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Preface: research at Liang Bua, Flores, Indonesia

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ABSTRACT

Excavations at Liang Bua, Flores, Indonesia, have yielded evidence for an endemic human species, *Homo floresiensis*, a population that occupied the cave between ~95–17 ka. This discovery has major implications for early hominin evolution and dispersal in Africa and Asia, attracting worldwide interest. This preface describes the rationale for the excavations in historical, geographical, and wider research contexts, as well as the methods used. It also introduces the other papers on aspects of Liang Bua research that feature in this edition of the *Journal of Human Evolution*.

Introduction

Liang Bua, a limestone cave on the island of Flores in East Indonesia, has deeply stratified deposits of stone artifacts and faunal remains spanning the last 95 k. yr. When we commenced excavations at the site, we certainly did not anticipate finding evidence for a diminutive, endemic human species living there until just 17 ka[1]. But this is exactly what our Australian-Indonesian team reported in describing *Homo floresiensis* - or "Hobbit," as the species holotype has become known in the popular press.

Professional and public reaction to the find has been virtually unparalleled in the annals of archaeology. Why? Firstly, Indonesia, at the periphery of the Old World, has been considered tangential to major events in hominin evolution: a view supported by the fact that, despite over 100 years of active field research, only two hominin species were previously known from the region – *H. erectus* and modern humans. Secondly, there are the characteristics of the species itself – people only a meter tall, with a tiny brain and ape-like limb proportions (Morwood et al., 2005). This pushes the generally accepted view of what it is to be human. *H. floresiensis* challenges us because the species does not fit with the many preconceptions about where, how, and when humans evolved, and what they should look like.

Given the amount of interest in the Liang Bua hominins, as well as claims by critics that they were merely modern humans with pathological abnormalities (e.g., Weber et al., 2005; Jacob et al., 2006; Martin et al., 2006; Richards, 2006; Obendorf et al., 2008; Rauch et al., 2008; Henneberg and Schofield, 2008), we felt that the evidence from the type-site, Liang Bua, and its context in scientific, as well as popular venues, was important. This preface explains why and how the work was undertaken; describes the historical, geographical, and archaeological context; and introduces the other papers featured in this edition of *Journal of Human Evolution*.

Research rationale

The excavations at Liang Bua undertaken between 2001 and 2004 were part of a project funded by the Australian Research Council – *Astride the Wallace Line*. This project targeted six fundamental "when, why, and how" problems with ramifications far beyond Indonesia: 1) when did hominins first arrive in the Indonesian archipelago? 2) when and why did early hominins, such as *Homo erectus*, become extinct? 3) when and how did fully modern humans first appear in the region? 4) when and why did people start cultivating plants and domesticating animals? 5) when and why did

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[1] Previously, we argued that *Homo floresiensis* and *Stegodon* disappeared from the Liang Bua sequence ~12 ka (Morwood et al., 2004). Evidence from further excavations at the site in 2007 and 2008 now indicate ~17 ka.

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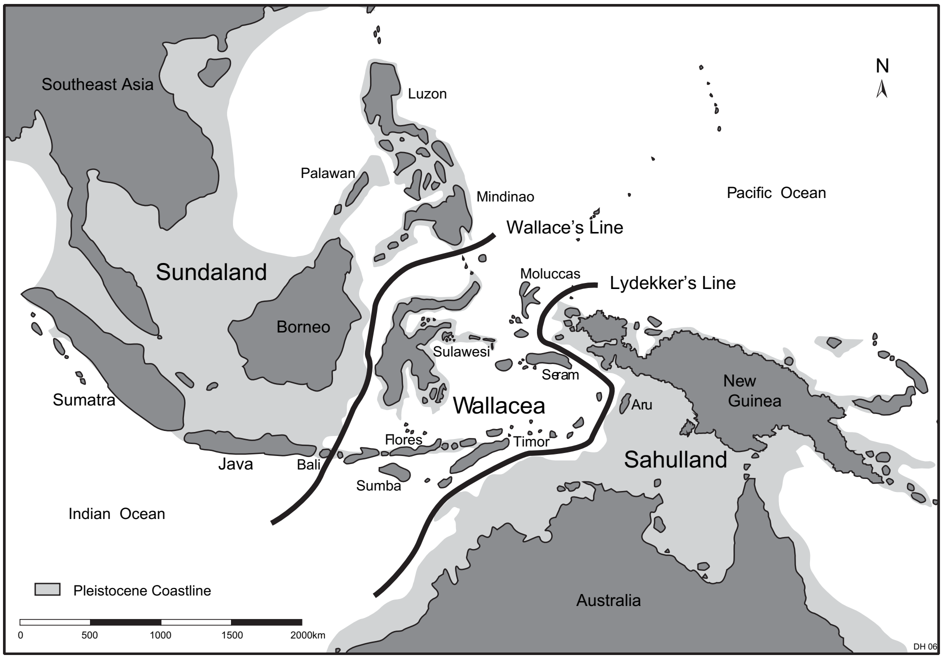


Figure 1. Map of Southeast Asia showing the location of the Wallace Line and the islands referred to in the main text. Flores lies midway between the Asian and Greater Australian continents.

technological changes (e.g., the introduction of ground tools, pottery, and metal) occur and what were their impacts? and 6) what major environmental changes occurred during the time span of hominin occupation of the region, and what were their impacts?

In turn, these questions determined the choice of study areas, sites, techniques employed, and participants. The development and application of a range of dating techniques, for instance, was crucial, as were undertaking deep trench excavations to obtain long stratified sequences.

As the title of the project indicates, the rationale was to carry out comparable archaeological, palaeontological, and palaeo-environmental research on both sides of the Wallace Line – named after the 19th Century English naturalist Alfred Russel Wallace, and the most significant biogeographic boundary in Southeast Asia (Fig. 1). In Indonesia, the Wallace Line demarcates the eastern edge of the Asian continental shelf. Continental islands to the west, such as Borneo and Java, were joined to the Asian mainland by land bridges at times of glacially-induced, low sea level, and could be populated by a full range of Asian land animals. In contrast, islands to the east, such as Flores, Sulawesi, and Timor, were always separated by sea barriers from the Asian (Sunda) and Greater Australian (Sahul) continents.

More specifically, we decided to concentrate our research on two Indonesian islands - the continental island of Java, and the oceanic island of Flores that is located midway between Sunda and Sahul. These islands were selected as case studies because prior research demonstrated their potential for answering the questions posed in setting up our research program: both have Lower and Middle Pleistocene open fossil sites located in close proximity to limestone uplands that included caves with deeply stratified deposits in which faunal remains were well preserved. Although this volume focuses on Liang Bua on the island of Flores, evidence from other sites on Flores, Java, and elsewhere in Southeast Asia is used when relevant.

Flores: geographical, historical, and archaeological context

Flores is also located on the geographical, cultural, and linguistic boundary between Asia and Australia–Melanesia, and lies on a possible route for initial colonization of Greater Australia by modern humans (Birdsell, 1977; O'Connor, 2007). The island is about 400 km long and at 13,500 km^2 is the largest in the Nusa Tenggara, or Lesser Sunda, chain of volcanic and coral-reef islands. It was pushed up from the seabed by collision of the Eurasian and Indian tectonic plates at least 8 m. yr., and is now characterized by rugged volcanic mountains up to 2400 m high, deep canyons, and gravel plains. The main range runs east-west across the length of the island and sheds water to the north and south coasts.

Even at low sea levels, reaching Flores from mainland Asia or Greater Australia requires at least two sea crossings. Coming from

Figure 2. Father Theodor Verhoeven excavating at Mata Menge in the Soa Basin, central Flores (Photo: Verhoeven, 1968).

