CAVE ARCHAEOLOGY AND SAMPLING ISSUES IN THE TROPICS:

A Case Study from Lene Hara Cave, a 42,000 Year Old Occupation Site in East Timor, Island Southeast Asia

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Abstract

New evidence from Lene Hara Cave, East Timor, demonstrates that it was first occupied by modern humans by 42,454±450 cal BP at approximately the same time as nearby Jerimalai shelter. Together these sites constitute the earliest evidence for modern human colonisation of Island Southeast Asia east of the Sunda Shelf. Here we report on the dating and stratigraphy from the 2000 and 2002 test excavations at Lene Hara, as well as new dates obtained by sampling breccia deposits in 2009. The post-2000 excavations and sampling demonstrate that different areas of the cave preserve different sedimentary sequences and necessitate a revision of our earlier interpretations of the occupation history of the cave. At Lene Hara, and other caves with complex depositional histories in tropical regions, the occupation sequence will only be revealed through integrating information from extensive areal sampling.

When calibrated, the early dates from East Timor now align closer to the oldest evidence for occupation in northern Australia, with substantial implications for current theories on the colonisation of this region by modern humans. The Nusa Tenggara (Lesser Sunda) island chain emerges as a likely passage for modern human entry into Greater Australia. In view of the short water crossings required to reach Flores from Timor, the apparent absence of modern humans on Flores prior to the Holocene appears highly anomalous.

Introduction

The initial human peopling of Australia is now generally accepted to have occurred between 45,000 and 50,000 years ago, and was possibly as early as 60,000 years ago (O'Connor 2007; Roberts *et al.* 1994; Veth *et al.* 2009). The earliest age estimates have resulted from the use of techniques such as thermoluminescene (TL), optically-stimulated luminesence (OSL) and electron spin resonance (ESR). In the absence of cross-dating on cultural materials, the reliability of these estimates has been questioned by some researchers (Allen and O'Connell 2003). TL, OSL and ESR have also not been widely applied in archaeological contexts in Southeast Asia, making comparison with sites only dated by the radiocarbon technique problematic.

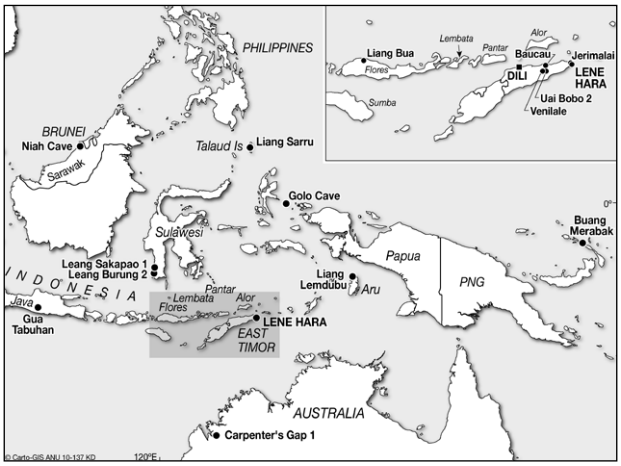

Figure 1 Map of Island Southeast Asia showing East Timor and surrounding islands and Lene Hara Cave.

The Niah Caves of Sarawak and Tabuhan Cave in Java were first used by modern foragers about 45,000 years ago when these islands were part of the Asian mainland (Barker 2005; Sémah *et al.* 2004). AMS radiocarbon dates in the same general age range – between about 51,890±3310 cal BP and 46,738±1550 cal BP – have been obtained for occupation levels in caves in both northern and southern Australia (Table 1) (McConnell and O'Connor 1997; O'Connor and Chappell 2003; Turney *et al.* 2001). Islands to the east of New Guinea requiring further water crossings were also first settled by at least 43,772±448 cal BP (Table 1) (Leavesley and Chappell 2004). However, until recently, islands on potential migration routes between Sunda and Sahul have failed to produce dates for modern human colonisation on a par with those obtained for Australia and Papua New Guinea, with earliest settlement registered at c.36,000 cal BP (O'Connor 2007). The lowest level in Golo Cave, Halmahera is dated to 36,194±457 cal BP (Bellwood *et al.* 1998; Szabó *et al.* 2007). Habitation at Leang Burung 2 and Leang Sakapao 1 in Sulawesi is currently dated no earlier than 35,837±578 cal BP (Glover 1981, Bulbeck *et al.* 2004). Liang Lemdubu in the Aru Islands, far eastern Maluku, was first occupied about 27,020±290 cal BP (O'Connor *et al.* 2002a; O'Connor *et al.* 2005). Even Liang Sarru, in the remote Talaud Islands, between Mindanao and North Sulawesi, has an early occupation phase dating to 35,109±429 cal BP (Tanudirjo 2001). Morwood and colleagues have recently re-excavated Leang Burung 2 and significantly extended the depth of Glover's earlier excavation (Kira Westaway, Department of Environment and Geography, Macquarie University, pers.

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comm., 2010), however dates for the extended excavation have not yet been published.

Flores and Timor are two of the largest islands in Wallacea and the closest to the Sahul Shelf (Figure 1) and should have been settled early by modern humans if migration to Sahul proceeded via a southern route through the Nusa Tenggara island chain and onto the expanded northern Australian coastline; the route regarded as most likely by Birdsell (1977) and others (Butlin 1993:15, 44-51; O'Connor and Chappell 2003). One of Ian Glover's primary goals when he undertook his pioneering research in East Timor in the 1960s was to investigate this question. Glover's research produced a baseline cultural sequence for East Timor, but his oldest site dated to only 16,129±802 cal BP (Table 1) (Glover 1986). Recent work in Flores, which is closer to the Asian mainland than Timor, indicates that it was occupied by the pre-modern hominin *Homo floresiensis* until after 18,473±284 cal BP (Table 1) (Morwood *et al.* 2004:1090), and that definite evidence for modern human arrival did not occur until c.10,000 BP (Brumm *et al.* 2006:628; Morwood and van Oosterzee 2007:224) (the date of 10,000 BP is uncalibrated as we have been unable to locate a radiocarbon measurement to confirm it). The East Timor Archaeological Project initiated in 2000 by three of the authors (SOC, MS and PV) took up afresh some of Glover's unresolved research aims, most prominently the goal of testing for early maritime voyaging to this important area of Wallacea.

