivers. The upper reaches of the *sungai* are fed by freshwater streams coming off the higher limestone karst, and at

Table 9.4 Liang Lemdubu: Test Pit C, marine and estuarine shellfish weights (g) and minimum numbers of individuals (MNI) represented by spit

SPIT	ANADARA SP.		BATISSA VIOLACEA		ISOGNOMON SP.		GEOLOINA COAXANS		TEREBRALIA SP.		ELLOBIUM SP.		CYPRAEIDAE		UNIDENTIFIED SHELL	TOTAL SHELL
	(g)	MNI	(g)	MNI	(g)	MNI	(g)	MNI	(g)	MNI	(g)	MNI	(g)	MNI	(g)	(g)
1	17.6	1			3.4	2	1118.4	23	280.0	60	399.2	24			409.3	2227.9
2	31.6	2			8.9	2	167.4	6	98.6	19	128.8	7	0.7	1	79.1	515.1
3	0.9	1			1.0	1	311.6	5	56.3	12	94.6	5	1.2	2	60.6	526.2
4			16.0	2	0.7	1	200.7	10	1.0	1	10.0	1			57.6	286.0
5	1.3	1					15.7	1	0.3	1	2.4	1			32.9	52.6
6			5.0	1			6.8	1	0.3	1	0.8	1			10.8	23.7
7							1.3	1	0.1	1					0.8	2.2
8															0.2	0.2
9							2.0	1	0.7	1						2.7
10			4.1	1												4.1
11							1.3	1							0.7	2.0
12							0.1	1								0.1
13											2.4	1				2.4
14											1.2	1				1.2
15									0.1	1						0.1
16							1.7	1								1.7
17							9.5	1								9.5
18											1.5	1				1.5
19							7.2	1								7.2

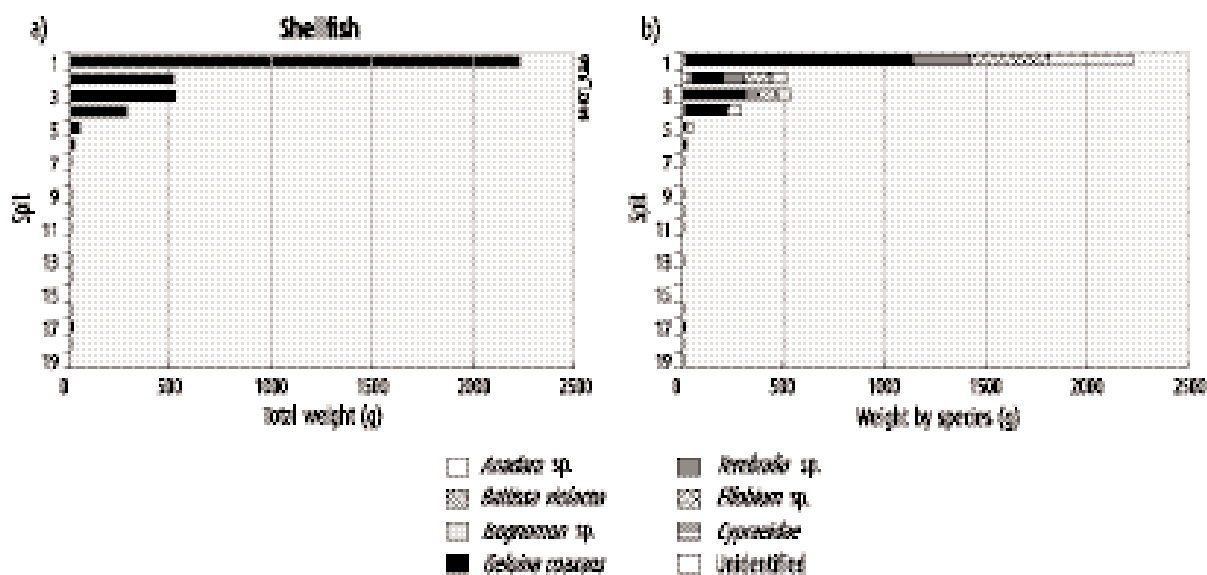


Figure 9.8 Liang Lemdubu: Test Pit C, a) shellfish raw weights (g) per spit and b) weight (g) by species per spit

low tide fresh to brackish water conditions prevail in some areas. *Batissa violacea* has been included with the estuarine molluscs as it may be obtainable in brackish pools at the head of the *sungai*, although none were observed in that habitat.

Small numbers of the marine/estuarine bivalve *Anadara* sp. — a group of species that inhabit sandy/muddy flats of the littoral zone — were recovered in the upper spits.

The few cowries must have been brought from a marine reefal environment and, in view of their small size, may have been transported inland as decorative items. However, none displayed any evidence of modification. Similarly, the *Geoloina* fragments found in the lower spits may have

been transported to the site for use as artefacts. *Geloina* with evidence of use wear and/or modification have been reported as artefacts from caves elsewhere in Island Southeast Asia. Their use as artefacts has also been confirmed in northern Australian sites where they occur at far greater distances inland (O'Connor 1999).

In terms of weight, the estuarine bivalve *Geloina* is clearly dominant within the shellfish assemblage (Fig. 9.8b). However, when measured by MNI, they are comparable to *Ellobium* but less numerous than *Terebralia* in the upper levels. Both measures of weight and MNI probably under-represent the importance of *Geloina* relative to *Terebralia* and *Ellobium*, as the bivalves tend to fracture along the pallial line, and once broken the valves often split through the hinge and cannot be used for MNI. For this reason it is believed that the weights provide a more accurate estimate of the relative contribution of the different species. Most of the shell in the unidentified category is probably attributable to *Geloina*.

The decrease in shellfish remains with depth is not likely to be due to preservation. Although the shell does become less well preserved with depth, the species recorded in the upper four spits were easily identifiable from the more eroded fragments and identifiable fragments of *Ellobium* and *Geloina* were found down to Spits 18 and 19 respectively. Further, thin-shelled terrestrial snails increase in number at the same time as the marine species begin to decline; an unlikely scenario if preservation was influencing the survival of shell down the profile.

The vertical distribution of shellfish suggests that it is only in the upper three spits that conditions similar to those prevailing in Sungai Papakulah today were fully established. The mangrove-associated species *Terebralia* and *Ellobium* are only present in any numbers in the top three spits. Although *Geloina* occur in some numbers in Spit 4, this species is not strictly mangrove-associated and might be expected to appear prior to *Terebralia* and *Ellobium*. The small quantity of shell below Spit 5 would suggest that it was transported from some distance away.

Terrestrial and freshwater gastropods

The most numerically important of the terrestrial gastropods are *Chloritis gruneri*, *Chloritis circumdata*, *Chloritis argillacea*, *Papuina* sp. cf. *P. pratti*, *Japonia* sp. and *Cyclotus politus*. A number of so far unidentified species were recorded simply as species A–H. The freshwater gastropods *Melanoides tuberculata*, and *Thiara scabra* also make a minor contribution (Table 9.5). The distribution of terrestrial and freshwater gastropods through time is shown in Table 9.5 and Figure 9.9. All the species recorded are likely to be part of the extant fauna; however, there is no modern day list of species from the Aru Islands.

The freshwater snails are found on rocky substrate in variable conditions from stagnant pools to fast flowing rivers (Haynes 2001). In Lemdubu they are most prevalent in the top two spits but occasional examples are found down to Spit 17 (Table 9.5). The individuals recovered are small in size and few in number and it seems likely that they were scooped up when freshwater was being collected and then brought to the site inadvertently in the water containers. The terrestrial snails are damp forest dwellers and their overall abundance may be taken as a general indication of the prevalence of wet forest in proximity to the cave. Low quantities of land snail are found in spits 28–24, dated to between ca. 27,000 and 23,000 cal BP (Fig. 9.9, Table 9.5). Terrestrial molluscs disappear almost entirely from Spit 22 to 10, probably reflecting drier conditions and less dense vegetation around the

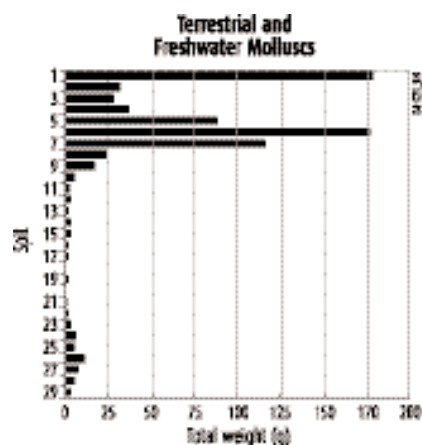


Figure 9.9 Liang Lemdubu: Test Pit C, raw weights (g) of terrestrial and freshwater molluscs

Table 9.5 Liang Lemdubu: Test Pit C, terrestrial and freshwater molluscs weights (g) and minimum numbers of individuals (MNI) represented by spit

SPIT	CAMAENIDAE										TO BE IDENTIFIED					UNID.	TOTAL WT.					
	CYCLOPHORIDAE		THIARIDAE		TROCHOMORPHIDAE		CHLORITIS GRUNERI		CHLORITIS ARGILLACEA		CHLORITIS SP.		PAPUINA SP. CF. P. PRATTI		PAPUINA SP. F. P. BLAINVILLEI			PAPUINA PILEUS		ALBERSIA TENUIUS		
1	16.1	11.9	11.4	0.5	0.7	0.1	0.7	0.4	11.1	39.6	1.1	16.6	4.0	1.3	1.0	2.4	0.1	0.6	0.01	0.01	79.2	198.9
2	4.4	2.6	0.1	0.03	0.8	0.1	0.1	0.1		2.1		6.2	0.5						0.2		13.8	31.0
3	1.1	0.3		0.04		0.1				1.2		1.0	0.7		0.1	0.04		0.03			23.1	27.8
4	0.4	0.5	0.03		0.1					0.3	1.3	7.0			0.1						28.7	36.7
5	0.2	0.1	0.2		0.1					0.4	1.2	24.1	0.1		0.4	0.01					61.0	87.8
6	0.1		0.04		0.1					0.4		56.8							0.02		118.1	176.7
7		0.04	0.1	0.01								39.5									75.9	115.6
8	0.5	0.01			0.1							6.4	0.1								16.2	23.4
9	0.1	0.01										2.4		0.1							14.0	16.6
10				0.06	0.5							0.7			0.03						3.1	4.4
11	0.2	0.1			0.2							0.1		0.3							0.7	1.5
12	0.2									0.04	0.5	0.8	0.3	0.2	0.04						0.5	2.5
13		0.1								0.2		0.3									0.6	1.2
14	0.7	0.1										1.8		0.03							0.2	2.8
15					0.3					0.7		0.3	0.1		0.04						1.0	2.5
16	0.1											0.3	0.02								1.1	1.5
17						0.2						0.1									0.7	1.0
18		0.1										0.2									0.8	1.1
19												0.2		0.1							0.2	0.2
20												0.1									0.2	0.2
21												0.2									0.3	0.4
22		0.1								1.0												1.2
23	1.3	0.01										0.4		0.1							1.4	3.2
24	1.1	0.3								0.1		0.6	0.2	0.03	0.01						3.2	5.5
25	0.7	0.1						0.02				0.8			0.01						3.1	4.7

cave through the terminal Pleistocene. From Spit 9 numbers begin to rise again, with a dramatic increase from Spit 7 to the top of the deposit.

