Reconstructing the Quaternary landscape evolution and climate history of western Flores: an environmental and chronological context for an archaeological site

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Chapter Eight:

Implications for archaeological analysis and interpretation

In the previous three chapters, an interdisciplinary approach has been applied to an archaeological site in Flores. In this chapter, the interpretative value of these archaeologically-relevant data will be evaluated (section 8.1), following the same structure as the last three chapters: 1) first exposure of the cave; 2) nature and timing of occupation; and 3) volcanic and climatic influences on occupation. By combining these three components, an environmental backdrop in a chronological framework is constructed, and is compared with proxy data sets for the intensity of occupation, as inferred from stone tool and bone intensities (section 8.2). These comparisons reveal some of the main influences on human occupation, and bear implications for the archaeological interpretation of this site, for regional and global archaeology and for the prospects of future research (section 8.3). Finally, the results of this interdisciplinary analysis will be used to argue the case for the more widespread application of this approach to assist with archaeological interpretation in Southeast Asia (section 8.4).

8.1 Archaeologically-relevant information gained from this study

8.1.1 First exposure of the cave

An analysis of the former extent and evolution of the cave, combined with the mechanisms and evidence for exposure, have generated two interlinking data sets relating to cave formation and exposure. This evidence has been used to illuminate the Quaternary history of the cave and its evolution into an environment suitable for human occupation.
Figure 8.1: Summary of the archaeologically-relevant information gained from using an interdisciplinary approach to the analysis of Liang Bua. The techniques used to obtain the information are marked in blue, while the information of direct relevance to archaeological interpretation is marked in red. The implications of this information are discussed in section 8.2. Note that the timescale axis is schematic, and is not labelled at equal time increments.
According to the evidence pertaining to cave formation, Liang Bua was formed as a subterranean chamber and as the lowest cave in a long stack at ~580 ka. This structure provides clues to the development of the cave over the last 600 ka, and its potential to provide a habitable space during this time period. The key to interpreting this evidence is an understanding of the role of tectonic uplift, which produced stacked caves, extensive sinkhole formation, and the development of front and rear chambers at Liang Bua. These secondary products of uplift influence the pattern of sedimentation in the cave, the archaeological significance of the deposits in the chambers, and the distribution of artefacts.

The evidence relating to cave exposure provides mechanisms and evidence for this event, and the application of chronological techniques has established a maximum age for exposure and occupation of the cave, and a minimum age for the occupation of the nearby area, ~190 ka. Hence, archaeological interpretation of the site is constrained to the last 190 ka. The pattern and timing of river terrace development places the river within flooding distance of the cave entrance between 250–118 ka, which agrees with the timing of conglomerate deposition at ~193 ka. The subsequent modifications to the form of the cave, by front entrance collapse, slowly transformed the initial, small opening into a wide entrance, thereby increasing its potential to provide a habitable space. The maximum age for occupation of the site according to the estimated age of the deepest archaeological finds in the cave floor excavations (at ~95 ka) has been extended by ~100 ka due to this geological, environmental and chronological analysis. The archaeologically-relevant information gained from Chapter Five is summarised in Figure 8.1a.

8.1.2 Nature and timing of occupation
By combining the evidence for the nature of the cave environment (inferred from the sedimentary evidence contained in the five sector excavations) with the timing of occupation (estimated using a combination of TL, OSL, U-series and $^{14}$C dating), phases of occupation have been identified for certain parts of the cave.

This evidence has revealed that the most significant sedimentological event occurred at ~100 ka, when the lake waters drained and occupation was feasible. Water action
created a complex cave floor topography and formed distinct areas of higher ground that were preserved in the sediment column for ~90 ka. This topography was consistently modified by a range of geomorphological processes that influenced when and where occupation could occur. The sloping stratigraphy and the distribution of artefacts has assisted in determining where the stone tools may have originated. This information, combined with the locations of higher ground in the cave, indicates the existence of three main zones of occupation: to the southwest of Sector IV and the southwest corner of Sector I from 74–61 ka, and to the south of Sector XI from 18 ka onwards. The recognition of these zones provides valuable evidence for determining patterns of occupation, estimating the potential number of cave inhabitants, and identifying locations for future excavations. The archaeologically-relevant information gained from this Chapter Six is summarised in Figure 8.1b.