The first field season in 2000 focused on a test excavation at Lene Hara Cave and a survey programme to locate other prospective caves and middens. Lene Hara Cave was first excavated in 1963 by the Portuguese anthropologist Antonio de Almeida who reported an 80cm deep cultural assemblage with marine shells and stone artefacts to the base. A brief report on the stone artefacts described them as typologically 'pre-Neolithic' (Almeida and Zbyszewski 1967:57-58). However, the site was never dated and the molluscan and terrestrial fauna were not described. In 1966 Glover visited the site with John Mulvaney and photographed Almeida's still open trench (Glover 1972:Vol. 1:40, Vol. 2:Plate 3.2). Glover observed that the pottery seemed to be confined to the surface and that the stone artefacts were unlike the 'distinctive tool types' found elsewhere in Timor (Glover 1986:40). He surmised that the Lene Hara assemblage might be 'far older' than those from his own excavations in the Baucau and Venilale regions in central East Timor (Glover 1986:7). Our 2000 test excavations aimed to follow up these observations. A brief report on the dates and finds from this test excavation was published in 2002 (O'Connor *et al.* 2002b) and the rock art has also been published (O'Connor 2003; O'Connor *et al.* 2010). Here we report in more detail on the dating and stratigraphy of the 2000 excavation at Lene Hara as well as providing preliminary results of excavation and dating of three other test pits (B, D and F) and dates on cultural material in breccia deposits sampled in

Table 1 Dates from sites discussed in the text. Radiocarbon ages were calibrated using OxCal (Version 4.1) (Bronk Ramsey 2009) and the IntCal09 and Marine09 calibration datasets (Reimer *et al.* 2009), except for the age marked with an asterisk from Devil's Lair, which exceeds the limit of IntCal09 and was calibrated with CalPal-2007 using the error range of 2590 (download version) (Weninger *et al.* 2010). ¥=Uranium-Thorium date.

Site	Material	Lab No.	Age BP	Mean Calibrated Age (68% probability)	Reference
Australia					
Carpenter's Gap 1	charcoal	OZD-161	42,800±1850	46,738±1550	McConnell and O'Connor 1997
Devil's Lair	charcoal	ANU-11511*	48,130+2590/-1960	51,890±3310	Turney *et al.* 2001
Papua New Guinea					
Buang Merabak	*Turbo argyrostoma*	ANUA-15809	40,090±550	43,772±448	Leavesley and Chappell 2004
Halmahera					
Golo Cave	marine shell	Wk-4629	32,210±320	36,194±457	Bellwood *et al.* 1998
Golo Cave	marine shell	Wk-17764	28,740±474	32,720±682	Szabó *et al.* 2007
Golo Cave	marine shell	Wk-17761	28,251±305	32,105±419	Szabó *et al.* 2007
Sulawesi and Talaud Islands					
Leang Burung 2	marine shell	GrN-8649	31,260±330	35,524±455	Glover 1981
Leang Sakapao 1	freshwater shell	Wk-3821	31,280±570	35,837±578	Bulbeck *et al.* 2004
Leang Sarru (Talaud Is.)	*Turbo* sp.	ANU-10203	9750±90	10,655±134	Tanudirjo 2001
Leang Sarru	*Turbo* sp.	ANU-10810	14,820±80	17,522±190	Tanudirjo 2001
Leang Sarru	*Turbo* sp.	ANU-10499	30,740±720	35,071±822	Tanudirjo 2001
Leang Sarru	*Turbo* sp.	ANU-10960	18,880±140	22,001±233	Tanudirjo 2001
Leang Sarru	*Turbo* sp.	ANU-10961	30,850±340	35,109±429	Tanudirjo 2001
Lesser Sunda Islands					
Uai Bobo 2 (East Timor)	charcoal	ANU-238	13,400±520	16,129±802	Glover 1986
Liang Bua (Flores)	charcoal	ANUA-27116	15,300±240	18,473±284	Morwood *et al.* 2004
Aru Island					
Liang Lemdubu	flowstone	LC28 (Site Code)		27,020±290¥	O'Connor *et al.* 2002a

Figure 2 Lene Hara Cave entrance showing ritual platform and stone walling looking towards Test Pits D and F in the northern chamber (Photograph: Sue O'Connor, 2002).

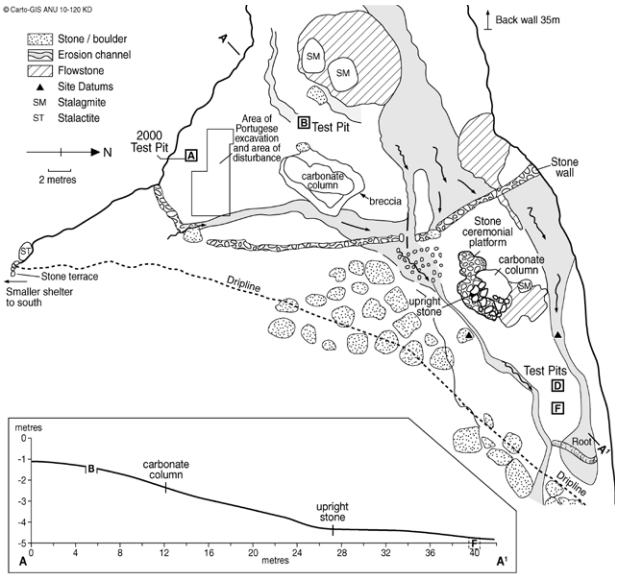

Figure 3 Lene Hara Cave plan showing stone walling, location of Test Pits A, B, D and F and the large speleothem column between the northern and southern chambers where the dated breccia deposit is located.

2009. These new data necessitate major revision of our initial interpretations regarding the occupation history of the cave.

The Environmental Context, Structural Morphology and Present Sedimentation Patterns of Lene Hara Cave

Lene Hara is a large limestone solution cave (Figures 2-3) at the extreme eastern tip of East Timor (Figure 1). It is situated at c.100m altitude in an uplifted coral terrace, which is less than 1km from the current coastline. As the offshore profile in this region is steeply shelving, the cave would always have been within walking distance of coastal resources, even when sea-level was at its lowest during the Last Glacial Maximum (28,000-18,000 cal BP).

The cave entrance faces east, with a well-developed dripline overhanging a partly vegetated terrace at the front of the cave. The limestone forming the cave is well-bedded, with folding in the limestone providing a structural control on much of the curvature of the walls, panel areas free of speleothem, and the arched cave roof. The cave is elliptical in cross-section and broadly open, possibly reflecting an early phreatic origin. Some modern tree roots have penetrated down through the cave roof but these are not sites of contemporary carbonate deposition. Isolated large speleothem deposits occur as 2–4m wide columns and 1–2m high mounds within the interior of the cave, and as both thin columns, and massive columnar complexes overlain by more recent flowstone veneer. Some speleothem columns are tilted, possibly reflecting tectonic activity. Many show elevated pedestals, suggesting past erosion of unconsolidated sediments from around the base of the columns, and net lowering of the cave floor abutting these structures. Contemporary speleothem growth appears to be restricted to minor stalactite formation and an area of active flowstone accretion on the southern side of a large speleothem column, adjacent to Pit B (Figure 3).

The present cave floor is inclined, highest in the south and sloping away to the north and northeast. The northern entrance is significantly lower than the floor of the southern chamber. Surficial cave floor sediment is generally a loose organic cave earth, comprised of fine sands to silt. High areas around the speleothem columns serve to channel episodic surface flow in washways that drain to outlets located near the northeast end wall of the cave entrance. Winnowing along the washways has produced small areas of gravel pavement and some exposure of flowstone deposits (Figure 3).

The dripline area at the mouth of the entrance is over 40m wide, and the main cave extends more than 50m into the hillside before entering narrow fissure systems. Under the dripline, large mounded areas of block fall, comprising both limestone and fallen speleothem, form 2–5m high piles of block debris, particularly towards the central area and extreme north of the entrance (Figure 3).