The dominant terrestrial snail genus is *Chloritis* spp. Judging from the size of the fragments, most of the pieces identified as *Chloritis* spp. were probably *C. gruneri*, however they were too broken to make identification to species possible. A large proportion of the unidentified snails were also likely to be *C. gruneri*.

The way in which the terrestrial snails entered the cave is open to question. They may have been brought into the cave attached to freshly cut vegetation used by the cave occupants as sitting mats, bedding or for wrapping food. Our field assistants commonly cut palm leaves and placed them on the floor of the cave to sit on while sorting or resting during breaks, or to produce a clean surface to prepare or serve food. The peak in land snails in Spits 7–5 compared with Spits 4–2 may indicate that wetter conditions and denser vegetation prevailed during the early Holocene. Alternatively, it may be that vegetation was reduced in the late Holocene following forest clearance for gardening (represented by Spits 1–4). *Chloritis gruneri* is a large species which could possibly have been brought in as food. If some of the terrestrial molluscs were food species, their decline at this time may indicate their replacement in the diet by estuarine species after the establishment of fully estuarine conditions (reflected in the fauna in Spit 4 and above). Distinguishing between these different scenarios is not possible on the basis of the available data.

Vertebrate fauna

The Liang Lemdubu excavation produced a large quantity of bone, with especially high densities encountered in the lower levels of Test Pit C (Tables 9.2 and 9.3). As observed also in the Liang Nabulei Lisa sequence (Chapter 7, this volume), the vertebrate fauna from the uppermost deposit in Lemdubu contrasts strongly in physical condition and taxonomic composition with that from the lower part of the sequence. Essentially, bone from the upper levels is more heavily burnt and fragmented, and includes a wide range of animal groups but without any overwhelming pattern of dominance. In contrast, bone from the lower levels is less fragmented and less often burned, and is dominated by the remains of only one family, the Macropodidae.

Analytical methods

All samples were washed in a fine-mesh sieve and air dried. Bone artefacts were separated from the remaining bone material at this stage; these are reported by Pasveer in Chapter 11 of this volume.

The analytical methods essentially follow those described for the treatment of the Nabulei Lisa assemblage (see Chapter 7 for details). The critical objectives were as follows:

- 1) to determine the range of species present;
- 2) to establish the pattern of distribution of each species through the sequence; and
- 3) to estimate the relative abundance of the major species, both within each unit (interspecific) and through the sequence (intraspecific).

The physical condition of the assemblage was documented in terms of the proportions of four different burning categories, as described in Chapter 7.

Vertical distribution and preservational state of bone

The vertical distribution of bone is shown in Figure 9.10a and the bone weights adjusted for spit volumes in Figure 9.10b (Table 9.3). Peak values for bone are observed in Spits 24–25; however, as explained above, this is probably an artefact of the heavily cemented condition of bone in these levels. Ignoring this artificial peak, the true maximum values are observed at two points in the sequence: a sharp peak at Spit 10, and a broad peak centred on Spit 20. Relatively smaller quantities of bone were recovered in the uppermost levels of the site, in Spit 6 and above, and at the base of the sequence, below Spit 27.

Three main stratigraphic zones are distinguished by the proportion of bone in each burning class (Fig. 9.11). Bone from the uppermost 11 spits shows a high proportion of burning, with calcined bone accounting for 3–17% of the total bone. The ‘lightly burnt’ category is particularly prominent in these levels. Between Spits 12 and 26 there is a marked decline in the proportion of the three burnt categories; unburnt bone makes up 60–80% of the total remains in these levels. Below Spit 26 less than 10% of the bone is burnt.

The bone is moderately well preserved throughout the sequence, with little indication of differential degradation. Material from the upper levels of the sequence (in Spit 11 and above) appears more highly fragmented than that from the lower levels. The greater degree of fragmentation and burning in the upper part of the deposit is likely to be causally related. In the lower levels, the bone is often thinly coated with a layer of calcium carbonate and fine sediment. In Spits 25–26, the encrustation is more extensive and there are several chunks of ‘bindstone’ — made up of densely packed bone fragments, thin layers of travertine, and cemented cave earth.

Origin of the remains

The preponderance of medium- to large-bodied animals such as macropodids, possums and large reptiles (Fig. 9.12), indicates that the Lemdubu fauna is predominantly derived from human activity, rather than being the product of non-human carnivore or raptor activity. The scarcity of tooth marks on the remains and the lack of rounding of fracture edges on all but a few specimens, also lend support to this view. This inference applies to all spits down to Spits 28 or 29. In contrast, the basal Spits 30 and 31 contain a higher proportion of smaller birds and mammals and may be derived wholly or in part from non-human activity. The fact that the lowest stone artefact was recovered from Spit 29 supports this view.

Material from the lowermost levels of human occupation (Spits 25–28) is noticeably less fragmented than that from the higher levels. In addition, the preserved fragments of ‘bindstone’ show several examples of anatomical association

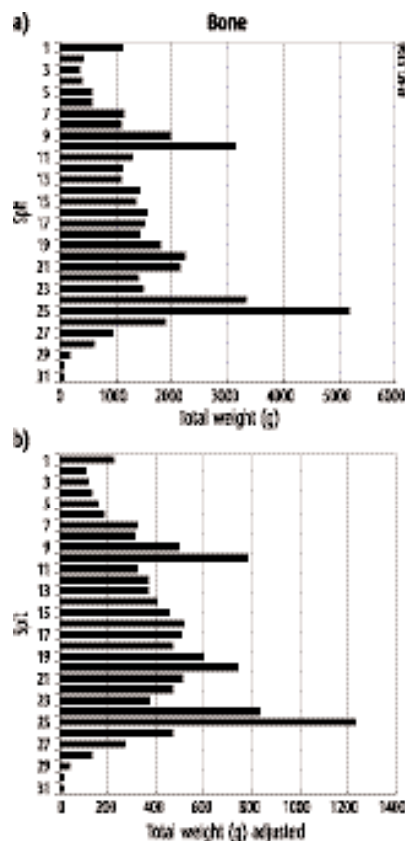


Figure 9.10 Liang Lemdubu: Test Pit C, a) raw weight (g) of bone through the sequence b) adjusted weight (g) of bone through the sequence

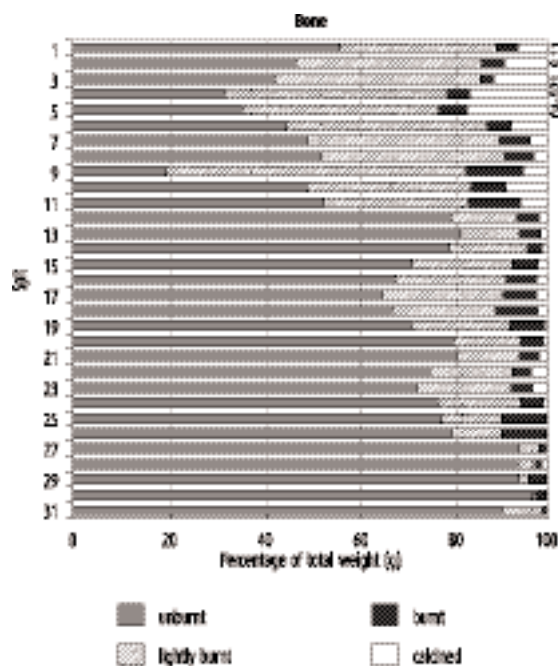


Figure 9.11 Liang Lemdubu: Test Pit C, percentage of total bone weight in each burning class

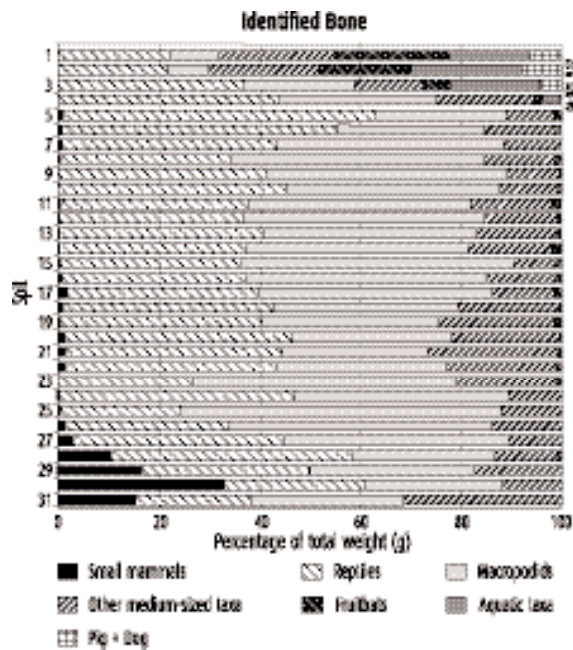


Figure 9.12 Liang Lemdubu: Test Pit C, summary of taxonomic categories (weight %) within the vertebrate faunal remains. Much of the small mammal category is likely to be derived from raptor use of the site. The 'reptile' category is dominated by large goannas and pythons

murid rodents, where recent taxonomic revisions have led to the recognition of some new species, and the reassignment of others into different genera. Changes in identification reflect more detailed study by Aplin of some groups since the previous publication; these principally concern the peroryctid bandicoots and the rodents. The other significant change concerns the phalanges (foot bones) previously reported as belonging to a large 'megafaunal' species of kangaroo, tentatively referred to the genus *Macropus*. Access to better comparative material has now clarified that these specimens are from a species of *Casuarius*, probably *C. casuarius* (see Chapter 3 for details).

The Lemdubu faunal assemblage includes many taxa that are not recorded from the contemporary fauna of the Aru Islands. These include three macropodids (*Macropus agilis*, *Thylogale stigmatica*, and *Dorcopsis* sp.), two or three bandicoots (*Isodon macrourus*, a previously unknown taxon, and possibly *Echymipera kalubu*), and the Short-beaked Echidna (*Tachyglossus aculeatus*). Other additions are a Native Cat (*Dasyurus albopunctatus*), several small rodents (*Rattus sordidus*, *Pogonomys* sp., *Pseudomys* sp. cf. *P. nanus*, *Melomys* sp. cf. *M. burtoni*), a medium-sized rodent (*Parahydromys asper*) and a small megachiropteran species (*Dobsonia* sp.).