8.1.3 Volcanic and climatic influences

An analysis of volcanic and climatic processes affecting this area has shed light on the environmental changes most likely to have influenced human occupation of the cave. During the last 100 ka occupational period, the cave underwent phases of environmental deterioration and recovery, ranging from wet and organic-rich to dry and stable with low bio-productivity, separated by transitionary periods with rapid fluctuations between the two extremes. These phases were punctuated by volcanic eruptions that would have influenced bio-productivity and the water supply.

According to the multi-proxy evidence, phases of high rainfall occurred at 110–98, 82–65, 49–39 and 17–5 ka on Flores and Java, which correlate with organic-rich environments, thick soil cover, dense vegetation and a flourishing food source. In contrast, a long period of reduced rainfall occurred from 36 to 17 ka. Combined with the sedimentary evidence, this suggests a period of drought, organically-depleted conditions, thinner soils, reduced vegetation cover and impoverished food supplies. During the occupational period, a number of significant events occurred with sufficient rapidity and magnitude to have affected human sustainability. For example, a rapid decrease in rainfall and bio-productivity occurred at ~39 ka in Java, and a brief shift to wet and organic-rich environments occurred at ~25 ka, followed by a rapid deterioration to dry conditions. The close correlation between wetter and drier climatic phases and the
phases of erosion, pooling and flowstone formation in Liang Bua, suggests that these climatic changes affected conditions inside the cave, interrupting or preventing occupational activities. The archaeologically-relevant information gained from Chapter Seven is summarised in Figure 8.1c.

8.2 Intensity of human occupation

An estimate of the intensity of occupation has been derived from the number of stone tools and quantity of charcoal found in each of the nine sedimentary units in the sectors (section 6.1.1). From these data, a total stone tool count has been made for each unit (Figure 8.2). These counts may have been influenced by frequent channel erosion (section 6.1.2.2) and by the inflation of artefact numbers due to exploding stones from the increased use of fire up-section (Moore et al., 2006). Despite these limitations, the counts can still provide an indication of occupational changes in the cave throughout the last ~190 ka.

The total number of bones found in each sedimentary unit and sector has also been used as a crude estimate of the intensity of occupation (Figure 8.3; see Appendix VII for a list of fauna). However, the use of these data sets assumes that bone preservation is the same in units containing a different sedimentary structure, and that preservation does not decrease with increasing time. The total bone counts for each Sector include *Stegodon* and *Homo*, but those for rats, bats and flying foxes have been presented as a separate column (Figure 8.3). As owls, rather than humans, are responsible for bringing rats into the cave as prey, and the occupation of the cave by bats was deterred by the presence of humans, it has been assumed that rat and bat bone counts are inversely related to human occupation intensity. For this reason, rat and bat counts represent a useful indication of environmental conditions that varied independently of human influences, in contrast to the total faunal counts that relate directly to the intensity of human occupation. Similarly, the total *Stegodon* counts reflect human influences, because the presence of cutmarks on many of the bones (Morwood et al., 2005a; van den Bergh and Due Awe, 2005) suggests that *Stegodon* were brought into the cave to be butchered. The total *Homo* bone counts provide an additional measure of human intensity within the cave, but in comparison to *Stegodon* they are relatively infrequent in
Figure 8.2: The intensity of occupation for the nine main sedimentary units, derived from the stone tool counts for each sector and the combined total for all five sectors. The vertical line in some of the columns indicates the presence of stone tools in numbers too small to be represented at the scale of the graph, while the smaller, horizontal red lines indicate the presence of charcoal. The long horizontal grey and black lines represent the deposition of the white silts (contain tephrat) and black volcanic sand, respectively; these represent periods of transition in the cave. The total bone counts for *Stegodon* and *Homo* (from Figure 8.3) are included; they also represent useful proxies for intensity of occupation in the cave, and can be correlated with the stone tool counts. Note that the columns for the number of artefacts in each sector have the same scale, whereas the columns for *Stegodon*, *Homo* and the total stone tool count have different scales. Certain time periods, e.g., 40-20, 60-55 and 95-85 ka are not represented by the nine, main sedimentary units due to either reduced sedimentation or erosion.
**Figure 8.3:** The intensity of occupation for the nine main sedimentary units derived from the bone counts for each sector and the total for all five sectors combined (see Appendix VII for faunal species). The total count includes *Stegodon* and *Homo* bones, but does not include the bones of rat, bat, and flying foxes, as these species are inversely related to human occupation (section 8.2). Instead, these species have been presented separately for individual interpretation. The bone counts for *Stegodon* and *Homo* have also been presented separately, as the presence of these species indicates occupational activities were occurring in the cave. The vertical lines in the SIII and Stegodon columns indicate the presence of bones, but too few in number to show at the scale of this graph. Note that the columns for the total number of bones from each sector have the same scale, but the rat / bat, *Stegodon*, *Homo* and total columns all have different scales. The horizontal grey and black lines represent the deposition of the white silts (containing tephra) and black volcanic sands, respectively, and have been included as they represent periods of transition in the cave. Note: units 1 and 2 do not contain any faunal remains. The inset box contains an enlarged version of the rat / bat, *Stegodon*, *Homo* and total data sets. The data are plotted according to depth, with the age of each unit placed alongside. Despite appearances, the timing of the major peaks may not necessarily correlate due to differences in sedimentation rates (section 6.2.3).
the sediment column. The timing of the thick deposits of tuffaceous silts and black volcanic sand are included in Figures 8.2 and 8.3 as they provide useful stratigraphic markers for periods of transition in the cave.