Patterns of recent sedimentation within the cave have been further complicated by the construction of linear stone walls. The walls have been built by collecting and piling up boulder rock fall, and in places by incorporating *in situ* speleothem columns into them. The walls are generally <0.5m in height, and extensive. One well-defined continuous arcuate wall crosses the cave floor about 2–5m inside the dripline in the south, and another lies 15m inside the dripline in the north. Despite the substantial nature of the stone walling, the cave does not appear to have ever been used to corral domestic animals, unlike some others recorded in East Timor (Pannell and O'Connor 2005). The main wall shows evidence for repeated reconstruction where it intersects the washways suggesting episodic water flows at these points, and some antiquity for the construction itself. A constructed ceremonial stone platform in the northern chamber lies outside the area enclosed by the wall and supports a prominent standing stone (Figures 2-3). This area is still used by the current Fataluku-speaking landowners for ritual purposes.

The central outer mounded rampart area of rock fall and, further inside, the large speleothem column, effectively separate the mouth of the cave into two main entrance routes which lead into different areas; the southern entrance opens into a broad deep chamber that contains most of the painted rock art. The art occurs in panels on the roof just inside the cave entrance and above the main speleothem formation in the central area of the cave (Figures 2-3).

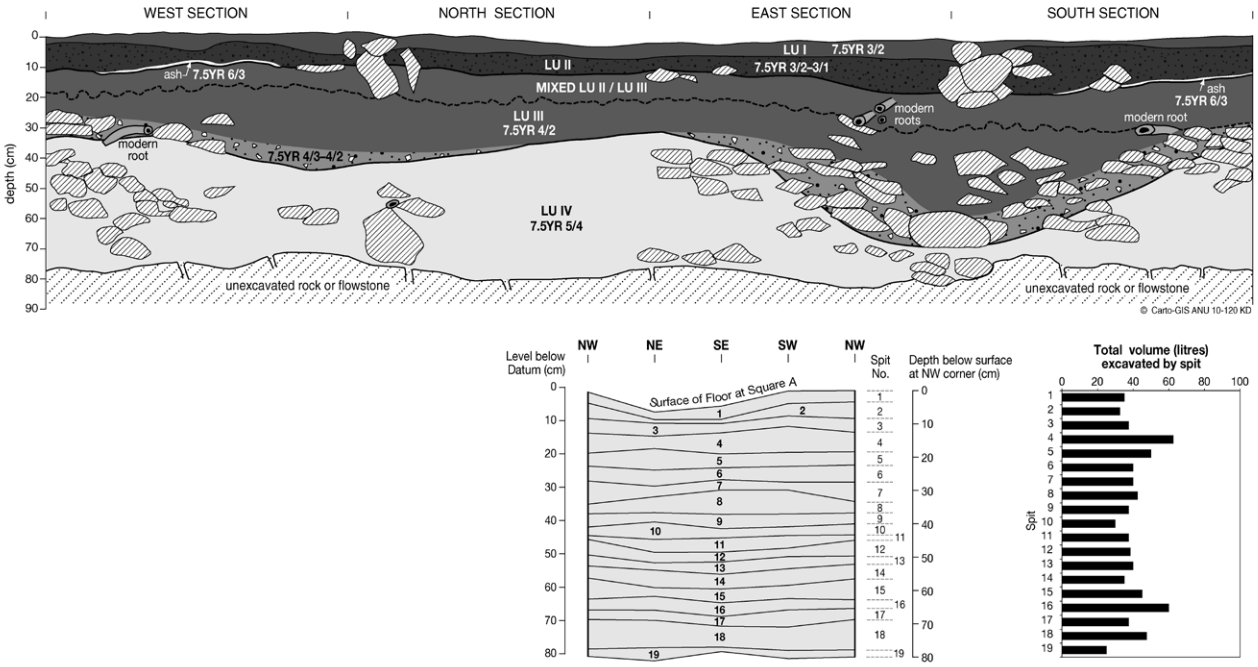

Figure 4 Lene Hara Test Pit A sections, depths and volume data for excavated spits.

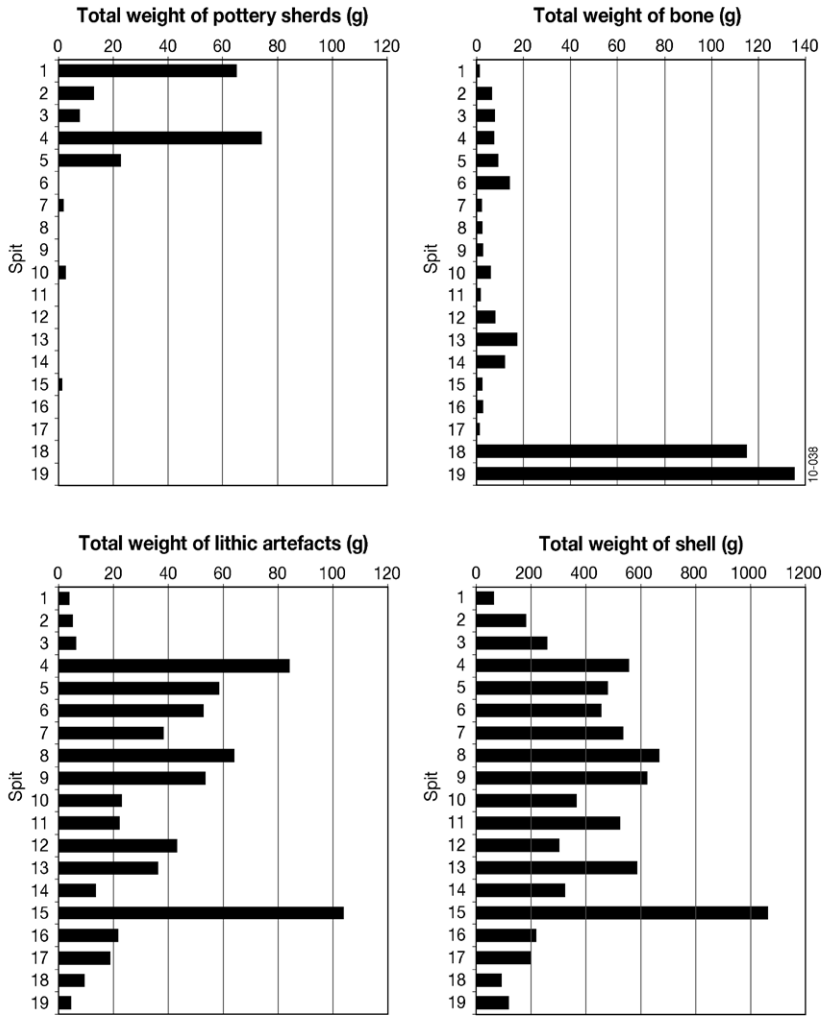

Figure 5 Lene Hara Test Pit A, pottery, stone artefacts, bone and marine shell, weight (g) by spit. In the lowest two spits treatment to dissolve encrusting carbonate and sediment failed to remove all the adherent sediment and 'bone' weights for these spits are thus somewhat inflated.