The Lemdubu fauna contains the same four species of macropodids as are recorded in the Nabulei Lisa fauna. Only one of these is found on the Aru Islands today — *Thylogale brunii*, a small, rainforest dwelling pademelon. As reported previously in O'Connor et al. (2002), a second group of *Thylogale* specimens compares most closely as a group with modern specimens of *T. stigmatica*. However, the archaeological sample shows greater size variation than would be expected within a single population and may include two closely related taxa. *Thylogale stigmatica* today is polytypic, with two or more subspecies usually recognized. Unfortunately, as it was not possible to allocate many of the less complete specimens to either the larger or smaller form of *T. stigmatica*, the two groups were not distinguished in the analysis. In Eastern Australia, *Thylogale stigmatica* is an

of skeletal elements, most notably among bones of the lower leg and hindfoot. The articulation of these elements suggests that little effort was being made to extract all available protein from these carcasses, and this in turn, may suggest an abundance of animal foods at that period in the history of cave occupation.

In all levels, some of the smaller mammal remains, including the occasional bones of smaller rodents and bats, might be derived from other sources including the regurgitated pellets of predatory birds roosting in the cave. However, as these are scattered through the sequence (Fig. 9.12), they do not influence the overall composition of the fauna.

Species distributions

The taxonomic composition of the Liang Lemdubu archaeological fauna was reported by O'Connor et al. (2002). NISP and weight data for all identified specimens are presented by spit in Appendix 9.3. Aplin and Pasveer (Chapter 3, this volume) document various subsequent changes in identifications and taxonomic nomenclature. Changes in nomenclature chiefly affect the

inhabitant of rainforest margins and wet gallery forests. The other macropodids are a true grassland/savannah wallaby, *Macropus agilis*, and an inhabitant of dense rainforest, *Dorcopsis* sp.

The changing proportional representation of the three most important species is illustrated by percentage weight of bone in Figure 9.13, and by NISP in Figure 9.14. Numerically, the two *Thylogale* species together make up the greater part of the macropodid remains throughout the sequence. *Thylogale brunii* shows two peaks in abundance: one centred on Spits 18 to 24, and the other on the uppermost four spits. In contrast, *T. stigmatica* is most abundant in the lowermost part of the deposit and between Spits 17 and 5. *Macropus agilis* also varies in abundance, with the lowest quantities in the upper three spits, the highest quantities between Spits 4–18, and intermediate values in Spit 19 and below. *Dorcopsis* sp. is represented by a single specimen: a very worn lower premolar, from Spit 24. This taxon is too poorly represented to register in the graphs.

The increased quantities of the savannah dwelling *M. agilis* between Spit 18 and Spit 4 suggests drier and more open conditions during this period. This inference is supported by the reduced abundance of *T. brunii* relative to *T. stigmatica* during this period. Where the two species occur in regional sympatry today, in the Trans-Fly region of New Guinea, it appears that *T. brunii* tends to occupy the core rainforest habitats, whereas *T. stigmatica* is perhaps pushed into rainforest margin habitats.

Four species of bandicoots are probably represented in the Lemdubu assemblage, compared with a single species in the modern fauna. The sole surviving taxon, *Echymipera rufescens*, is represented throughout the deposit but is only dominant in the uppermost levels. *Echymipera kalubu* is tentatively identified from Spits 3–4 only. Both species of *Echymipera* occur today in lowland rainforest habitats on the New Guinea mainland. *Isodon macrourus*, a species that is broadly associated with savannah grassland habitat in New Guinea and northern Australia (Flannery 1995), is present throughout the deposit but with peak values in Spits 17–25 (Fig. 9.15). A fourth bandicoot taxon, an unnamed taxon of uncertain ecological significance, is present in most spits between Spit 18 and Spit 27, with sporadic occurrences in higher levels (Spits 6 and 14). This taxon is also represented in Nabulei Lisa.

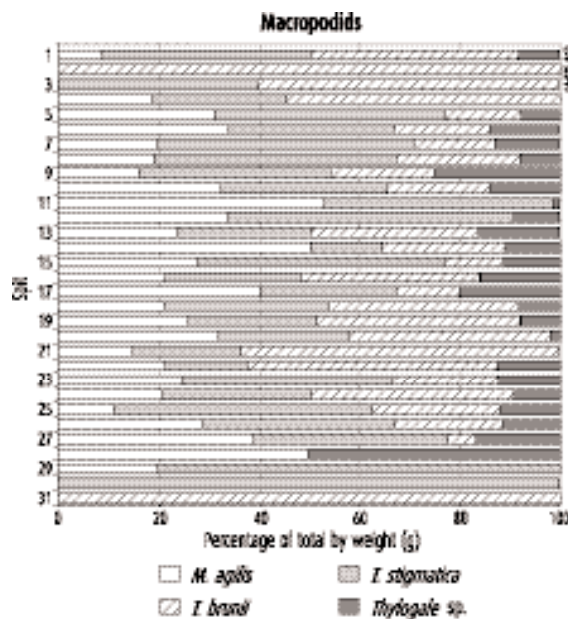


Figure 9.13 Liang Lemdubu: Test Pit C, the changing proportional representation (weight % of bone) of the macropodids through the sequence

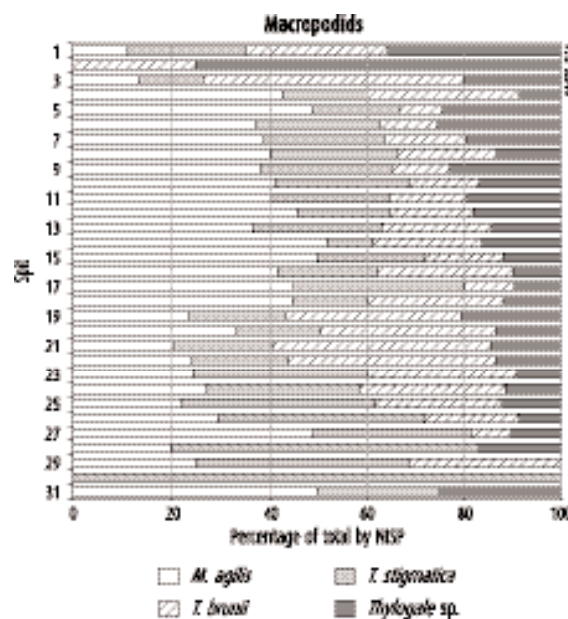


Figure 9.14 Liang Lemdubu: Test Pit C, the changing proportional representation (NISP) of the macropodids through the sequence

Four species of possums are represented in the assemblage. All are part of the contemporary fauna of the Aru Islands. The Spotted Cuscus, *Spilocuscus maculatus*, is present in almost all excavated spits, with the highest quantities in the lower part of the deposit (Spits 18 and below) and in the uppermost levels (Fig. 9.16a). Two smaller cuscuses, *Phalanger gymnotis* and *P. mimicus*, also occur through the sequence. *Phalanger mimicus* shows a similar pattern to that of *S. maculatus*, with greater quantities in the lower part of the deposit (Fig. 9.16b). *Phalanger gymnotis* occurs more sporadically through the deposit and is generally less abundant than the other cuscuses (Fig. 9.16c). The Striped Possum, *Dactylopsila trivirgata*, is poorly represented by comparison, with single fragments in each of Spits 1 and 9. All four species are indicative of forest habitats. *Phalanger gymnotis* has not been recorded outside of rainforest habitats. The remaining species are more adaptable and occur today in a variety of forest types including riparian forests and relatively open woodlands. The decrease in abundance of *S. maculatus* and *P. mimicus* above Spit 19 is compatible with the suggestion that the local vegetation was drier and more open from that time through until the more recent period represented by Spits 1–4.

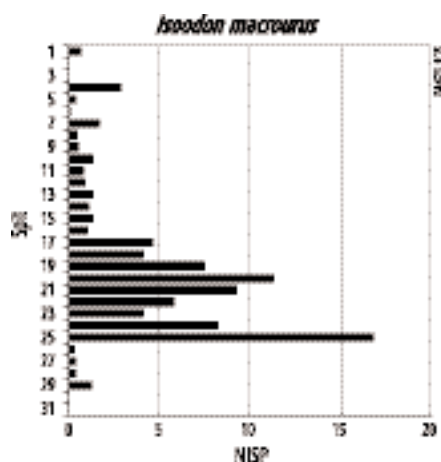


Figure 9.15 Liang Lemdubu: Test Pit C, the changing proportional representation (NISP) of the bandicoot *Isodon macrourus* through the sequence

Echidna (*Tachyglossus aculeatus*) is represented in most levels from Spits 25 to 5 (Fig. 9.17), with slightly higher quantities below Spit 18 than above (but with a localized peak in Spit 9). This taxon is absent from the Aru Islands today, despite it being present in both northern Australia and southern New Guinea.

The Lemdubu assemblage includes a limited quantity of small mammal remains. These are concentrated below Spit 10 and include examples of six or seven mammal species, such as *Myoictis wallacei*, another smaller dasyurid taxon, and five murid rodents. The murids include: *Parahydromys asper*, a partially

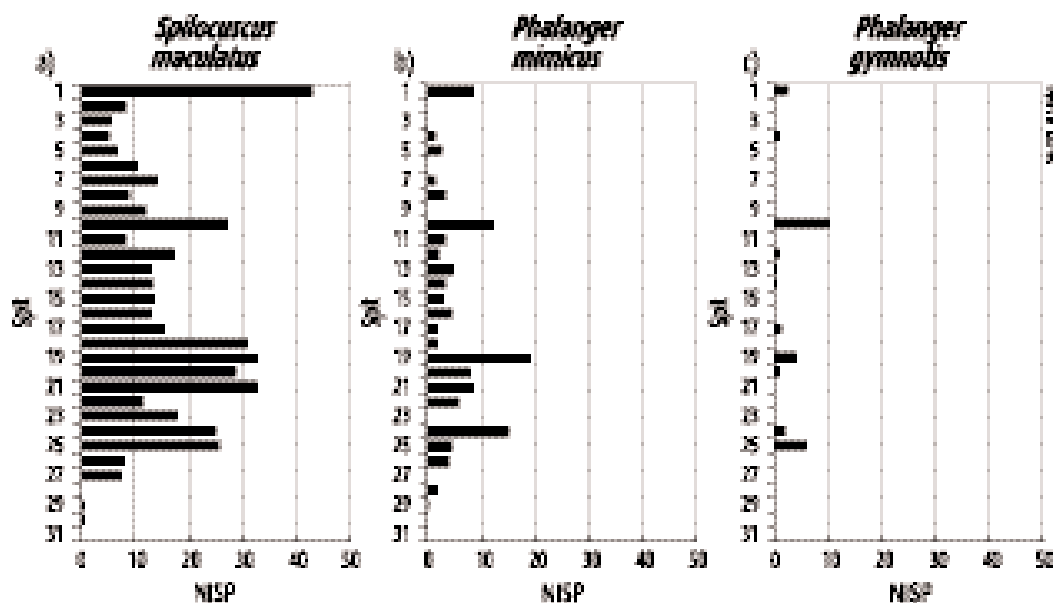


Figure 9.16 Liang Lemdubu: Test Pit C, distribution and proportional representation (NISP) of a) the Spotted Cuscus, *Spilocuscus maculatus* b) *Phalanger mimicus* and c) *Phalanger gymnotis* through the sequence

aquatic species found only in the lowermost part of the site; *Pogonomys* sp., a rainforest dwelling tree mouse found in Spits 30 to 13; *Rattus sordidus*, a tropical grassland taxon found in Spits 28 to 11; and species of *Pseudomys* (cf. *P. gracilicaudatus* group), represented by a few specimens only. The few larger murid specimens are all referable to *Uromys caudimaculatus*, a highly adaptable species that occurs across a variety of habitat types.