The stone tool data displays the greatest intensity in units 4, 7 and 9, and the lowest intensities in the relatively sterile lake sediments at the base of the stratigraphy (unit 2). Similarly, the faunal data display the highest bone counts in units 4, 7, 8 and 9 and the lowest counts in the basal units. The intensity of Stegodon bones in the cave correlates with Homo counts until ~11 ka, after which Stegodon bone counts diminish. Changes in rat, bat and flying fox counts are similar to the changes in Homo counts in units 3, 4 and 8, but also increase during periods of lower occupational intensity (e.g., units 6 and 7). The two large pulses in Homo bone counts in units 7/8 and 9 correlate to Homo floresiensis and Homo sapiens, respectively, and these separate groups are responsible for the stone tool manufacture on either side of the tuffaceous silt deposit. It is significant that peaks in the stone tool and Homo bone counts correlate during the 100 ka human occupation period, and suggest that these proxies for human occupation concur. Interestingly, the absence of Stegodon after the volcanic eruption at ~11 ka (marked by a horizontal grey line on Figure 8.2) represents the extinction of the species at this site, and possibly in Flores (Morwood et al., 2004, 2005a). According to the stone tool and the bone data, the most intensive phases of occupation occurred during the deposition of units 4, 7, 8, and 9, representing the periods 74–61 and 18–3 ka, and the least intensive during units 1 and 2 representing the period 190–100 ka. Unit 1 (conglomerate deposit) represents a coarse grained layer, deposited in an energetic fluvial environment (section 5.3.2) that is not conducive to bone preservation. In contrast, the silty composition of unit 2 (basal cave sediments) combined with its slightly alkaline conditions (Figures 6.1–6.3) represent an ideal sedimentary environment for bone preservation, but remained sterile from at least 110–95 ka.