Lene Hara Cave 2000 Excavation

In 2000 two of the authors (SOC and MS) positioned a 1m x 1m test pit (Pit A) adjacent to Almeida's trench near the southern entrance, which we located by reference to Glover's (1972:Vol. 2:Plate 3.2) published photograph and an area of surface disturbance indicating its approximate position (Figure 3). Pit A was located very close to the southern wall of the cave, where the roof is low. The sediments in this part of the cave floor are significantly higher than most other parts of the cave, and the surface slopes down toward the eroded pedestal base of the large speleothem to the north (Figure 3).

Our testing confirmed the depth of deposit in this region of the cave at c.80cm (Figure 4). The deposit was excavated in spit removals ranging from 3–6cm in depth (see Figure 4) and comprised poorly sorted sandy sediments, with large boulders and cobbles throughout the sequence. However, a broad lithostratigraphic division into an upper and lower deposit was noted during excavation, subsequently to be confirmed by radiocarbon dating.

The upper deposits (broadly from surface to 10 to 15cm) are comprised of dark brown sandy silts, which are subhorizontal, soft and generally well-sorted. Well-defined hearth features, preserved organics, and discrete areas of associated fire ash occur within this part of the profile. The lower deposits, from 25–30cm down to 80cm, consist of much coarser, poorly sorted and denser sediments, ranging from gravelly silty sands to very coarse clast-supported cobble gravels and boulder rubble. These sediments are clay-rich in places, and contain high proportions of clastic roof fall. In the southeast corner of the square these deposits are very coarse and are comprised of a well-defined cobble-filled depression (see Figure 4). The deposits become progressively more lithified below 60cm, where roof fall and cultural material are cemented together by carbonates to form a weakly to moderately lithified, very coarse breccia extending to the base of the test pit. These deposits were broken up with a geological pick. The stratigraphic contact between the 'upper' group of finer deposits and 'lower' more clastic deposits is gradational, undulating and difficult to define when excavating in plan.

The excavated deposit was first dry-sieved and then wet-sieved through fine mesh (<2mm). Only large fragments of roof fall were sorted and discarded at the cave, all remaining material being sorted after further washing and drying in good light. This ensured excellent recovery of small items including small lithic debitage, small pottery fragments and shell beads and probably accounts for the differences between our cultural assemblage and those of Almeida and Glover. Most pottery occurred in the top 25cm of the deposit along with stone artefacts, shell and bone (Figure 5). Two shell artefacts were recovered from Spits 7 and 10; these have been directly dated, as reported below (O'Connor *et al.* 2002c). Stone artefacts, marine shell and bone continue to bedrock at c.80–82cm (Figure 4). The faunal remains indicate a heavy reliance on marine resources such as turtle, fish and shellfish; especially in the Pleistocene levels (O'Connor and Aplin 2007). The pottery consists mostly of small sherds from globular vessels with rounded bases – in all probability simple undecorated cooking pots. The stone artefact assemblage is dominated by small unretouched flakes made on chert nodules.

The Sediment Stratigraphy at Test Pit A

Detailed recording, section drawing and sample analysis showed that the upper and lower groups of sediments are further divisible into a sequence of four stratified lithostratigraphic units (LUI–LUIV). The relationships between the drawn stratigraphy, lithostratigraphic units and excavation unit data (spit depths and volumes) are shown in Figure 4.

The surficial sediments (LUI) of Pit A consist of well-sorted sandy silt with near horizontal bedding. This unit is very soft, unconsolidated and variable in thickness, ranging from 0–5/8cm, and conformably overlies the slightly undulating surface of LUII, comprised of denser and more organic stained darker brown sandy silts. Unit LUII includes a small, well-defined hearth feature (9.5cm depth), which together with other discrete areas of charcoal, ash and preserved organics, suggest minimal bioturbation within this unit (Figure 4). LUII extends variably to 5–15cm below surface, and is in places disrupted as a laterally continuous deposit by patches of large cobbles and boulders. Larger clasts are both vertically and horizontally orientated and often concentrated together (e.g. south corner of Pit A), suggesting some winnowing and/or rotational movement of the larger clasts may be taking place within the finer sediment matrix.

LUIII consists of coarse to fine sandy silts, mixed with variable proportions of coarser gravels and shell; there is a general upward coarsening trend. LUIII extends from 8cm to 15cm below the surface, down to a highly undulating contact that stands as high as 25cm (in the west section), down to as low as 55–60cm in the southeast corner of the square. The lower part of LUIII is coarse and clast-supported and shows significant preferred dip and orientation of larger clasts associated with the sides of the depression in the southeast corner. Bioturbation by modern roots is common at 20–35cm depth, reflecting moisture storage.

LUIV comprises the underlying coarse shelly gravels which grade into a cemented breccia below 60cm. As shown in Figure 4, the surface of LUIV bears a broad trough-like feature, around which larger rock fall clasts are concentrated, running broadly southeast-northwest through the test pit. This feature is infilled by a loose rubbly lag of LUIII deposits, overlying denser and partly cemented gravels of LUIV.

Radiometric Dating of Test Pit A

Although all excavated material was wet-sieved and organics removed by floatation for each spit, charcoal was only recovered in small quantities from the upper two spits. Marine shell was therefore used to date the deposit. All marine shell described in the analysis and used for dating is anthropogenic. Occasional fossil casts of shell from the cave roof are found in the deposit. However these are easily distinguishable from the 'midden' material. All marine shells selected for radiocarbon dating were first thin-sectioned and examined by John Chappell (Research School of Earth Sciences, Australian National University) to ensure that no carbonate recrystallisation had occurred within the shell.

The eight radiocarbon dates obtained in 2001 (O'Connor *et al.* 2002b) indicated that most of the marine shell within the sampled sequence was of Pleistocene age, dating to the period 39,325±831 to 34,279±394 cal BP (Table 2). A single sample of *Trochus* sp. from Spit 2 (5-10cm depth) produced a late Holocene age. This suggested either that occupation of the cave was

discontinuous or spatially uneven, or that substantial erosion of the deposit had occurred, creating a 30,000 year hiatus in a formerly more complete sequence.

In our preliminary report on the site it was suggested that changes in sea-level may have made the cave less accessible during the terminal Pleistocene and early-to-mid-Holocene (O'Connor *et al.* 2002b:48). Subsequently a programme of direct dating of shell artefacts from Pit A produced mid-Holocene dates of 4559±74 cal BP and 3517±57 cal BP on two drilled beads from Spits 7 and 10 (O'Connor *et al.* 2002c:19). This demonstrated that at least some use had been made of the cave during the mid-Holocene and that fragments of Holocene-aged cultural materials were emplaced within the predominantly late Pleistocene lower units of Pit A.