Megachiropteran bats (family Pteropodidae) are present in virtually all samples. They show a minor peak in abundance in the lower levels, culminating in Spit 19 (Fig. 9.18), and a larger peak in Spits 1–3. The bulk of the more diagnostic material is referable to *Dobsonia moluccensis*. However, at least some of the material is derived from a smaller species of *Dobsonia*. The most likely candidate is *D. viridis*, a species known from the nearby Kei Islands (Aplin and Pasveer, Chapter 3, this volume).

The remains of introduced mammal species are confined to the upper four spits. Pig bones and teeth occur in Spits 2–4, whereas dog is represented exclusively in Spit 2. Although no deer remains were found during excavation, bones and teeth of *Rusa timorensis* were collected from the surface of the site.

Snakes are well-represented throughout the Liang Lemdubu sequence; in most spits they account for around 20% of all bone (Fig. 9.19). Almost all of the snake remains come from moderately large snakes belonging to the Boidae (pythons), with fewer examples of other groups including Colubridae. In view of the high meat weight to bone ratio of these large pythons they must have made a regular and important contribution to the diet. Monitors (*Varanus* spp.) are also represented in most levels, with peak values between Spits 19–25 and in Spit 10 (Fig. 9.20). Most varanid remains are from moderate to large-bodied individuals. Today, the only large *Varanus* found in the Aru Islands is the semi-aquatic *V. salvator*. However, under drier conditions and with land connections through to northern Australia, it is possible that other large-bodied species were represented, including *V. gouldi*, *V. panoptes* and *V. mertensi*.

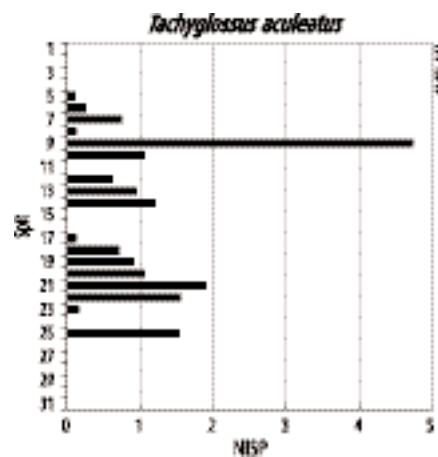


Figure 9.17 Liang Lemdubu: Test Pit C, distribution and proportional representation (NISP) of Echidna (*Tachyglossus aculeatus*) through the sequence. This species is represented in most levels from Spits 25–5

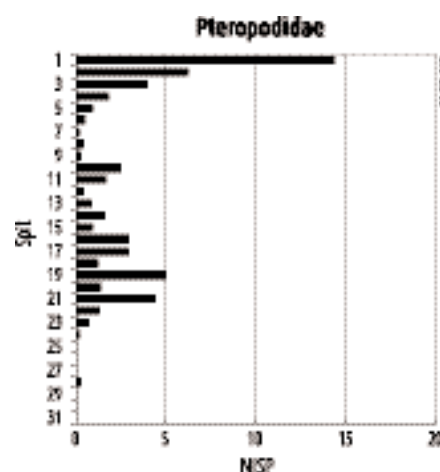


Figure 9.18 Liang Lemdubu: Test Pit C, distribution (NISP) of Pteropodidae bats through the sequence

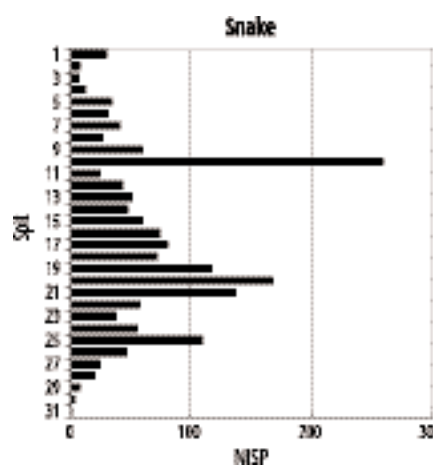


Figure 9.19 Liang Lemdubu: Test Pit C, distribution of snakes through the sequence (NISP)

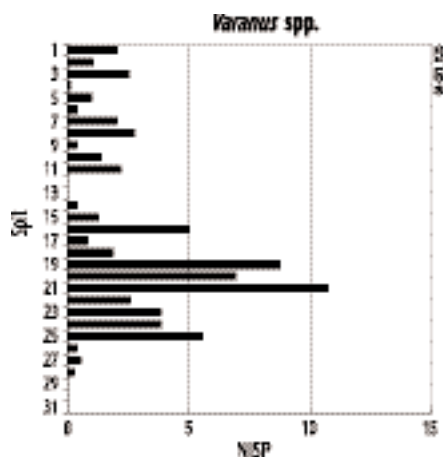


Figure 9.20 Liang Lemdubu: Test Pit C, distribution of Varanid lizards through the sequence (NISP)

Small quantities of bird bone are scattered through the deposit. This includes recognizable examples of cassowary bones in Spit 3 and Spits 20–21. Although three species of cassowary are found in New Guinea (*C. unappendiculatus*, *C. bennetti*, and *C. casuarius*), only *C. casuarius* subspecies *aruensis* is found in the Aru Islands today. Cassowaries are hunted in the forest around Lemdubu today and the eggs collected for food.

Cassowary eggshell fragments were found in Spits 1–5 and 17–20 of the Lemdubu excavation (see Clarke and Miller, Chapter 13, this volume). Identification of the eggshell from Spits 17–20 as cassowary (*Casuarius* sp.) rather than emu (*Dromaius novaehollandiae*) requires further comment. As Aru was connected to northern Australia in the late Pleistocene, and the other terrestrial fauna from the lower levels of the site suggest savannah grassland conditions prevailed at this time, it is possible that the area supported populations of emu, perhaps living in regional sympatry with one or more cassowary species. Emu and cassowary eggshell are difficult to tell apart on the basis of morphology. Fortunately, eggshell of the two groups differs in the rate of amino acid racemisation and in their carbon stable isotope signals. As described by Clarke and Miller (Chapter 13, this volume), the rate of racemisation in the samples of egg shell from Lemdubu is comparable with that documented in samples from Toé and Kria Caves in the Bird’s Head of Indonesian Papua. These sites contain exclusively closed forest fauna, and it is certain that the Bird’s Head eggshell is from a species of cassowary (Pasveer 2004). Further, the carbon stable isotope results on the

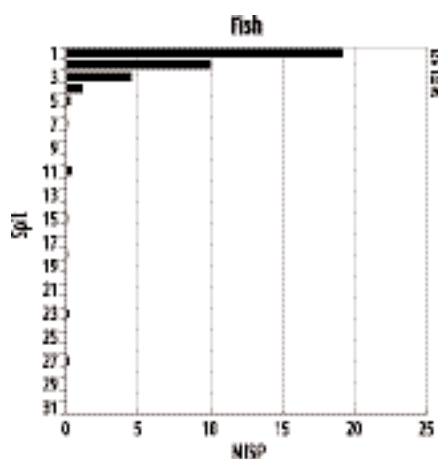


Figure 9.21 Liang Lemdubu: Test Pit C, distribution of fish bone through the sequence (NISP)

eggshell from Lemdubu indicate a bird whose diet consists of less than 20% tropical grasses (Clarke pers. comm).

All cassowary eggshell in the deposit must derive from eggs brought into the site by people as food. Although no information is available on breeding times of *C. casuarius* in Aru, in north Queensland breeding ‘occurs mostly in the dry season’ coinciding ‘with the average maximum availability of fruit in the forest’ (Crome 1975:9, 13). The archaeological eggshell fragments presumably demonstrate use of the site in the dry season. The absence of eggshell fragments between Spit 6–16 and below Spit 20 is noteworthy; coupled with the absence of

cassowary bone in the same levels, it suggests a genuine scarcity or absence of remains of this prized game item through much of the occupation of the site.

Fish remains are concentrated in the uppermost four spits, with scattered examples from lower levels (Fig. 9.21). The sample from the upper levels includes both freshwater (e.g. Ariidae) and marine (e.g. Scariidae) taxa.

Plant material

Charcoal was sparse below Spit 2 but occurs in measurable quantities down to Spit 10 (Tables 9.2 and 9.3). Small flecks of what appear to be charcoal were found after wet sieving in all spits, down to the base of the site, but as they were not recovered *in situ* these fragments were considered unreliable for dating. In view of the large quantity of burnt bone and shell in units below Spit 3, the paucity of charcoal is presumed to be due to taphonomic factors leading to the progressive destruction of charcoal over time.

The only seeds preserved were those of *Celtis philippinensis* which were found in Spits 1–11 (Table 9.2). *Celtis* seeds are commonly found in archaeological sites and are usually assumed to enter sites independently of people. They may enter incidentally attached to branches destined for firewood or other purposes. *Celtis* grow close to the entrances of Lemdubu today, however, the faunal data demonstrate that during the Pleistocene vegetation around the cave was much more open. It is significant that *Celtis* seeds were not recovered from the lower spits coinciding with this period of open vegetation.

Palaeoenvironmental Interpretation

The combined molluscan and vertebrate faunal analysis provides a detailed picture of environmental changes and human responses in the vicinity of Liang Lemdubu over the past 28,000 years. The sequence of changes is most conveniently described as a succession of three time periods. However, the exact delineation of these periods should be regarded as somewhat arbitrary.