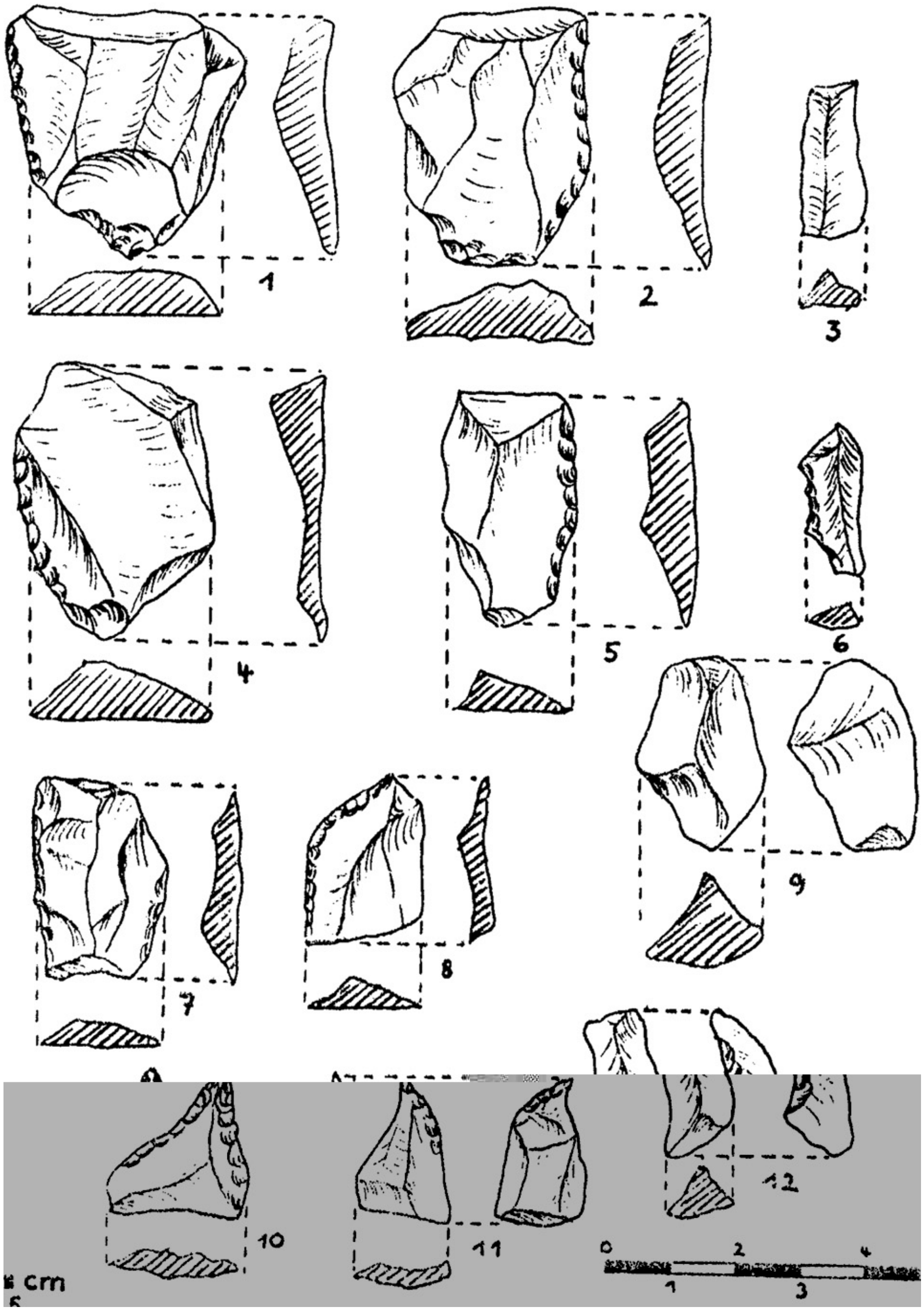


Figure 3. Artifacts excavated by Verhoeven at Boa Lesa in the Soa Basin of central Flores (from Maringer and Verhoeven, 1970b). The archaeological establishment generally did not accept his evidence or claims for early hominins on Flores.

Asia, the first of these deepwater sea barriers is a 25 km strait between the islands of Bali and Lombok; the second is a 9 km strait between Sumbawa and Flores. Although Lombok can be clearly seen from Bali, the strait between them is the main channel of the Indonesian Throughflow by which the Pacific Ocean drains south into the Indian Ocean (Kuhnt et al., 2004). The associated currents are very strong and the strait, which is beyond the swimming capabilities of terrestrial animals, therefore comprises a formidable section of the Wallace Line. As a result, before humans transported animals between islands in the Holocene, islands lying between Bali and Greater Australia had very impoverished terrestrial faunas.

Archaeology on Flores was pioneered by a Dutch priest with archaeological qualifications, Father Theodor Verhoeven, who was based at the Mataloko Catholic Seminary. Between 1950 and 1967, he carried out excavations and collections at many limestone rock shelters and caves in east, central, and west Flores, including Liang Bua, Liang Panas, Liang Michael, Liang Momer, Liang Toge, Batu Cermin, Liang Melima, and Liang Tekip. With the exception of the excavated human remains (e.g., Jacob, 1967), most of his work and findings went unreported, or were only sketchily described (e.g., Verhoeven, 1953,1958; Maringer and Verhoeven, 1977).

In 1959, Verhoeven also initiated excavations at open fossil sites in the Soa Basin of central Flores. These included Ola Bula, Mata Menge, Lemba Menge, and Boa Lesa (Verhoeven, 1968; Maringer and Verhoeven, 1970a,b; Fig. 2). At Mata Menge, Lemba Menge, and

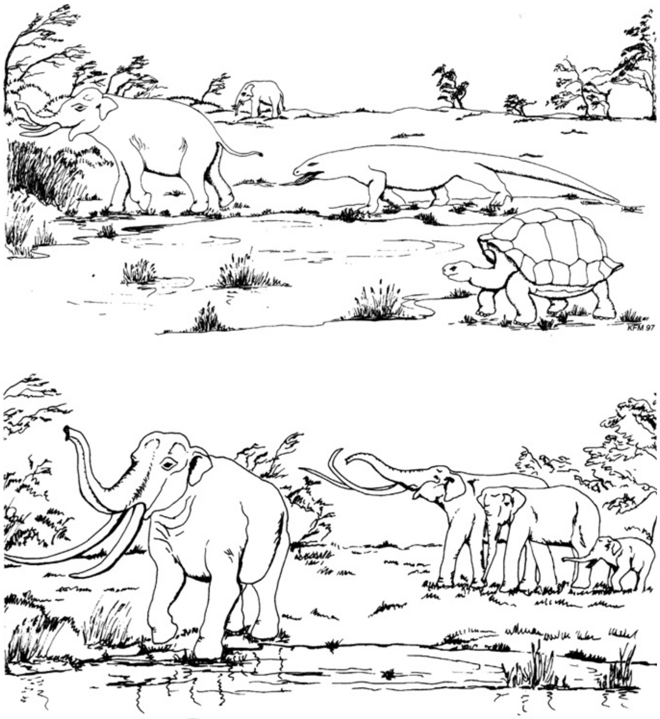


Figure 4. Pleistocene faunal turnover in the Soa Basin of central Flores. Fauna represented at Tangi Talo ~900 ka included giant tortoise, the pygmy *Stegodon sondaari*, and Komodo dragon. By 880 ka, giant tortoise and pygmy *Stegodon* had become extinct, to be replaced by the large-bodied *Stegodon florensis* (Drawings by Kathy Morwood).

Boa Lesa, he found stone artifacts including flake tools, chopping tools, and hand axes, together with large *Stegodon* remains in sandstone layers sandwiched between layers of volcanic ash (Fig. 3). Verhoeven concluded that early humans and *Stegodon* co-existed on Flores. Furthermore, because tektites occur in the same fossils beds (von Koenigswald, 1958), and *Stegodon* and *H. erectus* were known to have lived in Java about 750 ka, he argued that the Soa Basin fossil sites were of similar age, and that *H. erectus* had somehow reached Flores.

Verhoeven published these findings and claims in a series of papers in the journal *Anthropos*, but they were generally dismissed or ignored as inconclusive because of doubts about his identification of stone artifacts, the possibility that any actual stone tools might have become mixed up with much older fossils, and the fact that no one knew when *Stegodon* had become extinct on Flores (e.g., Allen, 1991). In fact, it was to be thirty years before Verhoeven's work in the Soa Basin was followed up by a palaeontological investigation of Mata Menge, undertaken in April–May 1994 by Fachroel Aziz of the Indonesian Geological Research and Development Centre (GRDC), and his Dutch colleagues Paul Sondaar, John de Vos, and Gert van den Bergh, as part of a broader study of sedimentology and faunal succession in Indonesia.