Chronostratigraphic Interpretation of Test Pit A

The lithostratigraphy indicates a cave floor deposit accumulated largely as a result of clastic roof fall. This material has weathered *in situ* and has been reworked to create a steeply undulating topography, either through local scour activity or perhaps through subsidence. The lower part of LUIV is interpreted as contemporary with, or slightly earlier than, initial human occupation at c.39,000 cal BP. Subsequent infilling of that topography (to approximately 25cm below present surface) was associated with a c.5000 year phase of human occupation, with deposition of shell, bone and lithic material. A phase of very low net sediment accumulation, possibly without associated human occupation, is represented by the sediments from 8–15cm to around 25cm depth. Further localised rock fall

Table 2 Radiocarbon determinations from Test Pits A, B, D and F and breccia deposit at Lene Hara Cave. The values of $\delta^{13}C$ are assumed if followed by 'e'. As the natural range of $\delta^{13}C$ for marine carbonates is -3‰ to +2‰ (VPDB scale) the potential impact of the $\delta^{13}C$ correction on the ^{14}C age is very small. A 1‰ change in $\delta^{13}C$ makes an 8 year difference in the reported age. Dates were calibrated using Oxcal (version 4.1) (Bronk Ramsey 2009; Reimer *et al.* 2009).

Excavation Unit	Depth (cm)	Material	Lab. No.	$\delta^{13}C$ (‰)	^{14}C Age (years BP)	Mean Calibrated Age (68% probability)
Square A						
2	4-8	*Trochus niloticus*	ANU-11400	3.0±2.0	1030±60	601±48
4(A)	12-16	*Lambis lambis*	ANU-11419	0.0±2.0[e]	33,150±550	37,523±673
4(B)	12-16	*Strombus luhuanus*	ANU-11420	2.2±0.1	30,970±460	35,316±529
5	16-20	*Strombus luhuanus*	ANU-11398	2.3±2.0	30,110±320	34,279±394
7	24-28	*Trochus* sp. bead	OZF-212	0.0±2.0[e]	4400±40	4559±74
10	36-40	*Strombus* sp. bead	OZF-213	0.0±2.0[e]	3620±40	3517±57
10	36-40	*Strombus luhuanus*	ANU-11399	1.9±2.0	32,440±400	36,560±586
14(A)	52-56	*Strombus luhuanus*	ANU-11397	2.1±2.0	30,990±340	35,262±462
14(B)	52-56	*Trochus* sp.	ANU-11418	2.9±0.1	34,650±630	39,325±831
18	67-75	*Strombus luhuanus*	ANU-11401	1.9±2.0	30,950±360	35,237±468
Square B						
2	1-4	*Turbo argyrostoma*	ANU-12138	0.0±2.0[e]	18,740±400	21,904±512
5	8-11	*Trochus niloticus*	ANU-12141	0.0±2.0[e]	18,380±220	21,485±361
10	25-28	*Trochus niloticus*	ANU-12139	0.0±2.0[e]	23,790±210	28,202±229
15	50-56	*Trochus niloticus*	ANU-12142	0.0±2.0[e]	25,770±630	30,145±563
Square D						
18	62-64	*Trochus niloticus*	ANU-12059	0.0±2.0[e]	3820±80	3772±108
20	67-70	*Trochus niloticus*	ANU-12060	0.0±2.0[e]	3650±70	3558±91
Square F						
5	10-14	*Trochus niloticus*	ANU-12140	0.0±2.0[e]	1170±190	760±175
10	35.5-40	*Trochus niloticus*	ANU-12136	0.0±2.0[e]	3305±190	3148±229
16	61-68	charcoal	ANU-12029	–24.0±2.0[e]	3200±240	3433±306
16	61-68	*Trochus niloticus*	ANU-12041	0.0±2.0[e]	3850±70	3809±98
20	83-88	*Trochus niloticus*	ANU-12042	0.0±2.0[e]	4370±70	4529±106
23	98-103	*Trochus niloticus*	ANU-12045	0.0±2.0[e]	5270±80	5643±92
27	120-125	*Nautilus* sp. bead	NZA-16998	1.95±0.2	5782±45	6203±54
30	135-139	*Trochus niloticus*	ANU-12044	0.0±2.0[e]	6200±90	6643±111
35	160-165	*Trochus niloticus*	ANU-12043	0.0±2.0[e]	6140±100	6576±117
40	182-187	*Oliva* sp. bead	NZA-16999	0.97±0.2	7945±65	8414±68
42	192-196	*T. niloticus* fish hook	NZA-17000	2.57±0.2	9741±60	10,613±78
43	196-202	*Trochus niloticus*	ANU-12040	0.0±2.0[e]	10,050±80	11,005±125
Breccia						
Breccia sample B	–	*Trochus* sp. prob. *niloticus*	Wk-26404	3.3±0.2	37,956±506	42,266±369
Breccia sample B	–	Trochidae	Wk-26405	2.5±0.2	38,207±610	42,454±450

and minor sedimentation have taken place since the terminal Pleistocene, along with some deposition of cultural material related to human activity during the late Holocene. No erosional unconformity is indicated. Rather, the unconsolidated nature of the upper part of the late Pleistocene unit would account for the incorporation of some more recent artefacts into this unit through minor local disturbance associated with human activity in the site. Downward movement of larger materials might also result from bioturbation by insects, with associated upwards movements of fines. Deeper root bioturbation might also lead to vertical mixing.

The two shallow, surficial units (LUI and II) are interpreted as the only *in situ* Holocene deposits in this part of the cave. However, they may well derive in part from winnowing and reworking of the underlying deposits, especially by upwards movement of fines through the profile (e.g. through bioturbation by insects).

Dipping interfaces and thin beds dominate much of the stratigraphy from 15–65cm. This suggests that excavation in approximate 5cm spits would have sliced across some chronostratigraphic units (time surfaces) around the steeply dipping margins of the trough. Stratigraphic integrity of lithic artefact and bioassemblages is probably highest for levels from 0–15cm (Spits 1-3) and below 55cm (Spits 11-19), but compromised to varying degrees from 25–55cm depth (i.e. Spits 6-11) by mixing during excavation of different chronostratigraphic units.

The 2002 Excavations, Test Pits B, D and F

In September 2002 further test-pitting was carried out at Lene Hara by authors SOC and PV with the aims of sampling other parts of the extensive floor area and clarifying the chronology of cave use. In particular, we wished to compare the litho- and chrono-stratigraphy present in Pit A with adjacent, higher parts of the cave floor, and also with deposits in the northern part of the cave floor, where the cave floor lies at a much lower level.

Three further test pits were excavated in 2002 (Figure 2). Pit B was located in the same southern higher area of the cave as Pit A. Two other pits excavated in 2002, D and F, were located in the lower, northern chamber outside the walled region of the deposit and northeast of the stone ceremonial platform surrounding a large carbonate column (Figures 2-3). The broad stratigraphic results and chronology from these test squares are presented here for comparison with Pit A, and for exemplifying the chronostratigraphic variability across the cave.

Pit B was situated on a gently sloping area of the inner cave floor, c.12m out from the southern wall. The square was 4m east of the large (9m diameter) speleothem column, with two large stalagmite columns positioned 4–5m further west into the cave.