To determine the main influences on the intensity of occupation, the timing of geomorphological events occurring inside the cave (Figure 8.1a, b), and the timing of climatic and environmental events occurring outside the cave (Figure 8.1c), have been compared with the total stone tool and bone data shown in Figures 8.2 and 8.3. This comparison enables a link to be established between hominids and their environment,
Figure 8.4: The intensity of occupation for the nine main sedimentary units derived from the stone tool and bone counts for each sector, compared with the timing of the main geomorphological and sedimentological events in the cave, the climate and bio-productivity outside the cave, and the timing of volcanic events. The total stone tool and fauna counts are taken from Figures 8.2 and 8.3, respectively. The climate data are taken from Figure 7.14, using all six speleothem records (colour coding for each sample is the same as presented in Figure 7.14), while the bio-productivity data are taken from Figure 7.30 using three different proxies for sample SPJ3 (fluorescence wavelength in green, fluorescence intensity in orange, and $\delta^{13}$C in dark blue). The $\delta^{13}$C record from SPJ11 (118-57 ka) is included to provide environmental data for the earlier period of occupation (100-60 ka). The timing of the assumed volcanic events (depicted by red arrows with dashed lines) have been determined using the heat reset TL signal (Figure 7.1).
both inside and outside the cave (Figure 8.4). Periods of channel formation and erosion correlate with high rainfall and high intensities of occupation, and phases of reduced channel activity that revert to shallow pools correlate with drier periods and a lower intensity of occupation; flowstone precipitation occurs in the transition between these two phases. According to the climate and bio-productivity data sets (4th and 5th columns in Figure 8.4), during a ~100 ka period (from 105 to 5 ka) there were three organic-rich phases (green shading), which correlate with the highest sedimentation rates (Table 6.9) and were of sufficient magnitude to have influenced the food supply in the area around the cave. Interestingly, environmental recovery and increasing intensity of occupation occurred prior to the volcanic eruption at ~11 ka, which greatly contrasts with the sudden decrease in *Homo, Stegodon*, total bone and total stone tool counts after 11 ka (Figure 8.3).

8.3 Implications for the archaeological record

The archaeologically-relevant information in Figure 8.1, combined with the influences affecting the intensity of occupation of Liang Bua (Figure 8.4), have implications for archaeological interpretation that can be divided into: 1) local; 2) regional, for the Indonesian archaeological record; and 3) worldwide, for global models of human dispersal. There are also implications for fruitful avenues of future research.

8.3.1 Local implications

8.3.1.1 Significance of the site

The timing of subaerial exposure of Liang Bua (~190 ka) is significantly older than the maximum age of the occupational evidence found in the sector deposits (~95 ka), as the sedimentary evidence that has been preserved indicates that the cave could not be occupied until ~100 ka. The artefacts found concreted in the conglomerate deposit were crafted by toolmakers living outside the cave before or about ~190 ka. By including these artefacts in the occupational record for the site, the timing of occupation of the local area has been extended by a further ~90 ka. The site is significant in terms of: 1) the shelter it has provided over the last 100 ka; 2) the importance of its evidence; 3) the
relatively continuous time span it represents and the value of this period; and 4) its deeply stratified nature.

The initial exposure of the cave by the river, and the subsequent process of cave collapse, created a wide cave entrance. This entrance, combined with the size of the cave provided, a useful shelter for human occupation. Despite suffering from front-entrance collapse, the extent of this shelter has been maintained up to the present day. The cave was a safe haven from predators and volcanic episodes, and provided a space for cooking, eating and sleeping and a meeting point. The extent of preservation of the evidence for these activities contributes to the significance of the site.

Liang Bua has relatively continuous archaeological evidence over a 190 ka period, spanning the Palaeolithic through to the Metal Age. This period covers the environmental recovery at the Pleistocene–Holocene boundary, the arrival of modern humans, and the environmental deterioration associated with the LGM from ~20–17 ka. No other sites in Indonesia contain a record of occupation by two species of human in a single, long sequence. By contrast, detailed comparisons of zones of occupation, lithic technologies and occupation intensities are possible at Liang Bua. This, combined with the discovery of a new human species and associated taphonomic context, makes Liang Bua one of the most valuable sites in the Indonesian archaeological record.

The complexity of the depositional processes occurring in the cave, such as pooling, channel infilling, roof collapse and slopewash deposition, together with its position in the stacked cave system and sink cave structure, have contributed to its deeply stratified nature. The preservation of this stratigraphy occurred after the river had fallen below the elevation of the cave. The timing of these geomorphological events has important implications for accurate archaeological interpretation of the site, because prior to their occurrence, much of the occupational evidence would not have been preserved, as seen for the period between 190 and 100 ka. The deposition and preservation of fine silt laminations, found throughout the cave, have maintained taphonomic details that have greatly assisted archaeological and palaeontological interpretation. For example, the articulation in the hip and knee joints combined with the arrangement of bones at the base of a slope suggest that the skeleton had only moved a small distance down slope
during the burial period (Morwood et al., 2004, 2005a). This information greatly assisted in providing accurate age estimates. Similarly, the sedimentary and stratigraphic integrity enables correlation between layers in different sectors and facilitates comparisons between the archaeological evidence from different periods, such as stone tool manufacture, hunting and cooking activities. Without this degree of stratification, the evidence from the cave would prove difficult to interpret. Furthermore, the range of materials deposited in the cave has allowed firm chronologies to be established using multiple dating techniques (TL, OSL, $^{14}$C, U-series and ESR). The application of this range of techniques to different layers has enabled the construction of a reliable chronological framework.