Spits 31–19 (ca. 28,000–ca. 20,000 cal BP)

The basal two or three spits produced a small quantity of bone and no clear evidence of human activity; these may predate the earliest occupation of the site. However, from Spit 28 on, there is abundant evidence for human activity. From the composition of the vertebrate fauna from this period it is clear that the dominant vegetation community in the vicinity of the site was relatively dry and open vegetation, probably savannah woodland with grassy understorey. This supported a range of species today found in savannah woodland and grasslands of the Trans-Fly and across northern Australia, including *Macropus agilis*, *Isoodon macrourus* and *Rattus sordidus*. However, the presence in the same levels of many species found today in rainforest or dense gallery forest (i.e. *Thylogale* spp., *Dorcopsis* sp., *Echymipera rufescens*, *Poponomys* sp., *Spilocuscus maculatus* and *Phalanger* spp.), also points to the presence in the area of substantial patches of wetter, denser vegetation. These communities presumably occupied topographic lows in the karst landscape, including the major drainage features.

Exactly how much of the area was occupied by each of these vegetation communities is difficult to judge. However, the fact that the two largest of the obligate rainforest animals, namely *Dorcopsis* sp. and *Casuarius* sp., are recorded only sporadically through this period suggests either that the wetter forest communities were of insufficient size and continuity to support viable populations of larger animals, or that these patches were subject to early and intense hunting pressure such that the larger animals were rapidly extirpated. If the latter process took place, then it left no archaeological signature, at least not in the excavated part of Lemdubu.

Spits 18–5 (ca. 20,000–ca. 9000 cal BP)

This zone is characterized by an increase in the relative abundance of the dry community taxa, and a corresponding fall in those taxa associated with wetter, denser habitats. Although the transition point between this zone and the last is set at the boundary between Spits 18 and 19, the transition between the two zones is really a gradual one, with different taxa most likely responding to common stimuli at different times and rates. Thus *T. brunii*, a taxon of deep rainforest habitat, begins to decline in relative abundance from peak values in Spits 20–21, while *T. stigmatica*, a taxon of forest edge habitats, does not increase until after Spit 18. *Macropus agilis*, a true savannah grassland wallaby, is relatively more abundant in Spit 18 and above. The two cuscuses, *S. maculatus* and *P. mimicus*, decrease in abundance after Spit 19, as do varanids and megachiropteran bats. In contrast, cassowary eggshell is present through to Spit 17. A somewhat anomalous trend is the decrease in abundance of *I. macrourus*, a bandicoot of tropical grassland habitats, above Spit 17.

The overall impression, then, is that the rainforest patches probably declined in both extent and quality through this period, perhaps starting from the time Spit 20 was deposited onwards. This may have occurred as a result of climatic deterioration, or through increasing pressure on these habitats as a consequence of hunting and/or general exploitation of forest products. The timing of this change, which corresponds with the peak of the last glaciation, perhaps lends weight in favour of a climatic explanation.

Spits 4–1 (ca. mid-Holocene?–present)

This period is characterized by numerous changes in the faunal assemblage. Most conspicuous is the marked increase in the quantities of shellfish remains and in fish bone, clearly marking the emergence of a marine drainage system within the *sungai* and their tributaries. Other changes include a marked decrease in the relative abundance of wallabies relative to all other groups, an increase in the abundance of *T. brunii* relative to the other macropodids, and a marked increase of both megachiropteran bats and cuscuses. Cassowary bone and eggshell reappear during this period. All of these changes point to an expansion of closed rainforest habitats at the expense of open savannah communities. The addition of pig and dog remains to the assemblage also represents a significant change, indicative of external cultural influence.

The general composition of the vertebrate fauna in this zone is thus consistent with the contemporary habitat of the Aru Islands. In this light, the continued presence of various savannah elements such as *M. agilis* and *I. macrourus* into these levels begs comment. Two possibilities spring to mind. The first is that populations of various savannah dwelling taxa persisted long after the general expansion of rainforests. The second is that the upper levels of Lemdubu are disturbed to the extent that a small quantity of material from the lower levels has moved up into the uppermost spits. One observation that would favour the latter view is the fact that *M. agilis* and *I. macrourus* both disappear before 7700 BP in the extended Nabulei Lisa sequence.

Human Skeletal Material

Human bones which appear to constitute a single burial were recovered from Spits 18–23. The remains are described in detail by Bulbeck (Chapter 12, this volume). The burial is capped by a large flat slab of limestone which occurs in Spits 17 and 18, and which can be seen in the section in Figures 9.5 and 9.6.

The burial is judged to be that of a female. Although the bones are in approximate anatomical position, occasional bones are misplaced or misaligned, and the foot and hand bones are missing altogether. This arrangement suggests a secondary burial; however, it is also possible that it is a primary burial that has been subject to inquest or disturbance after burial.

Dating the Lemdubu burial was essential both to provide an age for the burial itself and in order to ascertain the degree of stratigraphic disturbance within the site. On stratigraphic grounds, it appeared that the body or skeleton had been placed in a hole dug to a depth of approximately 25–30cm from Spit 18 into the surface of Spit 19, and the capping stone placed on top (with subsequent accumulation of the sediment of Spit 18 and 17). The alternative scenario, that the burial and capping stone had been placed at this depth from much higher in the sequence, potentially even from the late Holocene unit, would have major implications for potential mixing of cultural materials in all spits above the burial. However, the clear patterning in the vertebrate and invertebrate faunal remains argues against major disturbance of this kind, as does the evidence for the late Pleistocene age of the burial itself, as indicated by the ESR dating results.

Bone Artefacts

Thirty-seven bone artefacts were recovered from the excavation, of which 34 occurred in Spits 1 to 5, one in Spit 16, and two in Spit 24 (Fig. 9.22). Pasveer (Chapter 11, this volume) provides a full description and analysis of the bone artefact assemblage from Lemdubu. The assemblage comprises unipointed and spatulate artefacts, but within each of these categories there is great variability. Many artefacts are manufactured on fragments of long-bone shaft, such as wallaby fibulae. A high proportion of lightly burnt examples may indicate preparation or intentional selection of this material for bone artefact manufacture. The fact that all specimens found at Lemdubu were ‘fragments’ makes it likely that the artefacts were used and broken on site. It would also seem likely that maintenance activities, such as replacement or repair, took place on site given that mid sections (or butts) occur. A relatively high incidence of specimens with unpolished and undamaged tips may also indicate that primary manufacture took place at the cave, however, since no half-products or ‘unfinished’ specimens were found this remains uncertain.

Pasveer discusses possible functions for the bone artefacts from Lemdubu based on the use-wear and damage they exhibit, and concludes that while the historical accounts from the Aru Islands emphasize the importance of bows and composite arrows as hunting weapons (Merton 1910:60), the wear patterns on the Lemdubu artefacts do not support their use as projectile tips. The Lemdubu assemblage display various combinations of damage and polish, often of quite high intensity. The presence of polish in general suggests a mode of use including repeated friction, and this is unlikely to accumulate on artefacts that are subjected to high velocity impact such as arrow tips or spear points. Pasveer concludes that the bone artefacts were most likely used for drilling holes or in engraving activities; the actions most likely to generate both polish and damage such as crushing or step fracturing of the tip. A similar conclusion was reached by Pasveer (2004) and Pasveer & Bellwood (2004) for the bone artefacts from the Bird’s Head of New Guinea and Northern Maluku, respectively.

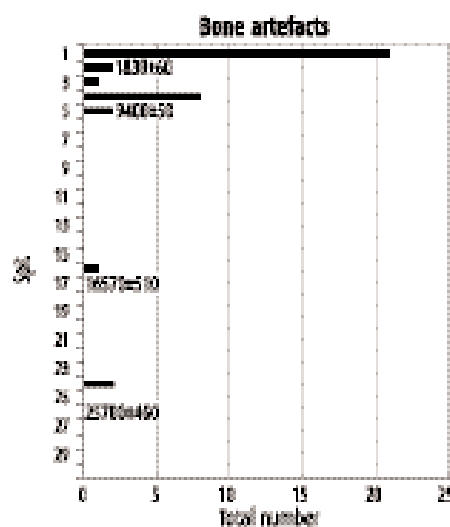


Figure 9.22 Liang Lemdubu: Test Pit C, distribution of bone artefacts through the sequence, also showing selected radiometric dates

Stone Artefacts

Stone artefacts occurred throughout the excavation, generally in low numbers (Tables 9.2 and 9.3). The stone artefacts are described in detail by Hiscock in the following chapter (Chapter 10). The assemblage is essentially composed of small percussion struck flakes (Fig. 9.23), with a minor modified component represented by a few retouched/utilized flakes. An interesting change in dominant lithology occurs within the sequence, with silicified limestone dominant in the upper five spits and cherts present in larger proportion in the lower levels. One interesting and unusual feature of the assemblage is the near absence of both cores and micro-debitage of the kind produced during flake manufacture or retouch. This may indicate that manufacturing took place off site, i.e. that the flakes in the assemblage were brought into the site, ready-made for use. Most artefacts occur between Spits 7 and 10 at the terminal Pleistocene/Holocene boundary. The peak value for stone artefacts in Spit 1 is due to the presence of a single large specimen.

The change in lithology may be due to changes in the local site environment. It is possible that the source of the chert used to produce artefacts in the Pleistocene became inaccessible when present sea level conditions were established (thought to coincide with the deposition of Spit 4). Alternatively, it may simply be that there was a change in site function in the late Holocene, after which time the site was presumably used in much the same way as it is today, by hunter-horticulturalists with metal and bamboo tools. Hunters today use predominantly metal and sharp bamboo knives to skin and butcher their catch. While there is no indication of the appearance of metal in the site, we may presume from the dates for the upper three spits that metal tools were in general circulation by this time.

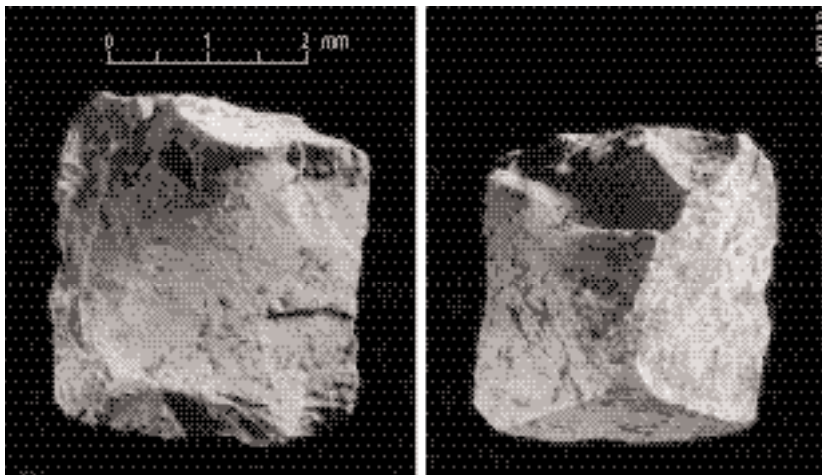


Figure 9.23 Liang Lemdubu: Test Pit C, typical small chert flake

Pottery

Aside from the historic porcelain and pottery vessels cemented to the natural flowstone platform in the central area of the cave, there was little pottery to be seen on the surface of the cave floor. Three sherds were recovered from the upper two spits in Test Pit C but were returned to Jakarta and were not included in the petrological analysis of the Aru sherds. The field records indicate that these were small body fragments of earthenware pots, and were calcite-quartz tempered.