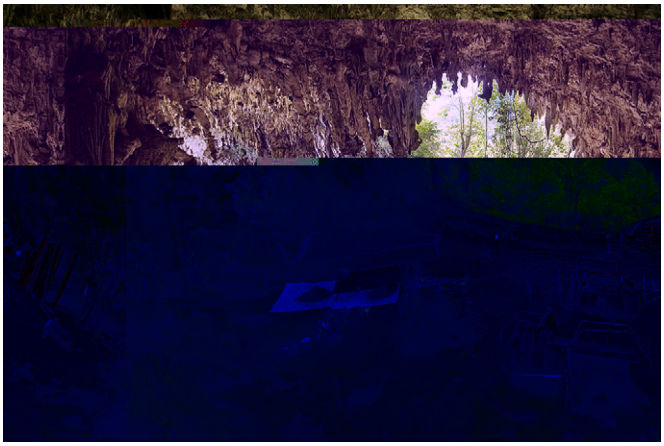


Figure 5. General view of Liang Bua during our archaeological excavations in 2007. Note use of shoring (Photo: Djuna Ivereigh).

Intrigued by Verhoeven's claims that *H. erectus* had reached Flores, Sondaar had previously visited the Soa Basin, checked out Mata Menge, and also found a stratigraphically older site, Tangi Talo, that contained the remains of pygmy *Stegodon* (*S. sondaari*), giant tortoise (*Geochelone* sp.) and Komodo dragon (*Varanus komodoensis*). He had a long-standing interest in the evolution of animals on islands (Sondaar, 1987), and immediately realized that here was a real opportunity to examine the impact of early humans on a pristine island. More specifically, Sondaar wanted to know if the arrival of humans had been responsible for the extinction of pygmy *Stegodon* and giant tortoise on Flores, and whether or not the large-bodied *Stegodon* that subsequently recolonized the island had not reduced in size over time because of the presence of human hunters.

Excavations by the Indonesian-Dutch team confirmed Verhoeven's major claims: at Mata Menge and another site, Dozu Dhalu, stone artifacts were found *in situ* with the remains of large-bodied *Stegodon* (*S. florensis*), crocodile, and giant rat (*Hooijeromis nusatenggara*) (van den Bergh et al., 1996: 32–34). In contrast, their excavations at Tangi Talo yielded abundant remains of pygmy *Stegodon*, giant tortoise, and Komodo dragon, but no associated stone artifacts. They concluded that a major turnover in Soa Basin fauna coincided with the appearance of stone artifacts in the sequence (Fig. 4), and that this turnover actually resulted from the arrival on Flores of a new predator, *H. erectus*. Palaeo-magnetic determinations from Tangi Talo and Mata Menge suggested that the former site was 900,000 years old and the latter "slightly less than" 730 ka (Sondaar et al., 1994: 1260).

Reaction to these renewed claims was again muted, and, when published, generally cautious because of doubts about the identification of stone artifacts, the lack of taphonomic detail, and the chronological ambivalence of a palaeo-magnetic transition 3 m below the Mata Menge fossil/artifact deposit (e.g., Bellwood, 1997: 67–68).

The next phase of archaeological and palaeontological research on Flores began in 1996, when Aziz and Morwood revisited Mata Menge and Tangi Talo to take stratigraphically-provenanced samples of tuffaceous silts for fission track dating of the fossil-bearing sediments. The results confirmed that Tangi Talo with its pygmy *Stegodon* and giant tortoise was 900 ka, while Mata Menge, which had stone artifacts in primary association with *Stegodon* fossils, was between 880–800 ka (Morwood et al., 1998).

In 1998, Morwood and Aziz obtained a grant from the Australian Research Council for a larger project, *Archaeology and palaeontology of the Ola Bula Formation, central Flores, Indonesia*. This project included geological mapping of the entire Soa Basin; the recording of 15 fossil sites; fission track dating of major strata and sites throughout the basin; and large-scale excavations at Mata Menge, Boa Lesa, Kobatuwa, Kopowatu, and Tangi Talo (e.g., Morwood et al., 1999; O'Sullivan et al., 2001; Brumm et al., 2006; Aziz et al., 2009; Suminto et al., 2009; van den Bergh et al., 2009a). They were able to establish that the fluviatile and lacustrine deposits in the area were laid down between 1 Ma–680 ka; that the strata had since remained horizontal with minimal distortion, allowing the relative ages of fossil sites to be easily gauged; and that stone artifacts

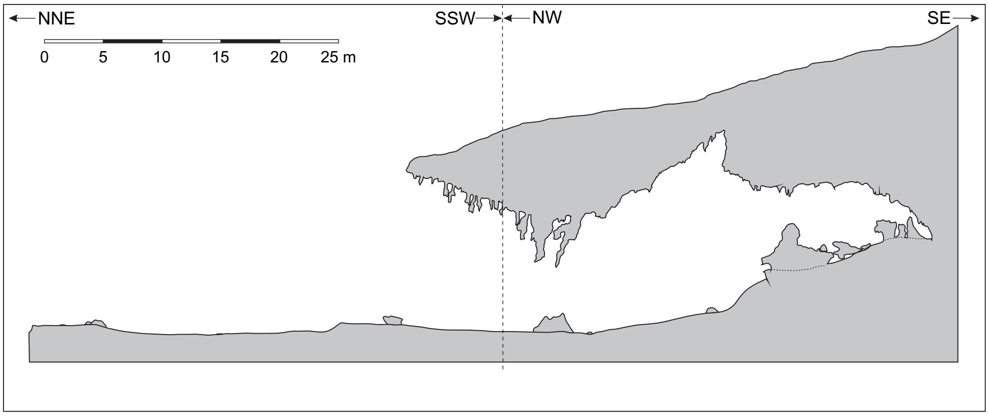


Figure 6. Liang Bua in longitudinal (north-south) cross section. Overall, the cave is 40 m deep, 50 m wide, and 25 m high at the entrance, but it actually comprises inner and outer chambers of different geomorphic histories and ages.

consistently occur in sites less than 880 ka, associated with the remains of large-bodied *Stegodon.*

The major problem with research in the Soa Basin is that the deposits containing *Stegodon* fossils and stone artifacts stop around 680 ka. The record there does not pick up again until very recent times – Neolithic and historic sites directly overlay deposits of much greater age. To find out what happened in the intervening period, information was needed from sites in other parts of Flores with geological deposits of Middle Pleistocene to Holocene age. Liang Bua was one site that seemed to fit the bill.

Liang Bua: geographical, historical, and archaeological context

Liang Bua is a large limestone cave 7 km northwest of Ruteng, the regional capital of Manggarai Regency, west Flores, at an altitude of 500 m above sea level and 30 km from both the north and south coasts. It is located in the base of a limestone hill on the southern edge of the Wae Racang River Valley, and directly overlooks the alluvial flats of the westerly flowing river, 200 m to the north (Figs. 5 and 6). Two other large caves occur in close proximity along the same scarp – Liang Galan, 100 m to the east, and Liang Tanah, 100 m to the northwest.

Research at Liang Bua began with the excavations by Verhoeven. He first visited the cave when it was being used as an elementary school and excavated a test-trench against the west wall in 1950, soon after the school was moved to a more conventional classroom. This excavation yielded promising amounts of pottery and stone artifacts. Verhoeven returned to the site in 1965, and during a two-week excavation on the west side of the cave, he found six Neolithic and Proto-Metallic age burials with grave goods, as well as concentrations of stone artifacts and faunal remains (Figs. 7 and 8).

Verhoeven's work at Liang Bua was never published, but, in 1973, he wrote to Professor R.P. Soejono of the Indonesian National Centre of Archaeology (ARKENAS) describing his results and the potential of the site. Soejono followed up with excavations there in 1978, 1981, 1982, 1985, 1987, and 1989, during which he excavated ten squares to a maximum depth of 4.2 m to obtain a radiocarbon date of 10,000 BP. These excavations, which yielded further burials of Neolithic and Palaeo-Metallic age (Fig. 9a and b), were described in a series of in-house reports, but never published (e.g., Soejono, 1980,1985).