The loose, surficial sediments of Pit B are comprised of 0–6cm of well-sorted fine sands and silts, with some fine gravel (Figure 6). This upper unit is interpreted as a recent wash accumulation. This unit overlies denser deposits on a largely planar contact. Underlying deposits comprise weakly-bedded coarse sandy silts with frequent larger boulders and cobbles. Most clasts are oriented in a subhorizontal plain, although steeper-angle preferred dips were observed in the southeast area of the square, where limestone slabs up to 350mm in length infill a depression. These coarser gravelly earths in turn overlie horizontally-bedded, finer deposits. Lower again, the deposit is coarser, showing thickening of the inclined bedding into a depression in the southeast corner of the square. The lowest sediments comprise partly lithified light brown silty gravels, infilling an undulating surface over flowstone breccia and/or bedrock.

The general sequence is broadly similar to that in Pit A, in that infilling of earlier cave floor topography appears to be the main determinant of gravel clast deposition and bedding. Modern roots again penetrate to the basal breccia, and some large voids encountered during excavation appear to mark the former course of larger roots. Overall the stratigraphy is less gravelly than at Pit A, and the upper 12cm of deposit appear to unconformably overlie an eroded surface. Radiocarbon dating indicates that this 60cm deep sequence accumulated between 30,145±563 to 21,485±361 cal BP (Table 2). Further dating is planned to test the unconformable nature of the upper 12cm of deposit. The cultural sequence in Pit B mirrors that of Pit A, with pottery predominantly in the top 20cm of the deposit and bone, marine shell and stone artefacts recovered throughout.

Pits D and F were located 1m apart, and 4m out from the steep northern wall of the cave (Figure 3). The area is much closer to the dripline, and falls within a well-defined, 5–8m wide washway that receives surface wash from various smaller washways originating in various areas of the cave. The surficial sediments in this area are sandy silts, with patches of fine gravels. Clastic roof fall is absent from this area.

Pit D was excavated to a depth of c.70cm below surface level (Figure 7). The upper 10–15cm were well-sorted gritty sandy silts, with thin and slightly undulating, subhorizontal, planar bedding and some vertical grading. Several poorly-defined darker patches were noted within the upper stratigraphy. At 10–30cm depth a well-defined medium grey brown ashy organic deposit (7.5YR 5/2-4/2 and 7.5YR 4/2) forms an unbroken thin bed across the square (this unit is traceable laterally into Pit F at c.20-25cm). Underlying this unit, the sediments become coarser and less well-sorted, although, in contrast to Pits A and B, angular, cobble-sized roof fall is rarely encountered. At 50–70cm larger limestone clasts were encountered, embedded within fine, gravelly to sandy silts. At 70cm a complete human cranium was located in the context of what appeared to be a burial. This raised serious concerns for the landowner of the cave. The excavation in this area was discontinued and the pit backfilled without removal of any of the skeletal material. Burial of the skull clearly pre-dates deposition of the darker soil layer at 20–30cm depth. The cultural material that was recovered from sediments overlying the burial was retained for analysis. The age estimate obtained on a marine shell from the lowest excavated level (unit 20) was 3558±91 cal BP and provides a maximum age for the burial. A second test pit, F, was begun 1m northwest of Pit D (Figures 2-3).

Pit F was excavated to a depth of 200cm (Figure 8). Excavation was discontinued prior to reaching bedrock owing to safety concerns (shoring was not feasible without expanding the excavation area). The upper deposits are similar to those in Pit D. The well-defined brown ashy organic bed (7.5YR 4/2) can be traced laterally from Pit D but in Pit F it is shallower, thinner and associated locally with occasional larger fragments of rock fall that rest horizontally on the upper surface of the unit (Figure 8). Weakly-bedded, sands with variable gravel and silt content form a well-defined unit down to 70cm. At this level a distinct thin bed of light grey ashy sands and silts form a continuous band

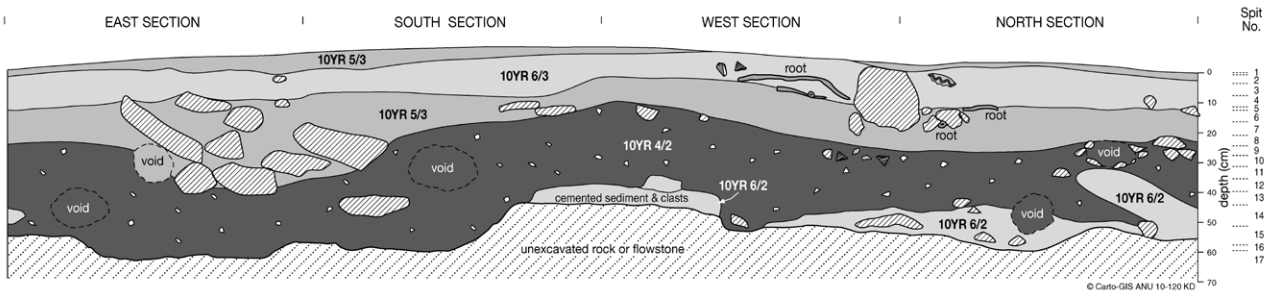

Figure 6 Lene Hara Test Pit B sections showing stratigraphy and depths for excavated spits.

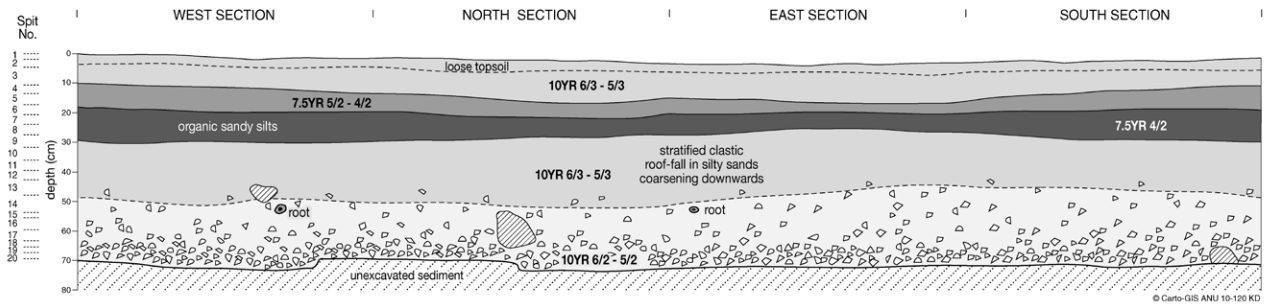

Figure 7 Lene Hara Test Pit D sections showing stratigraphy and depths for excavated spits.

across the square. This unit probably equates stratigraphically to the surface onto which the human skull was interred in Pit D, and coincides with the lowest levels containing pottery in Pit F (see O'Connor and Veth 2005:Figure 4). From 70cm to 220cm the deposits comprise a moderately- to well-stratified fining upwards sequence of fine sandy gravels and sandy silts, variably interstratified and mixed with medium and coarse gravels. Sandy lenses and discontinuous beds of poorly-sorted roof fall clastic debris are common. Several cycles of deposition are evident in the bedding structures and the radiocarbon ages in the vertical sequence. Brief episodes of erosional surface wash and winnowing across the cave floor are interspersed with deposition through creep, roof fall and human discard. The lowest 50–60cm of the excavated sequence in Pit F was significantly coarser, more cemented and accumulated more slowly than the overlying deposit (Figure 4) (O'Connor and Veth 2005:250-251).