Conclusions

The lowest stone artefact at Liang Lemdubu is found in Spit 29. The earliest dated level with evidence for occupation is Spit 28, dated at 27,000 BP. As the fauna in Spits 30 and 31 is probably not humanly derived, it seems likely that the date of 27,000 years is close to the real age for initial human occupation at the site.

The initial occupation of Liang Lemdubu is considerably later than that documented from areas elsewhere in Melanesia and in northern Australia (O'Connor and Chappell 2003). This begs the question as to whether evidence for older occupation might be found with more extensive sampling of Lemdubu or elsewhere on the Aru Islands, or alternatively, whether the Aru Plateau may have been unattractive to human occupants of the wider region prior to 27,000 BP. Evidence from elsewhere in the region does suggest that the period prior to 28,000 BP was wetter than subsequently (van der Kaars 1991; van der Kaars et al. 2000), and it is probable that the Aru Plateau would have supported a rainforest community at that time. The Aru Plateau may have become more favourable for human occupation after 27,000 as drier conditions ensued and the vegetation opened up, producing more diverse habitats for an array of mammal fauna.

The Liang Lemdubu faunal sequence beginning 27,000 years ago, documents the presence on the late Pleistocene Koproor Plateau of open savannah with denser, lush vegetation present in pockets along watercourses and in other sheltered areas. The mammal fauna present at that time was basically similar to that found today in the Trans-Fly region of New Guinea and in parts of Cape York Peninsula, but included more species than either of these areas has today. People using the site at this time focussed their efforts on the procurement of the large-bodied Agile Wallaby (*Macropus agilis*) and several smaller wallabies (*Thylogale* spp.), with more casual acquisition of various medium-sized animals including cuscuses, bandicoots and pythons. Around 20,000 BP, the faunal assemblage changes slightly, with an increase in savannah elements at the expense of rainforest fauna. This may reflect a deterioration of climatic conditions associated with the glacial maximum or it might be related to a progressive deterioration of the rainforest patches over time.

The terminal Pleistocene saw the inundation of the Carpentarian Plain, the change to insular conditions, and the expansion of rainforest habitats across the Aru Islands. Human occupation of the cave and net sediment accumulation appears to have ceased entirely or been minimal during this time, at least in the area of Test Pit C.

In an earlier paper (O'Connor et al. 2002) we questioned whether widespread human abandonment may have been a response to the spread of rainforest in the early Holocene, and discussed this possibility within the context of hunter/gatherer responses to rainforest elsewhere in the tropical world (e.g. Bailey and Headland 1991; Roosevelt et al. 1996). The disappearance of the savannah species such as the Agile Wallaby, which appear to have been a significant component of the Pleistocene subsistence strategy, led us to question whether Aru may have represented a similar case to southwest Tasmania, where Kiernan et al. (1983) argued that 'recolonization of the region by forest tree species [in the Holocene] reduced the preferred habitats of the game species; game became scarce and humans also left' (see also Porch and Allen 1995:725). The excavation and dating of Liang Nabulei Lisa (Chapter 6, this volume) has demonstrated beyond doubt that Aru was occupied throughout the Holocene. If Liang Lemdubu was indeed abandoned at this time, it was perhaps as a response to local rather than regional changes. The cave may have been too remote from the *sungai* to make regular visitation worthwhile once the rich savannah plains were no longer a hunting drawcard. Alternatively, this chronostratigraphic gap may simply be a product of limited sampling in a large cave where material is unevenly distributed across the floor.

The stone artefacts in Liang Lemdubu show little variation through time, with the exception of a change in dominant lithologies. Silicified limestone dominates the upper five spits, and below Spit 9 around 80-90% of all artefacts are made on chert. It may be that the source of the chert became inaccessible in the mid-late Holocene following sea level rise. As noted earlier, a similar situation has been reported in the southwest of Western Australia where offshore chert sources were drowned by post-glacial sea level rise and cease to be available after 6000 BP, and consequently late Holocene tools are predominantly made on other lithologies (Glover 1975; Pearce 1977). Alternatively, it may simply be that in the late Holocene the site was being used predominantly by 'horticultural' hunters who acquired and used stone on a much more expedient basis and probably also used metal tools.

One interesting and unusual feature of the stone artefact assemblage is the near absence of cores and very small flakes resulting from artefact manufacture or retouch, indicating that manufacturing took place off site, and the flakes in the assemblage were brought into the site for use. The highest numbers of artefacts occur between Spits 7 and 10, whereas bone weights are highest in Spits 24 and 25, following fairly fast on initial occupation of the site. However, the bone above Spit 12 is more heavily burnt and highly reduced, suggesting more intense use of the site and local resources — including stone — and perhaps more intense reduction of the bone to extract marrow.

The late Holocene spits (1–4) indicate a shift in the patterns of resource use and presumably site use. They contain pottery, dog and pig bones, and presumably reflect the arrival of agriculturalists. The non-domesticated fauna indicates a change in the environment around the site as well as hunting strategy. There is an increased use of marine resources obtainable from the *sungai* following post-transgressive sea levels. Specific, targeted hunting of wallabies declines. This may simply reflect species availability following the spread of wetter forests and the loss of the open savannah element, most prominently the Agile Wallaby. The decrease in wallabies is countered by an increased use of riverine resources, such as fish and shellfish, and of various lesser game items such as cuscuses and fruitbats. This phase of cave use may have looked much like the present-day use of the cave, which is predominantly by people with a horticulturally-based economy who use it on hunting trips or when passing through the karst on their way from one area of gardens to another. Wallace's (1869:343) observation of the interior groups of this area contrasts sharply with the faunal deposit from the Pleistocene levels of Liang Lemdubu, but sits more comfortably with the Holocene assemblage:

Now and then they get wild pig or kangaroo, but too rarely to form anything like a regular part of their diet, which is essentially vegetable ... e.g. plantains, yams, sweet potatoes and raw sago; sugar cane, betel nuts, gambir and tobacco.

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Appendix 9.1: Liang Lemdubu: Test Pit C, Log of the Sediments from the Bulk Samples by Spit

SPIT	MUNSELL COLOUR	pH	DESCRIPTION
1	Grey: 10YR 6/1-5/1	8.0	Very well sorted medium and fine silts with minor very fine sands (loose unconsolidated powdery with no aggregates). Occasional 4-6mm angular to subangular fine gravels of limestone dispersed. Occasional clasts (<5mm) of travertine. The broken shell and bone component are unweathered
2		8.0	No bulk sample
3	Grey: 10YR 6/1-5/1	8.0	Very well sorted medium and fine silts, with minor very fine sands (loose unconsolidated powdery with no aggregates). Occasional to frequent 10-15mm irregular nodular subrounded concretions of calcrete. Occasional large broken shell and some bone to 35mm
4	Grey: 10YR 6/1-5/1	8.0	Very fine silts. Well sorted to very well sorted. Powdery and loose. Occasional irregular 20-30mm calcrete (?) nodules with pitted exteriors, angular limestone fragments (20-25mm) and broken shell/bone
5		8.5	No bulk sample
6		8.0	No bulk sample
7	Light Brownish Grey to Pale Brown: 10YR 6/2-6/3	8.0-9.0	Very fine to medium silts with minor component of fine sands. < frequency in 2-4mm aggregates (rounded nodular) of silts. < frequency in large calcrete nodules. Frequent clasts of 5-20mm — calcrete or limestone. Some bone
8	Light Brownish Grey: 10YR 6/2	8.5	Very fine to medium silts with minor component of fine sands (well sorted). With occasional poorly sorted inclusions and irregular angular clasts of limestone/calcrete (25-30mm), occasional large broken bone. Minor flecking of 0-5mm white carbonate through matrix. Very minor aggregates
9	Light Brownish Grey: 10YR 6/2	8.5	Very fine to medium silts with minor component of fine sands (well sorted). Numerous 2-4mm subrounded silt aggregates (> with respect to Spit 8). Decrease in % of large limestone clasts although occasional and still irregular clasts (angular to subangular) of limestone 15-30mm. Carbonate adhering to some smaller bones
10	Light Brownish Grey: 10YR 6/2	8.0-9.0	Fine to medium silts, well sorted. Minor fine sands. Minor aggregates (nodular) 2-4mm of silts. < in gravel-sized limestone/calcrete inclusions. Most inclusions 20-40mm are fractured bone
11			No bulk sample
12	Light Brownish Grey to Pale Brown: 10YR 6/2-6/3	8.5	Fine to medium slightly gritty silts. > in 1-3mm pellet aggregates. <1mm spotting of carbonate with loose matrix and ped aggregates. 10-15mm limestone/calcrete clasts (subrounded to subangular). Bone occasional only
13			No bulk sample
14			No bulk sample
15	Brown: 10YR 5/3	8.5	Moderately sorted fine sandy silts. Well developed aggregates (1-3mm, mostly subrounded) of sandy silts. Carbonate flecking (white) <1mm throughout both matrix and aggregates. Infrequent irregular 2-3mm inclusions of reddish — yellow colour (5YR 6/6) — possibly burnt clays/soil peds/Fe-rich
16	Brown: 10YR 5/3	8.0-9.0	Moderately sorted fine sandy medium to fine silts with frequent subrounded to subangular clasts of broken limestone/bone 10-20mm. Numerous aggregates of silty sands/sandy silts in 1-3mm range. Also minor fractured bone typically <10mm. NB: Infrequent particles of Fe-rich nodules/aggregates continue from previous sample (typically 1-2mm, case hardened, with dusty red-brown silty-clay (?) interiors
17			No bulk sample
18	Brown: 10YR 5/3	8.5	Moderately sorted fine sandy medium silts and coarse (1-5mm) sandy silt aggregates. Some aggregates 5-15mm — deposit better aggregated. Comminuted carbonate (1-2mm) in loose matrix and within aggregates. Occasional large (10-15mm) subrounded limestone clasts/calcrete clasts and broken bone (bone has sediment cemented to surface). Dusty red-brown clay-silt pellets 1-3mm continue