Morwood visited Liang Bua with Aziz in 1999 while working in the Soa Basin, and estimated, on the basis of the similarly-sized (but empty) Liang Galan, that the main chamber in Liang Bua contained a depth of at least 17 m of deposits. Potentially, the site could provide evidence for what happened to the early hominins of Flores, when modern humans arrived, when people began to cultivate, and the impacts of palaeo-environmental and technological changes over tens-of-thousands of years. Sites in the Soa

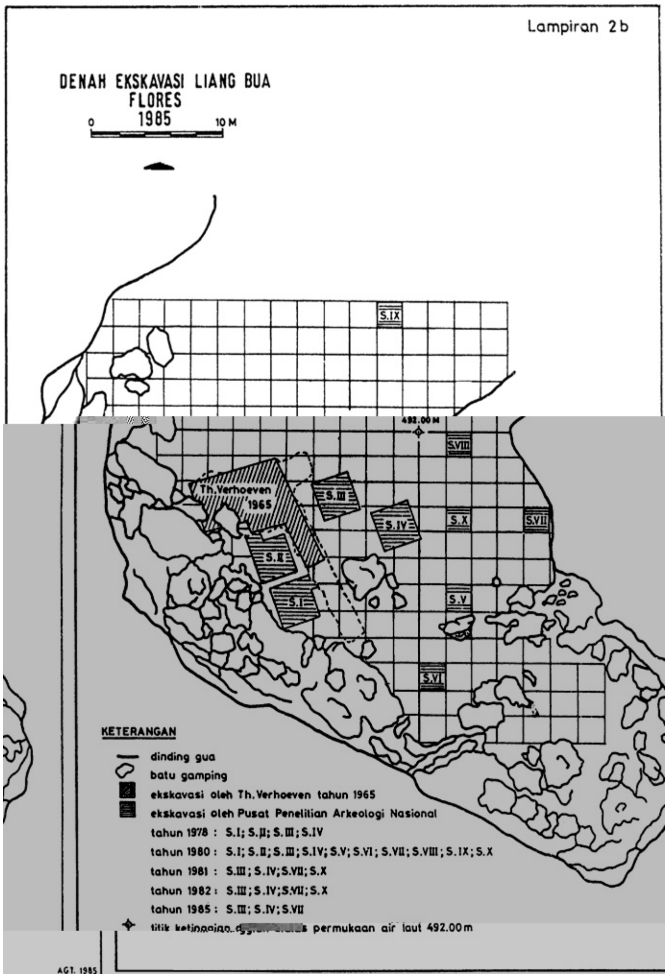


Figure 7. Plan of Liang Bua showing the 1965 excavation by Verhoeven and Soejono's excavated Sectors I to X (from Soejono, 1985).

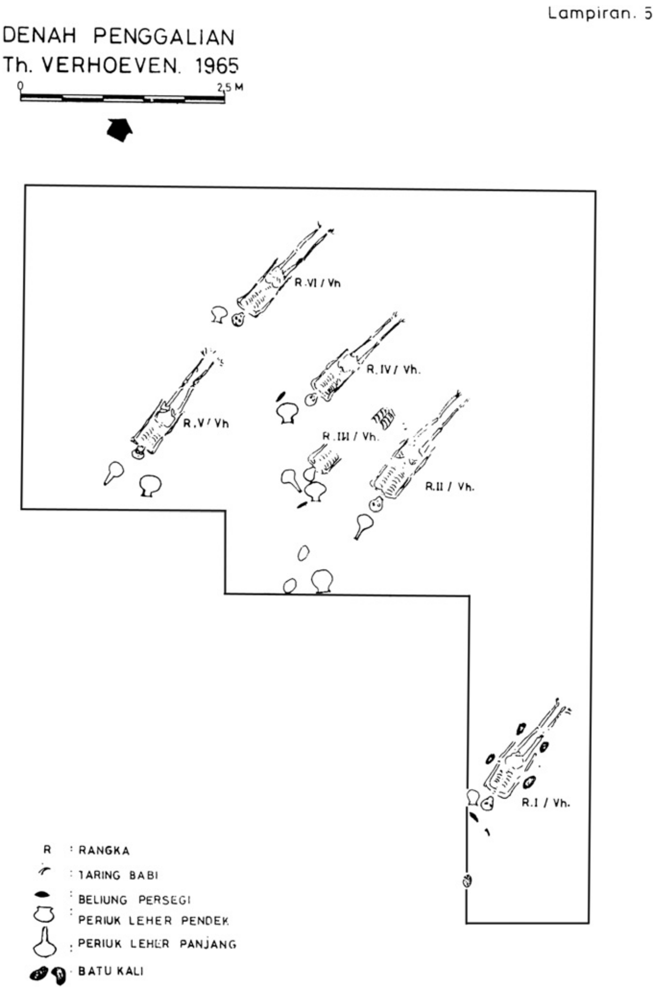


Figure 8. Plan of Verhoeven's 1965 excavation at Liang Bua showing six extended burials. Accompanying grave goods included pots, flaked adzes, pig tusks, and river stones (from Soejono, 1985).

Basin document the presence and activities of the first hominins to colonize Flores. Now here was a chance to see what had happened at the more recent end of the faunal, hominin, and cultural sequences.

The sheer potential of Liang Bua is what first prompted Soejono, Aziz, and Morwood to envisage a large-scale project involving comparative, interdisciplinary studies in both Java and Flores, of limestone caves containing deeply-stratified deposits and nearby fossil deposits, as a means of tackling some fundamental questions in Southeast Asian palaeontology, palaeo-environments, and archaeology. In this quest, they were subsequently joined by people with a range of relevant expertise from many disciplines and institutions (see other papers this volume).

As part of the resulting "*Astride the Wallace Line*" project, further excavations were carried out at Liang Bua in 2001, 2002, 2003, and 2004 under a "Memorandum for Understanding" negotiated between ARKENAS and the University of New England, for which Soejono and Morwood were the nominated institutional counterparts. In addition, Tular Sudarmadi (Gadjah Mada University, Indonesia) initiated an ethnoarchaeological study on the local ethnic group, the Manggarai, with a focus on village settlement patterns and the role of megaliths; Kerrie Grant (University of New England, Australia) visited a number of Flores pottery-making centers to assist with her work on the Liang Bua pottery sequence; Kira Westaway (then University of Wollongong, Australia) examined river terraces in the vicinity of Liang Bua to reconstruct landscape changes over time; Mark Moore (University of New England) explored the lithic terrain around the cave and conducted stone artifact replication experiments; and Carol Lentfer (Southern Cross University, Australia) and Netty Polhaupessy (Indonesian Geological Research and Development Centre) collected further plant species for a starch reference collection and took sediment cores from Rana Mese crater lake to obtain palaeo-environmental evidence.

Five methods for determining the absolute ages of various strata and finds were used: 1) standard and AMS radiocarbon by Alan Hogg (University of Waikato, New Zealand), Michael Bird (then University of St Andrews, Scotland), and Chris Turney (then University of Wollongong); 2) Optically Stimulated Luminescence, and 3) Thermoluminescence on sand and feldspar grains by Bert Roberts (University of Wollongong) and Kira Westaway; 4) Uranium-series on flowstones by Jian-xin Zhao (University of Queensland); and 5) Electron Spin Resonance on *Stegodon* teeth enamel by Jack Rink (McMaster University, Canada).