Radiocarbon dates from Pit F demonstrate that the entire sequence is of Holocene age, dating between 11,005±125 cal BP and 760±175 cal BP (Table 2) (O'Connor and Veth 2005). This finding fits well with the observed differences in pedogenesis between Pits A and B when compared with Pits D and F. Stone artefacts, animal bone and marine shell are comparatively sparse in the ceramic-bearing levels of Pit F, above 70cm, and increase in quantity below this level. A wide range of marine shell artefacts, including several types of beads and a shell fish hook occur throughout the Holocene levels in Pit F (O'Connor and Veth 2005) (Figure 8).

The broad stratigraphic sequence observed across the four test pits excavated in Lene Hara Cave is as follows. In the southern, higher parts of the cave sampled by Pits A and B, early rock fall debris formed platforms against the walls. These areas were occupied in the late Pleistocene, probably starting around 39,325±831 cal BP, and significant rapid infilling of natural hollows with midden refuse resulted. Sediment and cultural debris continued in this area of the cave for at least 5000 years. Sometime prior to 30,000 BP, the adjacent area sampled by Pit B was probably scoured to bedrock or to a massive flowstone level, followed by infilling with coarse sediment mixed with clastic roof fall and cultural material from 30,145±563 cal BP through to 21,485±361 cal BP or later. Scouring action evidently truncated the deposit on at least one more occasion in the area of Pit B, such that nothing survives apart from a thin veneer of Holocene wash deposits unconformably capping the truncated sequence. The same Holocene veneer probably caps the sedimentary sequence in the area of Pit A but without an obvious unconformity. Variable levels of bioturbation or other local disturbance probably account for the slight differences in stratigraphy between these areas. Further evidence that ancient erosional episodes have removed significant volumes of sediment in this part of the site is found around the base of the larger speleothems in the southern chamber of the cave, where elevated brecciated units signify a formerly higher cave floor level. It is in this area under the eroded base of a large speleothem that the sampled breccia deposit described below was located (Figure 3).

Evidence from the northern chamber of the cave indicates that contemporary sedimentary processes in the cave, involving transport of finer sediments in episodic surface wash flowing northeast across the cave floor, between and around the larger speleothems, has existed since the terminal Pleistocene or earliest Holocene. Most likely this was preceded either by a major scour episode or by subsidence of deposits in the northern chamber, thereby creating a depocentre lying as a southwest-northeast aligned trough close to the northern margin of the cave. Infilling of this trough has averaged net rates of 20cm/ka but has been irregular. Infilling sediments are both reworked cave earths and inwashed sands and gravels but, significantly, they contain little clastic roof fall. The combined evidence from Pits A, B, D and F thus suggests a significant change in cave floor sedimentation between the terminal Pleistocene and the Holocene – the earlier period characterised by deposition of large quantities of coarse

clastic rock fall and by speleothem activity, and the Holocene by low rates of clastic roof fall, coupled with redistribution of finer sediment fractions by surface wash channeled by a local template of lithified breccias and flowstones and possibly a major shift in depocentre into the northern chamber during the terminal Pleistocene or early Holocene.

Temporal resolution within the Lene Hara deposit varies markedly across remarkably short distances within the cave. Short intervals of Pleistocene time are well-preserved in the more elevated, southern chamber of the cave, but local erosion and infill events make the record non-synchronous over a distance of a few tens of metres. Holocene occupation of the cave is sparsely represented in this part of the cave, with some mixture of Holocene cultural materials into late Pleistocene sediments in Pits A and B, as shown by the dates of the shell beads in Pit A (Table 2). In the northern chamber of the cave, a major scour or subsidence event, probably dating to the terminal Pleistocene or earliest Holocene, created a deep trough that infilled progressively through the Holocene by the combined action of episodic surface wash and the deposition of cultural debris. The resultant infill unit provides an extended, well-stratified and temporally well-resolved Holocene sequence.

In September 2009 three of the authors (SOC, KA and ES-P) returned to Lene Hara Cave to search for cave breccia deposits and speleothem growths which might be suitable for palaeoclimate analysis. Breccias (poorly-sorted, carbonate-cemented, angular clastic deposits) are common in caves in Southeast Asia and can be a rich source of well-preserved cultural materials (Glover 1979). They often form against cave walls or speleothem columns in areas where carbonate-rich water flows over, or drips onto, the floor deposit causing it to lithify *in situ*. Because they cement to the walls or cave features, breccia deposits often survive when sedimentary deposits erode away, and can provide an excellent source of information on past occupation and erosion events (Glover 1979).

The 2009 survey resulted in the discovery of a breccia deposit which contained inclusions of cultural materials such as marine shell, stone artefacts and bone, cemented underneath the large speleothem located between the southern and northern chambers of the cave (Figure 3). The sampled breccia was approximately 50cm higher than the current floor surface in this part of the cave and itself supports the speleothem column. Cultural material extracted from the *in situ* breccia included a flake made on fine-grained red chert and several samples of marine shellfish. Two marine gastropods from the family Trochidae were dated and produced radiocarbon ages of 42,266±369 cal BP (Wk-26404) and 42,454±450 cal BP (Wk-26405) (Table 2). These dates are remarkably similar to the earliest dates from the lowest cultural deposits at nearby Jerimalai shelter (O'Connor 2007).

Discussion and Conclusions

One of the most significant findings from the archaeological programme at Lene Hara concerns sampling. The results clearly demonstrate that the cave deposit is stratigraphically complex, reflecting multiple erosional and depositional episodes together with long-term shifts in sedimentary processes. This complexity means that a complete cultural sequence may not survive as a stratigraphic column in any single part of the site. Rather, the history of human occupation may only be recovered

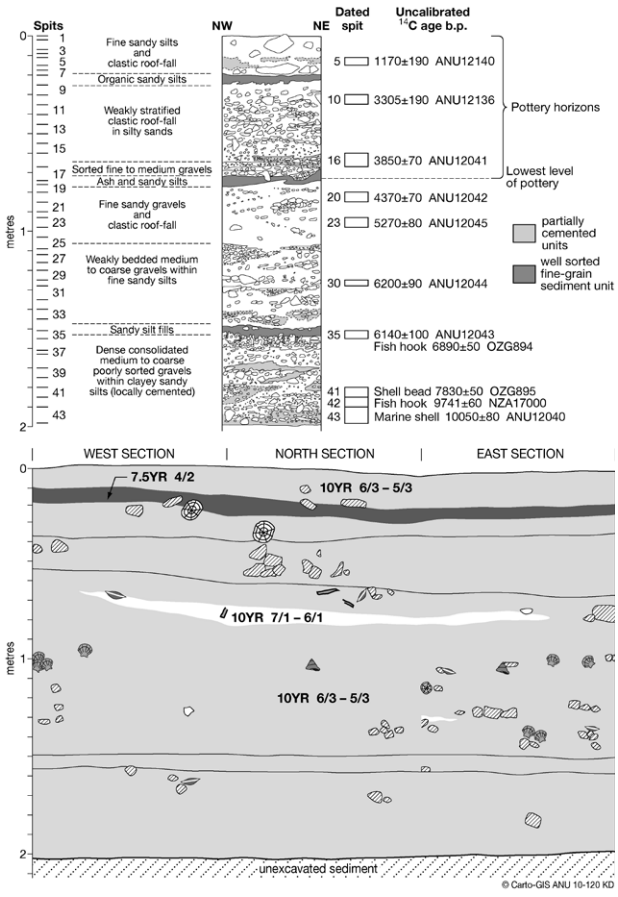

Figure 8 Lene Hara Test Pit F sections showing stratigraphy, depths for excavated spits and radiocarbon dates (after O'Connor and Veth 2005).