continued over

Appendix 9.1: continued

SPIT	MUNSELL COLOUR	pH	DESCRIPTION
19	Greyish Brown to Brown: 10YR 5/2-5/3	8.0-9.0	Moderately sorted fine sandy silts, and 2-5mm aggregates of sandy silts with carbonate bone inclusions. Sediment adheres to broken mammal bone and is within the long bone shafts. Occasional larger 5-12mm fragments irregular partially cemented. Aggregates of charcoal/sandy silts around nuclei of bone
20	Brown: 10YR 5/3	8.0-9.0	Moderately sorted fine to sandy silts. Aggregation increased with sizes 0-5mm to 10mm with amorphous carbonate present in aggregates. Broken bone/shell predominantly <10mm, and breakage in 2-4mm fraction very high. Occasional Fe-rich nodules/aggregates of 2-4mm size — 5YR 6/6-6/8 (reddish yellow)
21	Brown: 10YR 5/3	8.5	As for Spit 20 with some occasional larger bone fragments
22		8.0-9.0	No bulk sample
23		8.0-9.0	No bulk sample
24	Brown: 10YR 5/3	8.0-9.0	Moderately sorted sandy silts and sandy silt aggregates. High development of aggregation and partial cementation. Most sediment is aggregates 1-10mm wide size range. Frequent broken bone with partial mineralization of sediment onto exterior and infilling of marrow cavity within long bones with wide range of sediment sizes. Dark specking, possible charcoal 1-3mm?
25	Brown: 7.5YR 5/3-5/4	8.0-9.0	Poorly sorted aggregated sandy slightly gritty silts, possibly with some clay. Stiff cohesive aggregates with 1-3mm flecking of carbonates within silty matrix. Numerous broken fine fragments of bone (?) — larger bone appears to act as sites for matrix. (In situ deposit possibly a 1-2mm subrounded pellet aggregates — with voids, becoming cemented?)
26	Brown: 7.5YR 5/3-5/4	8.0-9.0	Poorly sorted to very poorly sorted. Stiff slightly sandy, gritty clayey silts with numerous 2-6mm limestone grits or flecking throughout. Some 10-15mm subrounded limestone gravels, occasional broken bone, partially encrusted. Occasional subrounded fine gravels (10-15mm) (elongate) of 10YR 7/6 (yellow) sandy marls. Majority of sediment is a matrix supported sandy clayey silt with fine carbonate pellets/ very fine gravels (Cave Earth)
27		8.0-9.0	No bulk sample
28	Brown: 7.5YR 5/3-5/4	8.0-9.0	Poorly sorted to very poorly sorted. A stiff slightly sandy clayey silt matrix supporting subrounded limestone grits/pellets. Again some 10-20mm 7.5YR 7/6-10YR 7/6 (reddish yellow — yellow) subrounded marlstone clasts. Also fragments of irregular travertine and fine carbonate pellets, and travertine/marls/limestone fine gravels (Cave Earth)
29		8.0-9.0	No bulk sample
30		8.0-9.0	No bulk sample
31	Dark Yellowish Brown: 10YR 4/4	8.0-9.0	Poorly sorted stiff sandy silty clays and clayey silts supporting dispersed limestone pellets (subrounded) 1-3mm throughout. Structure, massive. Clasts 8-15mm of limestone pitted/weathered on surface. Occasional marlstone and 2-4mm Fe-rich siltstone fine pellet casts. No bone or shell fragments

Appendix 9.2: Liang Lemdubu: Test Pit C, Depths (cm) of Excavation Units (Spits) and Deposit Volumes (m³) by Spit

SPIT	NW DEPTH	NE DEPTH	SE DEPTH	SW DEPTH	TOTAL VOLUME
1	10	6	9	9	5.0
2	5	6	5	3	4.0
3	5	5	5	5	3.0
4	5	6	5	4.5	3.0
5	5	5	5	.5	3.5
6	5	6	4	4	3.0
7	5	5	6	5	3.5
8	3	3	4	5	3.5
9	5	4	6	4	4.0
10	7	5	6	6	4.0
11	9	6	4	6	4.0
12	4	6	5	5	3.0
13	5	5	5	5	3.0
14	5	5	5	5	3.5
15	5	5	5	5	3.0
16	5	5	5	5	3.0
17	5	5	5	5	3.0
18	4	5	5	6	3.0
19	6	2	5	4	3.0
20	3	5	5	5	3.0
21	7	8	5	5	4.2
22	5	5	5	5	3.0
23	5	5	5	5	4.0
24	4	5	5	3	4.0
25	9	5	5	7	4.2
26	3	5	5	6	4.0
27	4	5	5	4	3.5
28	9	7	6	8	4.5
29	4	5	6	4	4.5
30	3	6	7	5	4.0
31	6	5	3	3	4.0

Appendix 9.3: Liang Lemdubu: Test Pit C, Faunal Data

NISP Data for all Identified Faunal Specimens by Spit

Spit	TACHYGLOSSUS ACULEATUS	DASYRUS ALBOPUNCTATUS	MYOICTIS WALLACEI	CF SMINTHOPSIS SP.	ISOODON MACRURUS	PERORYCTIDAE	UNIDENTIFIED BANDICOOT	DORCOPSIS SP.	THYOGALE STIGMATICA	THYOGALE BRUNII	THYOGALE SP. (BRUNII OR STIGMATICA)	MACROPUS AGILIS	SPILOSCUS MACULATUS	PHALANGER GYMNOTTIS	PHALANGER MIMICUS	PHALANGER SP. (GYMNOTTIS OR MIMICUS)	DACTYLOPSILA TRIVIRGATA	URONYX CAUDIMACULATUS	PARAHYDROMYS ASPER	MELOMYS SP. CF. M. BURTONI	PARAMELOMYS NASO	POGONOMYS SP.	PSEUDOMYS SP. CF. P. NANUS	RATTUS SORDIDUS	SMALL MURID	CHIROPTERA	SUIDAE	CANIDAE	PIG/DEER/DOG	FROG	SMALL BIRD	CASUARUS SP.	CHELUID TURTLE	BOIDAE	COLUBROIDEA	VARANIDAE	AGAMIDAE	SCINCIDAE	UNIDENTIFIED LIZARD	FISH				
1	0	0	1	0	1	2	6	0	11	13	16	5	39	4	21	59	1	9	0	0	0	0	0	0	5	103	28	0	15	1	1	1	1	1	86	0	0	1	8	1	0	69		
2	0	0	0	0	0	4	5	0	0	3	9	0	8	1	0	25	0	4	0	0	0	0	0	0	1	27	11	1	9	1	0	0	0	0	28	0	0	1	2	0	0	30		
3	0	0	0	0	1	2	0	0	2	8	3	2	5	1	0	1	0	0	0	0	0	0	0	0	1	4	3	0	0	0	0	0	0	0	21	0	0	0	1	1	1	12		
4	0	0	0	0	3	1	1	0	6	11	3	15	7	1	2	14	0	0	0	0	0	0	0	0	5	2	0	0	0	0	0	0	0	46	0	0	0	1	0	1	4			
5	0	0	0	1	2	1	2	0	8	4	11	22	6	0	4	4	0	0	1	0	0	0	0	4	3	0	0	0	0	0	0	0	104	0	1	2	0	0	1	2	0	0		
6	0	0	0	0	1	2	3	0	13	6	13	19	7	0	0	19	0	2	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	93	0	1	0	0	1	0	1	0		
7	0	0	0	0	2	0	3	0	33	22	26	52	19	0	2	14	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	124	0	2	0	0	2	0	0	1	0		
8	0	0	0	0	2	0	7	0	31	25	16	49	14	0	6	11	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	78	0	2	0	0	2	0	0	0	0		
9	4	0	0	0	2	0	9	0	53	23	45	75	9	0	3	28	1	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	164	0	1	0	0	1	0	0	1	0		
10	1	0	0	0	7	1	18	0	91	49	56	138	24	5	13	46	0	2	0	0	0	0	0	2	8	0	0	0	0	0	0	0	339	1	2	0	0	2	0	0	7	0		
11	0	0	0	0	3	0	7	0	28	18	22	46	10	0	3	35	0	0	0	0	0	0	0	1	3	5	0	0	0	0	0	0	88	0	4	0	0	4	0	0	3	0		
12	1	0	0	0	3	2	5	0	21	19	20	51	16	1	3	5	0	0	0	0	0	0	0	3	0	2	0	0	0	0	0	0	83	0	0	0	0	0	0	0	0	0	0	
13	1	0	0	0	3	0	4	0	26	22	14	36	12	1	8	19	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	91	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	3	3	13	0	12	29	21	67	12	3	6	20	0	1	0	0	0	0	0	2	4	5	0	0	0	0	0	0	106	1	0	0	1	0	0	0	0	0	1	0
15	0	0	0	0	3	2	1	0	40	30	22	92	12	1	2	11	0	0	0	0	0	0	0	3	5	4	0	0	0	0	0	0	118	0	0	0	0	2	0	0	0	0	1	1
16	0	0	0	0	3	1	11	0	35	47	17	71	16	0	7	20	0	0	0	0	0	0	1	12	5	0	0	0	0	0	0	0	121	0	4	1	0	4	1	0	0	0	0	
17	0	0	0	0	10	3	10	0	63	19	18	82	9	1	3	23	0	0	0	0	0	1	1	2	10	6	0	0	0	0	0	0	147	0	1	0	0	1	0	0	1	0	0	
18	1	0	0	0	11	3	18	0	18	33	14	53	15	0	2	22	0	0	0	0	0	0	0	5	7	2	0	0	0	1	0	0	126	0	2	0	0	2	0	0	3	0	0	
19	3	0	0	0	21	4	31	0	34	61	35	40	13	3	17	50	0	0	0	0	0	0	4	12	6	0	0	0	0	1	0	0	181	0	6	2	0	0	6	2	0	0	0	
20	0	0	0	0	25	5	27	0	26	55	21	51	18	1	7	37	0	0	0	0	0	0	4	0	2	3	1	0	0	0	1	0	213	0	3	0	0	3	0	0	2	0	0	