Excavations at Liang Bua, 2001–2004

A total of five squares were excavated at Liang Bua between 2001–2004: Sectors I, III, IV, VII, and XI. With the exception of Sector XI, these had been excavated previously to various depths by

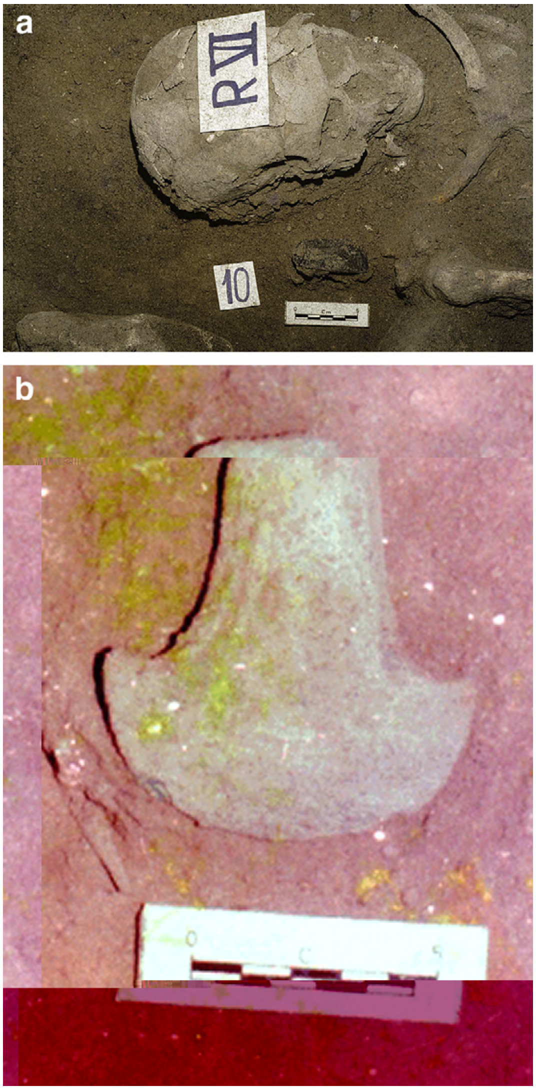


Figure 9. a) An extended Palaeometallic burial with grave goods, and b) a bronze axe, as excavated by Soejono at Liang Bua in 1980 (Photos: R.P. Soejono).

Soejono. Excavation procedure included removal of any backfill to expose *in situ* deposits; use of timber shoring of the baulks for safety (Fig. 10); excavation by 10 cm spits or stratigraphic units (whichever was the smaller); 3D plotting and bagging of artifacts and bones found by the excavators; weighing of deposits; dry sieving and sorting of all excavated deposits with a 2 mm mesh; and wet sieving of materials retained in the dry sieves with 2 mm mesh. Bulk samples of all stratigraphic units were also taken for dating, as well as for sediment, pollen, phytolith, and starch analyses. Bedrock was not encountered in any of the excavated sectors. A brief synopsis of the excavation in each sector is as follows.

Sector 1

The previous excavation of this sector in 1978 by Soejono was terminated at a thick slab of flowstone over the whole square, which was incorrectly interpreted as bedrock. In 2003, we cut a 3 × 2 m trench through the west-to-east sloping layer of flowstone, and excavated to a depth of 8.7 m (Fig. 11). Work was halted because no artifacts or faunal remains were found in the lowermost 6.5 m of the excavation, while the development of cracks and slumping of the basal tuffaceous clay clays raised safety concern.

Figure 10. Our deep-trench excavations at Liang Bua relied on construction of wooden shoring and platforms as an essential safety measure (Photo: Djuna Ivereigh).

The first evidence for hominin use of the site occurs at a depth of 2.6 m in Layer 10, a dark, yellowish brown clay. Associated faunal remains include *Stegodon* and Komodo dragon. Flowstone layers of varying thickness, extent, and hardness (Layers 9 and 7) then sealed in these deposits. Above the flowstones, the uppermost 1.7 m of the deposit comprise thin layers of fine, clay-rich sediments, of the type currently being washed into the cave. Only extant animals and modern humans, including burials, are represented in these layers, which document the appearance of Neolithic pottery around 70–80 cm in depth.

Sector III

Excavation of this 3 × 3 m square in 2002 recommenced at a depth of 3.1 m, and continued to 8.1 m (Fig. 12). The basal deposits of tuffaceous clays with lenses of sand and rockfall (Layer 8) are culturally sterile, apart from a retouched flake and hammerstone found in a sand lens at 7.6 m. The artifacts are not water-rolled, are unlikely to have been transported far, and indicate that occupation of some sections of the cave had commenced by ~100 ka. However, the first evidence for hominin occupation and faunal remains in this sector comes from near the base of Layer 5, a mottled clay in which stone artifacts are associated with the remains of hominins, *Stegodon*, birds, fish, varanids, snakes, rodents, and frog. Similar artifacts and faunal remains occur in the overlying sticky clay (Layer 4). However, only extant animals and modern humans are represented in the uppermost 3.6 m of deposits (Layers 3 to 1), which also contain burials, ornaments, pigments, and mollusk shells. Evidence for the Neolithic, as signalled by pottery, appears at a depth of 1.7 m.