8.3.1.2 Occupation of Liang Bua by Homo floresiensis

Stratigraphic evidence from the oldest sector deposits suggests that occupation of the cave was initiated at ~100 ka, possibly by hominids that were already occupying the local area. Artefacts with very few water worn features were found in the rivers former bedload (i.e., the conglomerate deposit), which suggests that the tool makers were using stones found in the river at ~190 ka, and may have occupied sites in the vicinity of Liang Bua (e.g., neighbouring caves). After cave exposure, river downcutting would have increased the elevational difference between the river and the cave entrance. Nevertheless, the presence of tools made from Wae Racang gravels at ~11 ka (Moore et al., 2006), suggests that, for 180 ka, the tool makers collected stones from the river and carried them back to the cave with the intention of making tools, implying that they possessed cognitive skills such as of forward planning.

The geomorphological evidence of cave chamber development suggests that, when the cave was first exposed and the two chambers were located at different elevations, only the front chamber was occupied by humans, and only in specific areas. The size and location of these areas provides clues to how Homo floresiensis may have lived. These zones of occupation were initially fairly small, concentrated near the centre of the cave and situated next to pools of water (e.g., to the southwest of Sector IV). This implies that only small numbers of hominids were occupying the cave at any one time, possibly because they lived in small groups. However, the development of an additional zone of occupation, from ~18 ka onwards, suggests that the community in the cave may have
increased in numbers, resulting in the extension of these zones of occupation to along the wall of the front chamber, from the southwest of Sector IV to the south of Sector XI. This increase in the number of zones provides clues to the intensity of occupation before the Holocene period, implying that the greatest occupational intensity occurred from ~18 to 11 ka.

The areas selected for occupation in the cave were influenced by available space and the location of higher ground. The three zones of occupation were located on sections of cave floor that were relatively flat, in comparison to the uneven topography that characterises the rest of the cave. This suggests that these zones were used for a range of living activities, including cooking and sleeping. The proximity of these zones to a large pool and a waterfall feature suggests that they were selected, at least in part, because of their locations close to a source of fresh water.

8.3.1.3 The survival of Homo floresiensis

It would appear that periods of increased rainfall (e.g., at 110–98, 82–65, 49–39 and 17–5 ka) nourished a flourishing flora and provided an ample food supply for a growing faunal population, which, in turn, could support a growing population of Homo floresiensis. Consequently, these organic-rich periods (marked in green shading in Figure 8.4) coincide with the four most intensive phases of occupation (sedimentary units 4, 7, 8, 9). However, if these organic rich phases resulted in the expansion of rainforest environments and the contraction of edge environments that were favoured for occupation, such as savannah (Bettis et al., 2005), then the increased occupational intensities in the cave reflect an change from open air to cave locations.

The decrease in bio-productivity during periods of drought (e.g., 36–17 ka) would have reduced food availability and impacted most heavily on larger animals, such as Stegodon, and their predators, such as Homo floresiensis. The reduction in rainforest and expansion in savannah environments during this period would have also encouraged open air occupation, resulting in a decrease in cave occupational intensities. As fluctuations in climatic conditions occurred relatively rapidly, at least in the terminal Pleistocene, the ensuing struggle for survival may have forced human migration to other parts of the island containing greater food resources. Indeed, this period of drought
(marked in brown shading in Figure 8.4) is not represented by the main sedimentary units, because either this layer was eroded, which is unlikely due to the reduced rainfall, or less sediment entered the cave due to reduced slopewash. The presence of thin soils during this period, as inferred from the fluorescence intensity data (Figure 7.13) supports the latter proposition. This evidence confirms that the environment was experiencing a reduction in geomorphological and biological activities. During this more arid period, the dominant type of vegetation also changed from trees to grasses, as indicated by local pollen records (section 7.3.1). This change may have further assisted the reduction of faunal (including hominid) populations, and a general decline in food supplies may have altered hunting and gathering techniques, resulting in increased competition for food between hominids and other fauna.