by integrating data from a number of different stratigraphic columns, each preserving parts of the depositional and erosional history of the site. This sampling issue is graphically illustrated in Figure 9. These results are perhaps not surprising of themselves. The 'complex and challenging' nature of sedimentary deposits in limestone caves in the humid tropics has been recognised in reports on the Niah Caves, Sarawak (Barker *et al.* 2005:4; Gilbertson *et al.* 2005), caves in the Maros region of Sulawesi (Glover 1979), and elsewhere in Southeast Asia (Anderson 1997). These reports have highlighted the problems such deposits pose for interpretation.

The recognition of the complexity of the chronostratigraphic sequence at Lene Hara Cave has completely changed our interpretation of the way in which the site was used in prehistory. In initial reporting of the dates from Lene Hara Pit A we argued that:

> changing coastal access may have removed the cave from communication routes after about 30,000 BP, occasioning its abandonment. There was no evidence for removal or truncation of the deposit in the area of the excavation, and it is possible that the site saw little or no occupation again until the last few thousand years of pottery-using Neolithic occupation in East Timor, when the cave may have been used as a shelter convenient to local gardens. Reoccupation may have taken place directly on the top of the abandoned Pleistocene living surface, accounting for some mixing of the deposit around Levels four and five, where a mid-late Holocene cultural and faunal assemblage is associated

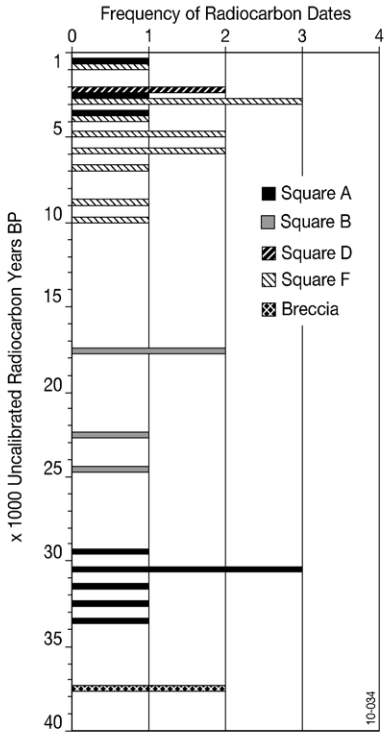

Figure 9 Lene Hara Cave, distribution of radiocarbon dates, Test Pits A, B, D, F and breccia.

with very old dates on marine shell midden (O'Connor *et al.* 2002b:48).

It is now clear that the cave was not abandoned at this time (34,000 cal BP) owing to difficulties of coastal access (O'Connor *et al.* 2002b). Rather the record of occupation falling within the Last Glacial Maximum is only preserved in another part of the cave, now sampled by Pit B (with dates of 21,904±512, 28,202±229 and 30,145±563 cal BP). Similarly, Holocene occupation did not just occur in the last few thousand years; a full and rich Holocene sequence preserving a detailed record of material culture and faunal change is present, but with the exception of the two shell beads in Pit A, is only registered in the northern chamber, as sampled in Pits D and F. There are still some lengthy gaps in the chronological sequence at Lene Hara, most notably 28,000–22,000 cal BP and 21–11,000 cal BP (Figure 9). Whether or not these gaps chronicle periods during which the site was abandoned or merely result from inadequate sampling is currently unknown. We suspect the latter, especially in view of the fact that Pit F was not excavated to bedrock. Further sampling at Lene Hara would be required to resolve this issue.

Archaeologists working in remote parts of Island Southeast Asia, New Guinea and Australia usually have limited budgets and short field seasons. Much field time is spent accessing field areas and as a result sampling is often confined to small 'test pits', or larger excavations in areas thought to have maximum depth of deposit. In reality the test pits we excavate often constitute all that we know of the archaeological record of entire continental regions or islands for many decades. Southeast Asian archaeologists working 'in country' sometimes carry out larger areal excavations and broader testing programmes, but owing to financial constraints rarely date multiple sample points within a single site. Recent projects by Morwood and Sémah and their Indonesian colleagues are changing this pattern (Sémah *et al.* 2004). Morwood has stressed the importance of extending the size and depth of excavations to ensure that earliest cultural deposits do not go undetected under sterile sediment horizons or thick flowstone (Morwood and van Oosterzee 2007:66-67). By example he has demonstrated that earlier excavations at both Liang Bua and Liang Burung 2 were abandoned prior to reaching the basal deposits. Our excavations at Lene Hara were the first to be carried out and published for East Timor since Ian Glover's excavations in the 1960s and added over 25,000 years to the known prehistory of the island. The recent dating of cultural material in breccia deposits at Lene Hara described here, and the age estimates for the basal levels of nearby Jerimalai shelter have extended this antiquity further, with ages obtained of c.42,000 cal BP.

As well as highlighting the potential of the region to produce yet older dates with more intensive sampling, the new discoveries have major implications for its initial colonisation. As O'Connor (2007) has shown elsewhere, these new dates place the East Timor sites comfortably within the age-range of the cohort of early Australian sites dated only by the radiocarbon technique, and the faunal remains in the earliest levels demonstrate that colonisation was accomplished by fully modern humans. Morwood, however, has argued that the dating of modern human presence in Liang Bua in Flores to after 12,000 years ago demonstrates that our species 'did not island-hop from Java along the Nusa Tenggara island chain to reach Greater Australia via Timor by 50,000 years ago … instead they may have moved into this part of Indonesia from Greater Australia' (Morwood and van Oosterzee 2007:224). Whatever route modern humans took to Greater Australia they had clearly reached East Timor by 42,000 cal BP. In view of this and the short water passages that separate the islands of Flores and Timor we find it surprising that they did not colonise Flores earlier than the Liang Bua evidence suggests. Even with today's high sea-level a water crossing of less than 32km is required to get from the north coast of East Timor to the island of Alor, and the crossing from Alor to Pantar is less than 12km, with similar short water crossings separating Pantar from Lembata, and Lembata from Flores (Figure 1). We suggest that a post-12,000 cal BP date for the arrival of modern humans in Flores is anomalous. Further sampling in Flores, Alor and elsewhere along the Nusa Tenggara chain, as well as in Sulawesi and the Maluku region, is critical for resolving this issue.

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