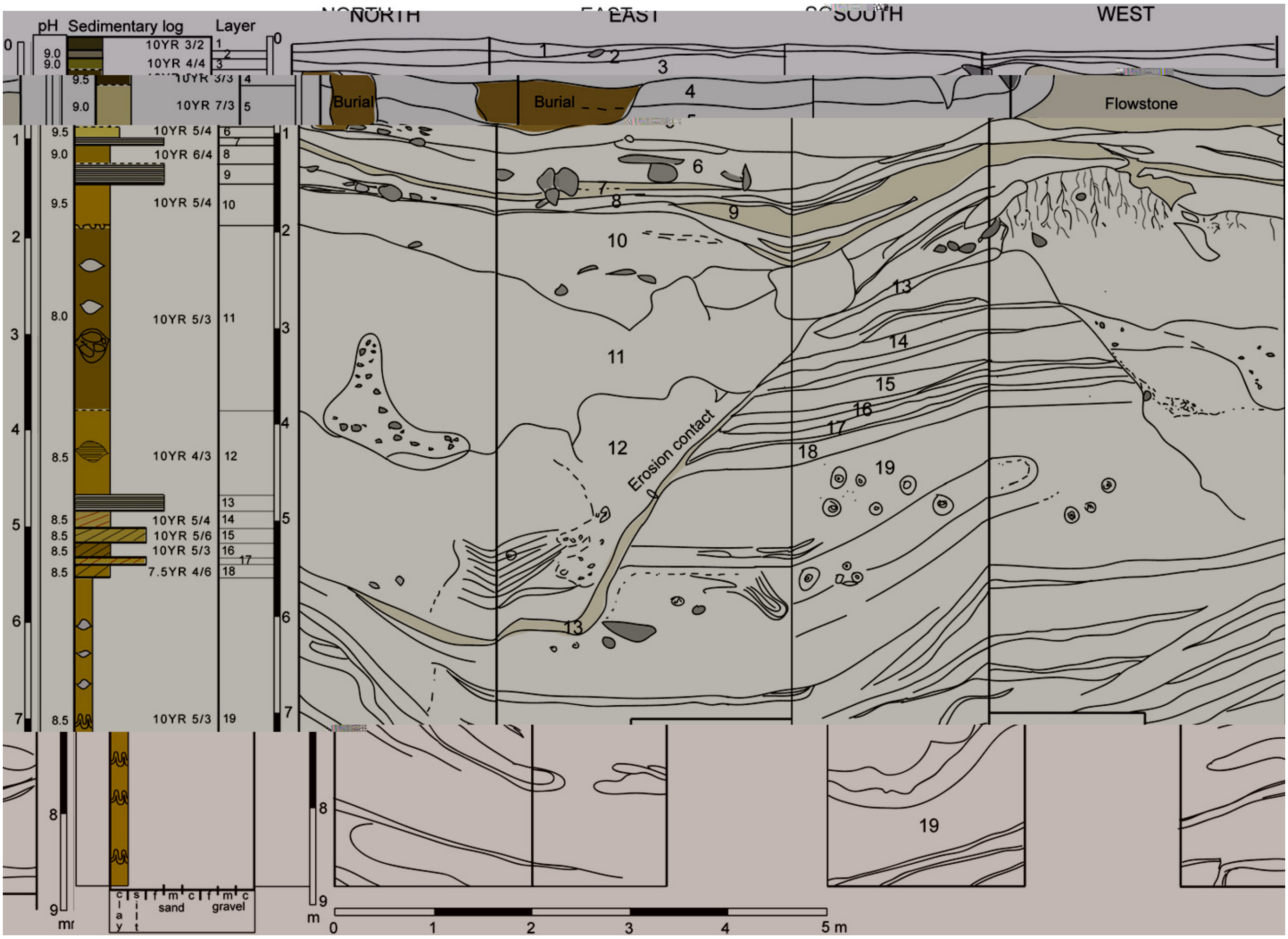


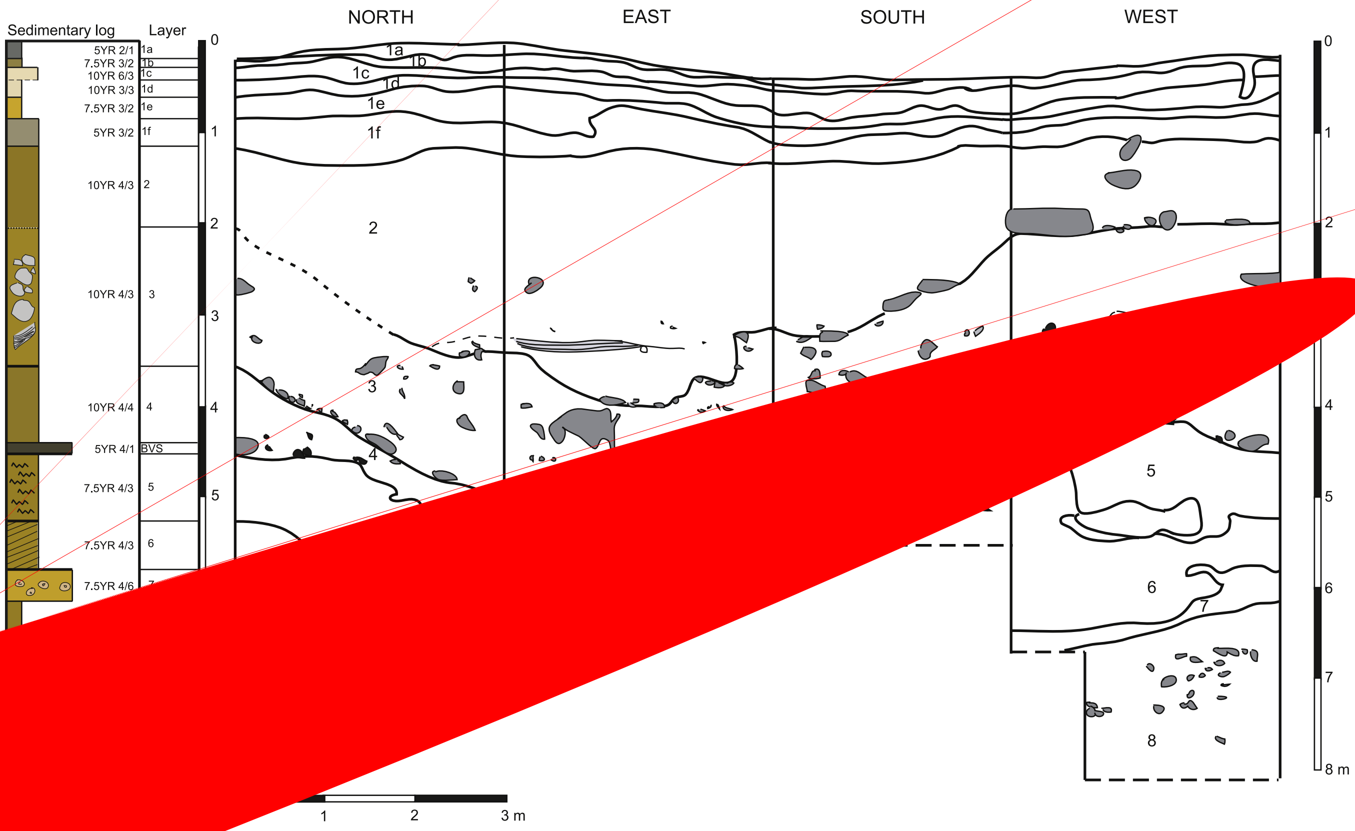
Figure 11. Stratigraphic section and sedimentary log of the Sector I excavation at Liang Bua. Layer key: Layers 1–3 are homogenous and compact clays and silts. Layers 4–5 are clayey silt with two burial features removed during a 1978 excavation. Layer 6 is a sandy silt with some angular limestone clasts. Layer 7 is a hard flowstone that caps most of this sector. Layer 8 is clayey silt that is sandwiched between flowstone (Layer 9) containing sandy silt, which slopes up to, and thickens towards the southwest and caps *Stegodon* remains. Layer 10 is clayey silt with loaded bedding structures. Layer 11 is silty clay with lenses of clay and rubble and reprecipitated calcite from the overlying flowstone. Layer 12 is silty clay with horizontal laminae of pure clay. Layer 13 contains concreted sand and flowstone that have precipitated down the side of a steep erosion contact. Layers 14–18 are low angle cross bedding of silty clay and clayey sand with iron oxide coatings and lenses of sand that represent the original deposit before cut and fill processes. Layer 19 is a clay with some lenses of sand and convoluted bedding towards the base. The log (left side) describes the sedimentary characteristics of each layer. A key for the symbols can be found at the bottom of the sedimentary log.

Sector IV

Excavations of this 3 × 3 m square in 2001 and 2003 began at a depth of 4.3 m and reached a maximum depth of 9.0 m, in a homogeneous, tuffaceous clay that was prone to cracking and collapse (Fig. 13). The earliest artifacts and faunal remains in this sector come from a strong, brown clay containing rockfall (Layer 9), which infills a channel cut down into earlier deposits. This clay contains stone artifacts and bone, including those of *Stegodon*, Komodo dragon, and *H. floresiensis*. The next deposit was a dark, yellowish brown clay comprising layers of alluvial slopewash with high concentrations of gravel, stone artifacts, and bone (Layer 8). Water and gravity have clearly transported the clays, stone artifacts, and bone downslope from higher levels to the south and west. The condition, concentration, and distribution of the latter indicate that the source is a hominin occupation area immediately adjacent to Sector IV. These occupation deposits were originally more extensive but have clearly been truncated both horizontally and vertically by water action and recutting of channels. A series of “sterile” white tuffaceous silts (Layers 5a-c) deposited in an erosion channel and up to 70 cm thick, are the most prominent stratigraphic units in the section. Deposits above the white tuffaceous silts, from a depth of 4 m to the surface, contain stone artifacts, charcoal, the remains of extant fauna and modern humans, and a range of evidence for symbolic behavior (burials, ornaments, pigments). Evidence for the Neolithic, as signalled by pottery appears at a depth of 170 cm.

Sectors VII and XI

In 2003, Sector VII, a 2 × 2 m square, was excavated to a depth of 7 m and yielded a partial hominin skeleton – LB1, the type specimen for *H. floresiensis* (Fig. 14). The following year, this excavation was continued to 11 m in depth, and, at the same time, another 2 × 2 m square immediately to the south was excavated to 9 m in depth (Sector XI). The purpose of the latter excavation was to recover the arm bones of LB1 along with additional contextual evidence. In fact, skeletal remains from at least 14 individuals were eventually recovered from this section of the cave. The combined VII/XI trench was terminated at a massive rockfall layer (Fig. 15). The deposits below 3.2 m in depth (Layers O to X) comprise clayey



silts laid down in pools, interspersed with layers of reworked conglomerate sloping down to the north. Stone artifacts and animal remains, including those of *Stegodon*, Komodo dragon, and *H. floresiensis*, were concentrated in a number of well-defined occupation floors between 5.2–3.2 m in depth in Layer Q of Sector XI. This layer was capped by a thick, consolidated layer of "black," volcanic sandy silt and coarse silty sand (BVS), corresponding to a massive volcanic eruption that coincided with the disappearance of *Stegodon* and *H. floresiensis* from the Liang Bua sequence. Later, most of the BVS and Layer Q were eroded away, as marked by fragments of BVS in deposits that first accumulated in the resulting channel (Layer O). A series of "sterile," white tuffaceous silts up to 90 cm thick (Layers Na-d) were then deposited in this channel: these silts comprise the most prominent stratigraphic units in the section. Although topographically below the BVS, they are stratigraphically younger. The same white tuffaceous silts, with fragments of BVS in underlying deposits, are evident in Sectors III and IV, and they provide a useful stratigraphic marker. Above the white tuffaceous silts, layers of silty clay contain only the remains of extant animals and modern humans. Evidence for the Neolithic, as signalled by pottery, appears at a depth of 1.4 m in Sector VII and 1 m in Sector XI.