Despite these problems, the *Homo floresiensis* population survived throughout this drought. From ~18 ka onwards, the increase in the number of zones of occupation and the number of *Homo* bones in units 7 and 8 (Figure 8.3) is interpreted as an increase in occupational intensity, which suggests that *Homo floresiensis* was flourishing in this area. This potential increase coincides with an increase in rainfall and a widespread environmental recovery from 17 to 11 ka (Figure 8.4). These interpretations strengthen the link between hominid occupation intensity and the environmental bio-productivity. But this link was broken by the volcanic eruption at ~11 ka, the influence of which will be discussed in the next section.

### 8.3.1.4 The last Stegodon and Homo floresiensis remains: a local extinction event?

The environmental recovery and population increase in the cave between 17 and 11 ka was abruptly halted by a large volcanic eruption that occurred ~11 ka. This volcanic event made human habitation in the vicinity of the cave increasingly difficult, by affecting the local food and water supplies. Indeed, the intensity of *Homo floresiensis, Stegodon* and total faunal counts below the tephra deposits contrast greatly with their complete absence above these deposits. The scale of environmental deterioration caused by this volcanic event is confirmed by the rapid decrease in the numbers of rat, bat and flying fox (Figure 8.3), which had previously usually displayed population increases during less intensive phases of human occupation. The dramatic decrease in *Homo*
numbers is speculated to be due to the disruption of food sources by the mass deposition of volcanic ash. This volcanic event may have either caused local extinction of fauna (including humans) or forced their large-scale migration to other parts of the island that were not so heavily impacted by volcanic ash. The source of the volcanic ejecta may have originated from as far west as Bali (Turney et al., 2006b). If so, then it is unlikely that ash covered the entire landmass of Flores and, hence, migrations to the less-affected eastern end of the island may have occurred. None of the excavated sites on Flores contain evidence of Stegodon after 11 ka (e.g., Maringer and Verhoeven 1977; Morwood et al., 2004), suggesting that the Pleistocene-Holocene boundary may represent an extinction event for this species. Further excavations, however, are required in other regions of Flores to determine the fate of Homo floresiensis, which is currently known only from the single site of Liang Bua.

8.3.1.5 An overlap between Homo floresiensis and modern humans?

Prior to 11 ka, skeletal evidence for Homo sapiens is absent from the stratigraphic record of Liang Bua (Morwood et al., 2004, 2005a). But after 11 ka, the only archaeological evidence found in the sector deposits is associated with Homo sapiens, as the tephra deposit marks the change-over in species of human that occupied the cave. As the age of the youngest occupational evidence for Homo floresiensis (~13 ka) does not overlap in time with the oldest evidence for Homo sapiens (~11 ka) on the island of Flores, claims for contemporaneity of the two species cannot be sustained solely on the basis of local archaeology. However, the late (~11 ka) arrival of Homo sapiens in this region would be surprising, considering the timing of modern human arrival in Southeast Asia by ~45 ka in Niah Cave, Sarawak (Barker et al., 2001), by $47^{+11/-10}$ ka in Tabon Cave, the Philippines (Detroit et al., 2004), and by 60–50 ka in northern Australia (Roberts et al., 1994). If the latter arrival times apply also to Flores, then there is a potential overlap of at least ~30 ka between the two species. During this time interval, modern humans may have encountered Homo floresiensis as they dispersed toward Australia. Indeed, the similarities in the stone tool manufacture by the two species (Brumm et al., 2006) suggest that modern humans may have adopted regionally-established methods through observation, and that this may have been crucial to their successful adaptation to Indonesia’s unique environments (Moore et al., 2006). The absence of Homo sapiens bones from the early stratigraphic record of Liang Bua may
reflect the successful colonisation by *Homo floresiensis* preventing modern humans from holding a competitive advantage, or it may indicate that modern humans preferred coastal environments and resources to those found inland. Hence, the evidence from Liang Bua does not directly contribute to the debate about modern human dispersal in Southeast Asia, but the presence of a new human species that could have potentially competed with modern humans makes the question of dispersal more complex than previously envisaged.