continued over

Appendix 9.3: continued

LIPIT	TACHYGLOSSUS ACULEATUS	DASYURUS ALBOPUNCTATUS	MYOICTIS WALLACEI	CF SMINTHOPSIS SP.	ISOODON MACRURUS	PERORYCTIDAE	UNIDENTIFIED BANDICOOT	DORCOPSIS SP.	THYLOGALE STIGMATICATA	THYLOGALE BRUNNI	THYLOGALE BRUNNI (BRUNNI OR STIGMATICATA)	MACROPUS AGILIS	SPILOSCUSCUS MACULATUS	PHALANGER GYMNOTTIS	PHALANGER MIMICUS	PHALANGER SP. (GYMNOTTIS OR MIMICUS)	DACTYLOPSILA TRIVIRGATA	UROMYS CAUDIMACULATUS	PARAHYDROMYS ASPER	MELOMYS SP. CF. M. BURTONI	PARAMELOMYS NASO	POGONOMYS SP.	PSEUDOMYS SP. CF. P. NANUS	RATTUS SORDIDUS	SMALL MURID	CHIROPTERA	SUIDAE	CANIDAE	PIG/DEER/DOG	FROG	SMALL BIRD	CASUARUS SP.	CHELUID TURTLE	BOIDAE	COLUBROIDEA	VARANIDAE	AGAMIDAE	SCINCIDAE	UNIDENTIFIED LIZARD	FISH												
21	0	0	0	0	19	6	46	0	27	59	19	27	19	0	6	35	0	1	0	0	0	4	0	2	14	3	0	0	0	0	0	0	1	0	182	0	4	2	0	0	2	0	0									
22	0	0	1	0	8	2	7	0	13	28	9	16	13	0	4	13	0	1	0	0	0	2	0	2	6	2	0	0	0	0	0	0	0	0	77	0	2	1	0	0	0	0	0	0	0							
23	0	0	0	0	9	4	0	0	35	30	9	24	16	0	0	10	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	46	0	2	1	0	0	0	0	0	0	0	0	0						
24	0	0	0	0	11	2	17	1	112	108	41	98	23	3	13	35	0	0	0	0	1	0	1	0	4	1	0	0	0	0	0	0	0	104	0	6	0	0	0	0	0	0	3	0	0	0						
25	0	0	0	0	21	5	16	0	212	141	66	120	30	4	7	30	0	0	0	0	0	0	0	1	8	0	0	0	0	0	0	0	0	192	0	3	0	0	0	0	0	0	5	0	0	0						
26	0	1	0	0	3	0	9	0	62	29	13	44	8	1	6	23	0	2	0	0	0	1	0	1	5	0	0	0	0	0	0	0	90	0	0	0	0	0	0	0	0	1	0	0	0	0						
27	0	1	0	0	1	1	4	0	19	5	6	29	6	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	53	0	0	0	0	0	0	0	0	0	0	1	0	0	0					
28	0	0	0	0	1	0	2	0	19	0	5	6	1	0	3	10	0	0	2	0	0	0	0	3	6	1	0	0	0	0	0	0	47	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0				
29	0	1	0	0	2	0	0	0	7	5	0	4	0	0	1	9	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
30	0	0	0	0	0	0	1	0	5	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
31	0	0	0	0	0	0	2	0	1	0	1	2	1	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Weight (g) of Bone for each Identified Taxonomic Group and Weight of Bone in Each Burning Category by Spit

SPIT	TOTAL UNBURNT BONE	TOTAL LIGHTLY BURNT BONE	TOTAL BURNT BONE	TOTAL CALCINED BONE	TOTAL BONE	TACHYGLOSSIDAE	DASYURIDAE	PERAMELOIDEA	MACROPODIDAE	PHALANGERIDAE	PETAURIDAE	MURIDAE	CHIROPTERA	SUIDAE	CANIDAE	PIG/DEER/DOG	FROG	CASUARIUS SP.	SMALL BIRD	CHELUID TURTLE	SNAKE	VARANIDAE	AGAMIDAE	SCINCIDAE	UNIDENTIFIED LIZARD	FISH	UNIDENTIFIED BONE
1	627.1	367.5	50.0	68.2	1112.8	0	0.2	3.7	32.9	69.8	0.2	1.0	14.3	0	0	56.2	0.2	4.4	0.1	4.0	30.0	2.0	2.5	0.04	0.8	19.1	871.6
2	197.5	163.7	20.1	37.7	419.0	0	0	2.4	7.0	17.3	0	0.6	6.2	8.9	0.1	34.9	0.1	0	0.03	0	8.2	1.0	0.4	0	0.1	10.1	321.8
3	145.6	148.7	10.0	38.3	342.5	0	0	2.6	12.7	9.0	0	0.0	3.9	18.1	0	0	0	0	0	0	7.2	2.5	0	0	3.5	4.5	278.4
4	124.6	182.5	19.3	63.7	390.1	0	0	3.1	16.9	10.2	0	0.9	1.8	0.8	0	0	0	0	0	0	12.6	0.1	0	0.01	0.5	1.1	341.8
5	199.1	230.8	32.4	93.9	556.2	0.1	0.1	2.3	35.1	11.7	0	0.6	0.9	0	0	0	0	0	0	0	34.4	1.0	0.3	0	0.3	0.3	469.1
6	249.3	234.6	27.2	42.7	553.7	0.3	0.3	3.2	74.2	15.5	0	1.2	0.5	0	0	0	0.02	0	0.1	0	31.5	0.4	0	0	0.1	0	426.9
7	560.8	455.1	74.8	42.5	1133.3	0.8	0.2	6.1	140.0	21.3	0	0	0.2	0	0	0	0	0	0.1	0	41.8	2.0	0	0	0.2	0.1	926.4
8	567.8	420.4	64.9	32.7	1085.9	0.1	0	4.1	153.7	14.7	0	0.1	0.4	0	0	0	0	0	0.3	0	26.8	2.7	0	0	0.0	0	886.1
9	389.9	1243.0	240.3	101.1	1974.2	4.7	0	4.7	236.4	23.8	0.02	0.0	0.2	0	0	0	0	0	0	0	59.3	0.4	0	0	0.7	0	1681.5
10	1549.5	1082.6	227.1	278.5	3137.7	1.1	0	12.9	354.7	58.8	0	0.3	2.5	0	0	0	0	0	0	0	259.7	1.4	0	0.02	1.6	0.04	2444.7
11	677.4	390.2	138.4	74.2	1280.2	0	0	3.9	82.8	16.4	0	0.3	1.6	0	0	0	0	0	0	0	24.4	2.2	0	0	0.8	0.3	1154.1
12	878.4	154.2	51.2	20.1	1103.9	0.6	0.1	6.2	126.6	22.5	0	0.3	0.4	0	0	0	0	0	0	0	43.6	0	0	0	0	0	909.6
13	895.8	135.5	48.2	15.8	1095.2	1.0	0	3.8	195.2	22.0	0	0.1	0.9	0	0	0	0.1	0	0	0	50.8	0	0	0	0	0	874.0
14	1122.2	230.2	42.1	18.5	1412.9	1.2	0	12.7	250.9	20.3	0	0.3	1.6	0	0	0	0	0	0	0.9	48.0	0.3	0	0.08	0.3	0	1133.7
15	973.8	289.5	71.0	27.5	1361.7	0	0	2.8	209.1	18.4	0	1.1	0.9	0	0	0	0	0	0	0	59.6	1.2	0	0	0.1	0.2	1099.9
16	1050.4	364.6	98.3	36.3	1549.5	0	0	10.8	189.6	22.7	0	0.7	2.9	0	0	0	0	0	0	0	74.7	5.0	0.2	0	0	0	1257.3
17	987.9	381.4	108.2	34.3	1511.8	0.1	0	15.8	190.0	26.6	0	1.1	2.9	0	0	0	0	0	0	0	80.3	0.8	0.3	0	0.2	0	1198.9
18	951.3	306.0	127.8	26.3	1411.3	0.7	0	23.2	153.5	44.0	0	1.1	1.2	0	0	0	0	0	1.1	0	71.9	1.9	0.03	0	0.5	0.1	1122.3
19	1278.5	374.0	128.7	11.1	1792.4	0.9	0.1	43.6	253.4	64.2	0	1.5	5.0	0	0	0	0	0	3.4	0	117.2	8.7	0	0	0.2	0	1432.9
20	1782.6	312.4	107.1	17.3	2219.5	1.1	0	39.6	295.6	54.9	0	1.2	1.3	0	0	0	0	4.3	0	0	168.1	6.9	0	0	0.6	0	1642.9
21	1746.2	277.6	90.2	37.2	2151.2	1.9	0	54.3	337.7	60.5	0	1.3	4.4	0	0	0	0	4.4	0	0	136.6	10.7	0.4	0	0.5	0	1573.8
22	1057.7	246.5	54.9	47.2	1406.3	1.6	0.2	16.4	113.2	26.1	0	1.6	1.3	0	0	0	0	0	0	0	57.8	2.6	0.1	0	0	0	1174.6
23	1082.6	294.2	69.0	47.3	1493.0	0.2	0.0	16.6	137.3	26.7	0	1.3	1.1	0	0	0	0	0	0	0	38.2	3.8	0.4	0	0	0.2	1253.4
24	2557.6	577.1	161.9	30.5	3327.1	0	0.1	23.8	360.8	50.2	0	0.3	0.2	0	0	0	0	0	0	0	55.7	3.8	0	0	0.8	0	2818.6
25	4022.6	644.9	482.1	20.0	5169.5	1.5	0.3	35.5	557.5	47.5	0	0.4	0	0	0	0	0	0	0	0	109.3	5.5	0	0	1.0	0	4399.5
26	1499.4	194.6	176.8	6.0	1876.8	0	0.8	4.4	143.9	14.2	0	0.9	0	0	0	0	0	0	0	0	46.4	0.4	0	0.3	0	0	1664.3
27	886.9	38.1	15.4	1.4	941.8	0	2.0	4.0	109.6	7.7	0	0.4	0	0	0	0	0	0	0	0	24.4	0.5	0	0	0.2	0.2	792.3

continued over

Weight (g) od Bone continued

SPIT	TOTAL UNBURNT BONE	TOTAL LIGHTLY BURNT BONE	TOTAL BURNT BONE	TOTAL CALCINED BONE	TOTAL BONE	TACHYGLOSSIDAE	DASYURIDAE	PERAMELOIDEA	MACROPODIDAE	PHALANGERIDAE	PETAURIDAE	MURIDAE	CHIROPTERA	SUIDAE	CANIDAE	PIG/DEER/DOG	FROG	CASUARUS SP.	SMALL BIRD	CHELUID TURTLE	SNAKE	VARANIDAE	AGAMIDAE	SCINCIDAE	UNIDENTIFIED LIZARD	FISH	UNIDENTIFIED BONE
28	562.6	22.1	8.7	6.4	599.8	0	0	1.1	34.5	3.2	0	1.2	0.3	0	0	0	0	0	0	0	20.0	0.2	0	0	0	0	539.4
29	170.3	3.8	6.3	0.7	181.1	0	1.2	1.2	19.5	1.6	0	0.6	0	0	0	0	0	0	0	1.4	8.6	0	0	0	0	0	146.9
30	47.4	0.4	1.1	0.1	49.0	0	0	0.2	1.4	0.7	0	0.3	0	0	0	0	0	0	0.1	0	3.5	0	0	0	0	0	42.8
31	44.5	4.2	0.6	0	49.3	0	0	0.4	0.8	0.7	0	0.2	0	0	0	0	0	0	0.1	0	1.4	0	0	0	0	0	45.6