Research results

Some of the findings made during excavations at Liang Bua have already been published, albeit briefly (e.g., Brown et al., 2004; Morwood et al., 2004, 2005; Brumm et al., 2006; Falk et al., 2005, 2009a, b; Moore, 2007; Moore and Brumm, 2007; Tocheri et al., 2007; Westaway et al., 2007; Jungers et al., 2009a, b). This volume provides an overview of our results to date, including studies on the geomorphic and palaeo-environmental setting of the excavated finds, and shows that there is much more to Liang Bua than *H. floresiensis*. The site and its context also provide evidence for the episodic nature of tectonic uplift and associated river downcutting; palaeoclimatic changes; insular evolutionary processes; the complexity of early modern human dispersal; pre-Austronesian economic intensification; and the arrival of new peoples, technologies, animals, and crops over the past 4000 years (Morwood and van Oosterzee, 2007).

In two papers, Westaway et al. (2009a, b) describe how Liang Bua was formed underground, opened by the Wae Racang River about 190 ka, and subsequently infilled with sediments – all processes that dictate the bounds of the archaeological evidence. They identify tectonic uplift as the major determinant of Flores landscapes, and follow this line of evidence by integrating information gleaned from study of river terraces in the river valley, speleothems in local caves, and stratified deposits in Liang Bua to reconstruct a detailed history of the cave, its sedimentary contents, and their context.

Archaeology is mainly about when things happen and where, from which we can sometimes infer why. The paper by Roberts et al. (2009) on Liang Bua geochronology, tabulates 94 radiometric ages available for deposits in and around the site; offers detailed discussions of the strengths and limitations of the various dating methods used - radiocarbon, U-series, luminescence, and electron

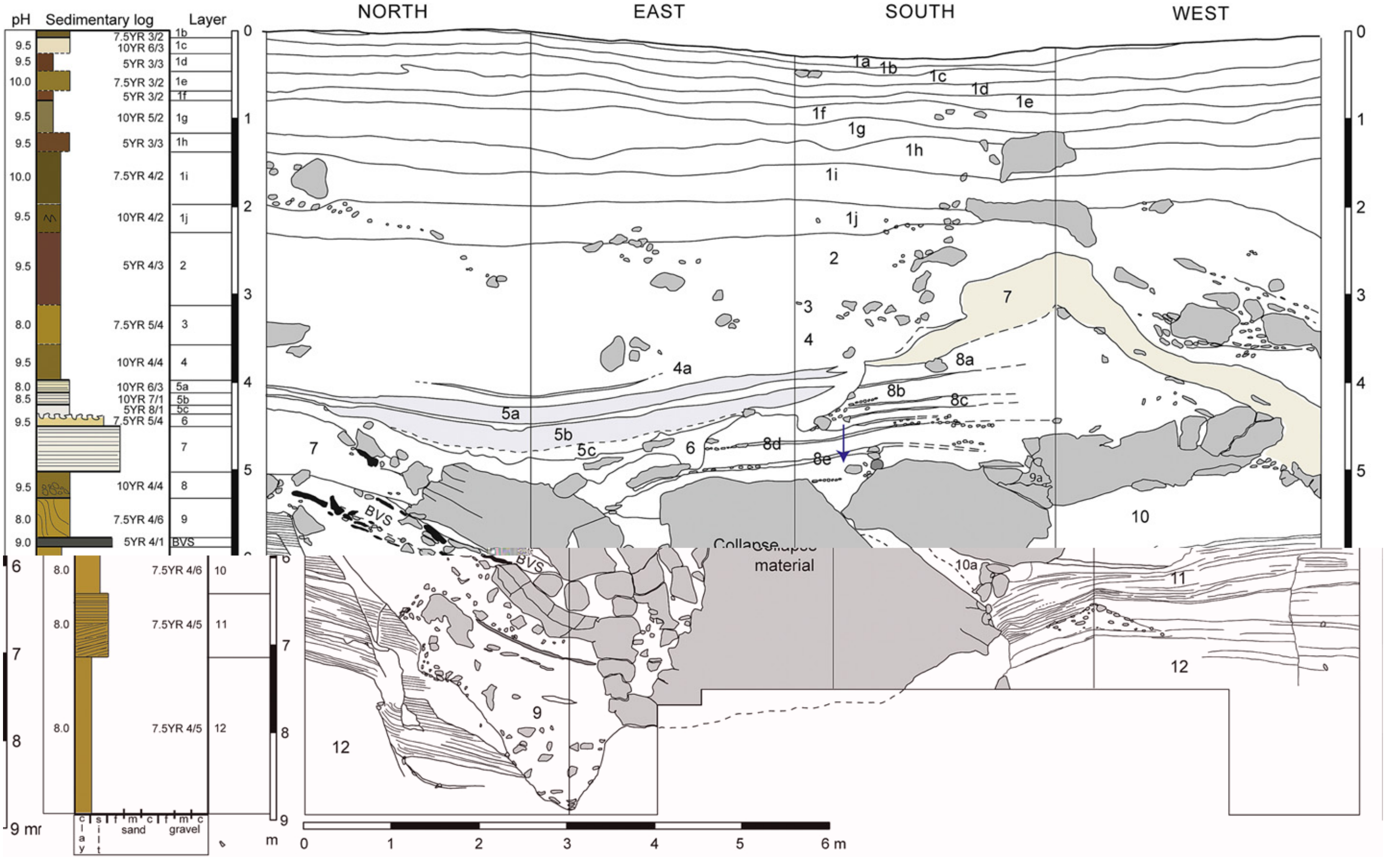
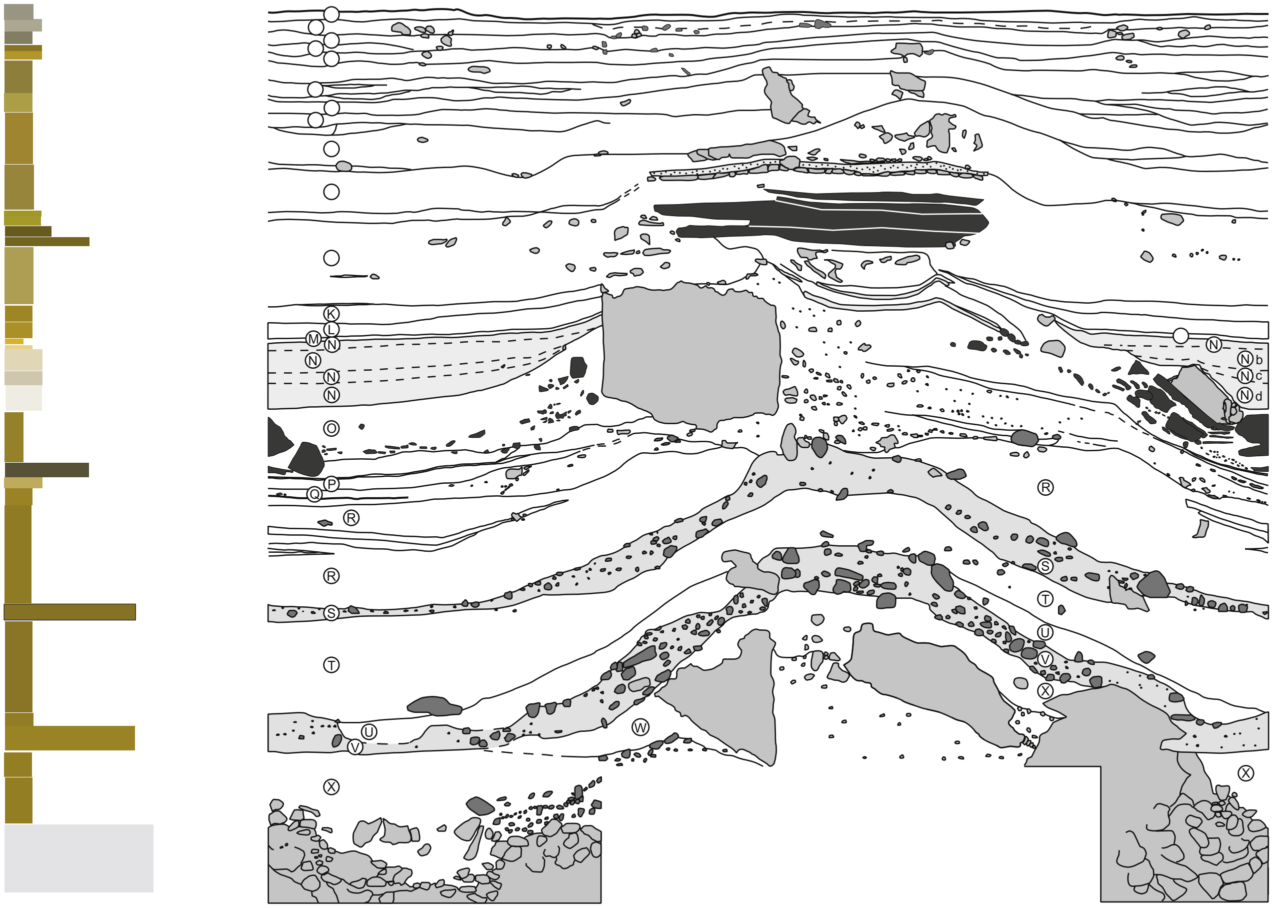