### 8.3.2 Implications for Indonesian archaeology

The discovery of a new human species at Liang Bua is sufficiently important to refocus archaeological and palaeoanthropological attention away from Africa and towards Southeast Asia (Dennell and Roebroeks, 2005). This potential paradigm shift has resulted in Indonesia once again being regarded as a centre for human evolution. The occupation of Flores by *Homo floresiensis* has revealed that the evolution of *Homo* in Asia involved more human species than is considered in most models, and, in doing so has provided further evidence of the complex history of human evolution and dispersal worldwide.

The deeply stratified deposits at Liang Bua provide a useful contrast to the fragmentary stratigraphic records and skeletal evidence for the *Homo erectus* sites in Java (e.g., Ngandong). Similarly, the Liang Bua stone tool record provides a Late Pleistocene comparison with the artefactual evidence from the Middle Pleistocene hominid sites on Flores, such as Mata Menge and Tangi Talo in the Soa Basin, as well as yielding the earliest human remains for the island (~95–74 ka). Furthermore, this discovery of *Homo floresiensis* on Flores has accentuated the archaeological potential of other equally remote islands in Wallacea, such as Sulawesi, that may have been subjected to similar evolutionary pressures as existed on Flores.

The assumption that *Homo erectus* (or some small-bodied hominid) did not have the capability to cross Wallace’s Line was discredited by the discovery of artefacts in the Soa Basin dated to ~880 ka (Morwood *et al.*, 1998; Brumm *et al.*, 2006). Similarly, the archaeological evidence from Liang Bua suggests that the diminutive hominids living on Flores in the Late Pleistocene were surprisingly intelligent (Morwood *et al.*, 2004,
2005a). These findings have implications for our understanding of the cognitive evolution of hominids, including the relation between the size of the brain and the level of intelligence (Falk et al., 2005).

8.3.3 Worldwide implications: models of human dispersal

The small difference in the timing of the occupation by *Homo floresiensis* (95–11 ka) and modern humans (from ~10 ka) does not preclude the possibility that these species occupied different regions of Flores at the same time in the Late Pleistocene. If so, then it would contribute to the debate over modern human dispersal out of Africa, as evidence of contemporaneity between human species would add weight to the Out of Africa II model (e.g., Stringer and Andrews, 1988; Stringer 2002), and weaken the Multi-regional Continuity model (e.g., Thorne and Wolpoff, 1981; Wolpoff et al., 1984). The discovery of *Homo floresiensis* combined with the discoveries at Dmanisi in Georgia (Gabunia et al., 2000; Lordkipanidze et al., 2005) have also generated discussion about the possibility that *Homo erectus*, (thought to be the species responsible for the first African migration, according to the Out of Africa I model) may not have been the only hominid to leave Africa. Instead *Homo floresiensis* may have evolved from a more primitive ancestor, such as a small-bodied hominid that has not yet been discovered (e.g., Groves, 2004), causing some to challenge the relevance of the Out of Africa I model (Dennell and Roebroeks, 2005).

8.3.4 Prospects for future research

Given the increasing interest in human evolution in Asia, and the potential for deeply stratified sites in the karst regions of Flores and Sulawesi, prospects for future research in Indonesia look promising. In western Flores, karst areas such as Nilla, Betengjawa, Reo and Boleng (Figure 8.5a) display the greatest potential for studies of cave formation, exposure and human occupation. For example, Liang Michael is situated in a karst area close to Labuanbajo, and contains deeply stratified rockshelter deposits that have potential for a long occupational record (Maringer and Verhoeven, 1977). Future work could establish if the sediments contain evidence to extend the age-range for modern humans on Flores and determine the persistence of *Homo floresiensis* after 11 ka.
Karst areas in Indonesia are a largely untapped palaeoenvironmental resource that would benefit from the application of an interdisciplinary approach to their analysis. For example, Sulawesi contains a highly endemic fauna (e.g., several dwarfed species of elephant, *Elephas celebensis*, *Stegodon*, *S. sompoensis*, and a giant tortoise, *Geochelone atlas*) that is indicative of long-term isolation and evolutionary pressures similar to those experienced on Flores. North Bone, on the east coast of South Sulawesi (Figure 8.5b), contains cone karst similar to that around Liang Bua, while Maros, on the west coast of South Sulawesi, is dominated by tower karst. Archaeological sites such as Leang Burung II have been previously excavated by Glover (1981) to depths of 3.5 m, but there still remains good potential to extend deeper into the Palaeolithic levels. These areas contain some of the best potential for future archaeological and palaeoanthropological research.