Figure 13. Stratigraphic section and sedimentary log of the Sector IV excavation at Liang Bua. Layer key: Layers 1-2 are silty clays and clayey silts with bands of coarser material indicating occasional flushes of stronger water flow in the lower layers. Layer 3 is a 30 cm thick pavement of water rolled boulders and roof fall in a silty clay matrix. Layer 4 is clayey silt with a thick layer of fire-reddened clay with pieces of charcoal. Layer 5 is fine laminated silts containing tephra that are water-laid, lap up against earlier concreted deposits, fine towards the northeast, and contain three distinct layers (a, b, c), of which c is the purest with loaded bedding structures. Layer 6 is a silty sand that has been extensively eroded by channel formation, and Layer 7 is a flowstone and clayey flowstone that formed prior to the deposition and erosion of Layer 6. Layer 8 is a clayey silt with flowstones and contains high densities of pebbles, stone artifacts, and bone, with defined layering 8 a-e. Layer 9 is a silty clay with lines of rockfall that has slumped into, and filled the channel cut into Layers 10, 11, and 12. It contains lenses of black volcanic silty sand (BVS) that also slope into the channel but represent a later infill. Layer 10 is a silty clay interspersed with and directly underneath rockfall. Layer 11 is silts with laminations and cross-bedding and interspersed with sand. Layer 12 is a fine silt with a massive sedimentary structure. The log (left side) describes the sedimentary characteristics of each layer. A key for the symbols can be found at the bottom of the sedimentary log.

Figure 14. The skull and mandible of LB1, type specimen for *Homo floresiensis*, still encased in sediment on August 10th, 2003 (Photo: Wahyu Saptomo).

spin resonance; and discuses the significance of the results. For instance, at Liang Bua the disappearance *of H. floresiensis* and *Stegodon* near the Pleistocene/Holocene boundary was followed stratigraphically by evidence for a volcanic eruption and the arrival of modern humans. The absolute ages of these events may indicate whether climate change, a natural catastrophe, modern humans, or a combination of factors were responsible for the demise of the only two large, endemic mammals on Flores.

In their study of the stone artifacts, Moore et al. (2009) demonstrate a remarkable degree of technological continuity throughout the Liang Bua sequence: a continuity that transcends the Pleistocene/Holocene boundary and the replacement of one hominin species by another. Significantly, the same range of production techniques and artifact types occur at sites in the Soa Basin that are 880–680 ka in age. When changes in the Liang Bua stone artifact sequence did occur, as with the first edge-gloss on tools 11 ka or the appearance of Neolithic rectangular sectioned adzes around 4 ka, they were “added on” to the pre-existing artifact production system - a pattern that seems to characterize Southeast Asian stone artifact sequences generally over the past million years. One implication is that, with the exception of such “add ons,” stone artifacts in Southeast Asia



cannot be used in isolation as indicators of age or associated hominin species.

In their paper on the Liang Bua fauna, van den Bergh et al. (2009) provide a wealth of information on the tens of thousands of excavated bones and teeth of stegodonts, pigs, monkeys, deer, bovids, rats, bats, varanids, snakes, lizards, amphibians, and fish – as well as mollusks. The differential distribution of these species in the sediments at the site adds up to a unique faunal record spanning the last 95 k. yr.: there is nothing else like this currently known in Southeast Asia. The Flores faunal record includes spectacular extinction events, but from 900 ka, is more characterized by long-term isolation, impoverishment, and phylogenetic continuity – until the terminal Pleistocene, when *Stegodon* and *H. floresiensis* went extinct. The pace of faunal change then accelerated in the Holocene, when newly arrived modern humans started to import animals and to clear extensive tracts for agriculture. A real strength of the paper is that the evidence from Liang Bua is considered in the light of finds from other islands in the region, and of evolutionary trends evident on islands worldwide. For instance, the occurrence of *Stegodon* until at least 17 ka on Flores is remarkable considering dates for disappearance of the genus elsewhere in Southeast Asia, their much earlier evolutionary history in the Soa Basin, and the fact that the two known *Stegodon* extinction events on Flores, around 900 ka and 17 ka, seem to coincide with massive volcanic eruptions (Aziz et al., 2009).

This volume includes six papers analyzing aspects of the *H. floresiensis* remains excavated from the Pleistocene levels of Liang Bua. Jungers et al. (2009b) focus on the lower limb bones that are from a minimum of 8 individuals – a pelvis, femora, tibiae, fibulae, patellae, and numerous foot bones. They conclude that the represented mosaic of primitive and derived traits is unlike any other known hominin species, including healthy or pathological modern humans. Larson et al. (2009) echo this interpretation with their assessment of the upper limb bones - a clavicle, a humerus, ulnae, carpals, metacarpals, and phalanges from at least 5 individuals. Brown and Maeda (2009) go further: on the basis of their study of the LB1 and LB6 mandibles and teeth, they conclude that *H. floresiensis* has many primitive traits outside the ranges of variation exhibited by *H. sapiens* and *H. erectus*, but similar to those of early *Homo* or *Australopithecus*.

Much of the controversy about *H. floresiensis* has explicitly been about the brain size of LB1, which at 417 cc is judged too small to be normal in a hominin who lived only 18 ka. Falk et al. (2009a, b) tackle the problem head on with their study of the LB1 endocast. They argue that the brain was globally reorganized despite its small size, then further rule out any possibility that LB1 might be a modern human microcephalic by undertaking comparative analysis of 9 microcephalic and 10 normal modern human endocasts. Multivariate analyses indicate that “normal” and “pathological” endocasts could be distinguished with 100% certainty, and that the LB1 endocast sorts as normal based on shape measures.

Similarly, Baab and McNulty’s (2009) study sets out to investigate the claim by some critics that the degree of asymmetry in the LB1 cranium suggests pathology. They examined the relationship between cranial size and shape in a range of hominin and African ape species, concluding that *H. floresiensis* probably derives from an early *Homo* species, not modern humans, and that the degree of asymmetry in LB1 is well within the range exhibited by extant specimens, is moderate compared with the asymmetry shown by most other fossil hominins, and can be explained as a result of taphonomic processes.

In their study of the LB1 cranium, Argue et al. (2009) concur with Baab and McNulty, but through cladistic approaches. Using 44 cranial characteristics recorded from a range of hominin species, including modern humans, *H. ergaster*, *H. erectus*, *H. habilis*, australopithecines, chimpanzees, and gorillas, they conclude that the *Homo floresiensis* lineage derived from an early member of genus *Homo*, but is unlikely to have resulted from insular dwarfing of *H. erectus* on Flores.’ Instead, they argue that the lineage either diverged between the emergence of *H. rudolfensis* and *H. habilis*; or just after *H. habilis*.

As argued in the concluding paper of this volume (Morwood and Jungers, 2009), evidence presented here on Liang Bua and its context provides the basis for more informed assessment of competing claims - that *H. floresiensis* is an endemic human species that evolved on Flores by dwarfing of an isolated *H. erectus* population, or is derived from a small-bodied pre-*erectus* hominin lineage in Asia. Hopefully, this synthesis, by presenting detailed information on geology, chronology, archaeology, and osteology will encourage further research in the region to “test” some of the really exciting implications that emerge from our findings.

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