![Figure 8.5](image_url)

**Figure 8.5**: Locations of karst areas for potential interdisciplinary research in Southeast Asia. (a) The location of karst areas in the Manggarai province of western Flores; (b) in southern Sulawesi; and (c) in mainland and island Southeast Asia. Specific areas for future reconnaissance and research are marked with red boxes, and cave locations (discussed in the text) are also highlighted.
Sites to the west of Wallace’s Line offer the potential to explore faunal evolution affected by periodic connections to the mainland, during glacial periods of lowered sea level, to contrast with sites on permanent islands, such as Flores. For example, Java contains karst areas on Madura Island, while, on Bali, sites such as Bukit Peninsula and Nusa Penida, which were periodically connected to mainland Asia (Figure 8.5c). Mainland sites west of Uthaithani, in central Thailand and in the Phangnga province on the west coast of southern Thailand have good stratigraphic potential (e.g., Long Rongrien; Anderson, 1987, 2005).

In this study, the DAP red TL dating technique proved to be very useful for establishing a chronological framework in a volcanic province, but it needs further development to obtain more precise ages and to extend the age-range so that older sites such as Mata Menge and Tangi Talo in the Soa Basin can be considered for dating. If this technique can be reliably extended to events older than 1 Ma (e.g., Fattahi and Stokes, 2000), then red TL dating would greatly contribute to the construction of a chronology for the Indonesian archaeological record, especially in areas where other dating techniques are not applicable. The data in Chapter Seven hints at the changing environments of Flores and Java over the last 120 ka period, but when used in conjunction with other samples from a wider geographical range, there is the potential to make more detailed analyses using micro-sampling and trace element techniques to provide high-resolution palaeoclimate records for the entire IPWP.

8.4 The case for an interdisciplinary approach

The application of an interdisciplinary approach to Liang Bua and its surrounding area has generated a wealth of archaeologically-relevant data. Luminescence techniques have established the timing of some major turning points in the archaeological record, such as the timing of cave exposure and the maximum age of cave occupation by humans (193 ± 33 ka); the minimum age of occupation for the area (~190 ka); the age range for cave occupation by Homo floresiensis (95–11 ka); the age of the holotype skeleton of Homo floresiensis (14 ± 2 to 36 ± 5 ka); the timing of the most intensive phases of human occupation (74–61 and 17–11 ka); and the ages of the oldest skeletal remains found on Flores (95–74 ka).
The evolving landscape has been constrained by an analysis of river terraces, cave form and cave sedimentation, to provide a Quaternary context for the site of Liang Bua. By providing evidence for its formation, exposure and occupation, and by constraining the pattern of sedimentation, the cave environment has been reconstructed for the last 200 ka, thereby offering small glimpses of the occupational environment to ‘flesh out’ the archaeological evidence. In addition, an environmental backdrop to the arrival and dispersal of humans throughout Indonesia has been established by means of palaeoclimatic and palaeoenvironmental analyses of speleothem. These records reveal that the occupational success of *Homo floresiensis* in this area was governed in large part by the contemporaneous environmental conditions, thus demonstrating the strong influence that the environment exerts upon the local hominid population.

The use of various techniques has helped to identify the tempo and mode of human–environment interactions in the vicinity of Liang Bua, and has demonstrated the value of Quaternary analysis in the karst regions of Southeast Asia. When the resulting data are combined to form a chronological and environmental backdrop, they can provide insights into the rates and routes of dispersal by early hominids, and the nature of the environments they encountered.

This research has demonstrated that techniques such as luminescence dating and speleothem analysis can be successfully applied to new geographical regions, such as Indonesia, to overcome problems of interpreting the archaeological and palaeoanthropological evidence. Red TL dating also has the potential to establish chronological frameworks for other key sites and deposits in volcanic provinces around the world. Such interdisciplinary approaches, therefore, are recommended practice for future archaeological research conducted in Southeast Asia, and especially in areas where few Quaternary studies have been made previously.