1. Introduction: geology, palaeontology and archaeology of the Soa Basin, central Flores, Indonesia

F. Aziz[1] & M. J. Morwood[2,3]

[1]*Geological Survey Institute, Bandung 40122, Indonesia*

[2]*School of Earth and Environmental Sciences, University of Wollongong, Wollongong, NSW, Australia 2522*

[3]*School of Humanities, University of New England, Armidale, NSW, Australia 2350*

Corresponding authors: Fachroel Aziz (*azizf@bdg.centrin.net.id*) & Mike Morwood (*mikem@uow.edu.au*)

1.1. Geographic setting

Flores is located almost exactly halfway between the Southeast Asian (Sunda) and Australian (Sahul) continental areas (Fig. 1.1). It is right on the geographical, cultural and linguistic boundary between Asia and Melanesia. This is seen in the varied physical appearance of the people. Some such as the Ngadha of central Flores are typically dark-skinned and Melanesian in appearance, whereas others, such as seafaring communities around the coast, are more typically Asian. The histories of the various ethnic groups also tell of extensive population movements and confirm that they are of mixed origin (Erb, 1999).

Even at low sea levels, at least two sea crossings were needed to reach the island of Flores. Coming from Asia, the first of these deepwater sea barriers is a 25-kilometre strait between the islands of Bali and Lombok; the second is a nine-kilometre strait between Sumbawa and Flores. We know that there have never been land bridges connecting Flores to either the Asian or Australian continental areas because, prior to recent human intervention, these islands had very depauperate land faunas. In fact, the sudden drop of the number of animal species on Indonesian islands east of Bali corresponds to a major biogeographical boundary known as the Wallace Line (Fig. 1.1), which runs between Bali and Lombok, then north through the Macassar Strait between Borneo and Sulawesi (van Oosterzee, 1997).

First described by Alfred Russel Wallace, a nineteenth century English naturalist, the Wallace Line basically marks the eastern edge of the Asian continental shelf. At times of low sea level this shelf was exposed as dry land, and islands such as Sumatra, Java, Bali and Borneo were part of the Asian mainland - and so were originally populated by a full range of Indo-Malay land animals, including pigs, cattle, elephants, tigers, rhinos monkeys and apes. In the case of Java, evidence for hominins, specifically *Homo erectus,* goes back at least 1.4 million years (e.g. Ithara *et al.*, 1994; Morwood *et al.*, 2003).

By contrast, islands further to the east, such as Sulawesi, Lombok, Flores, Timor and the Moluccas, were separated by deep-sea barriers from both the Asian and Australian continents, and only a few animals capable of swimming, rafting or flying were able to establish themselves there. These

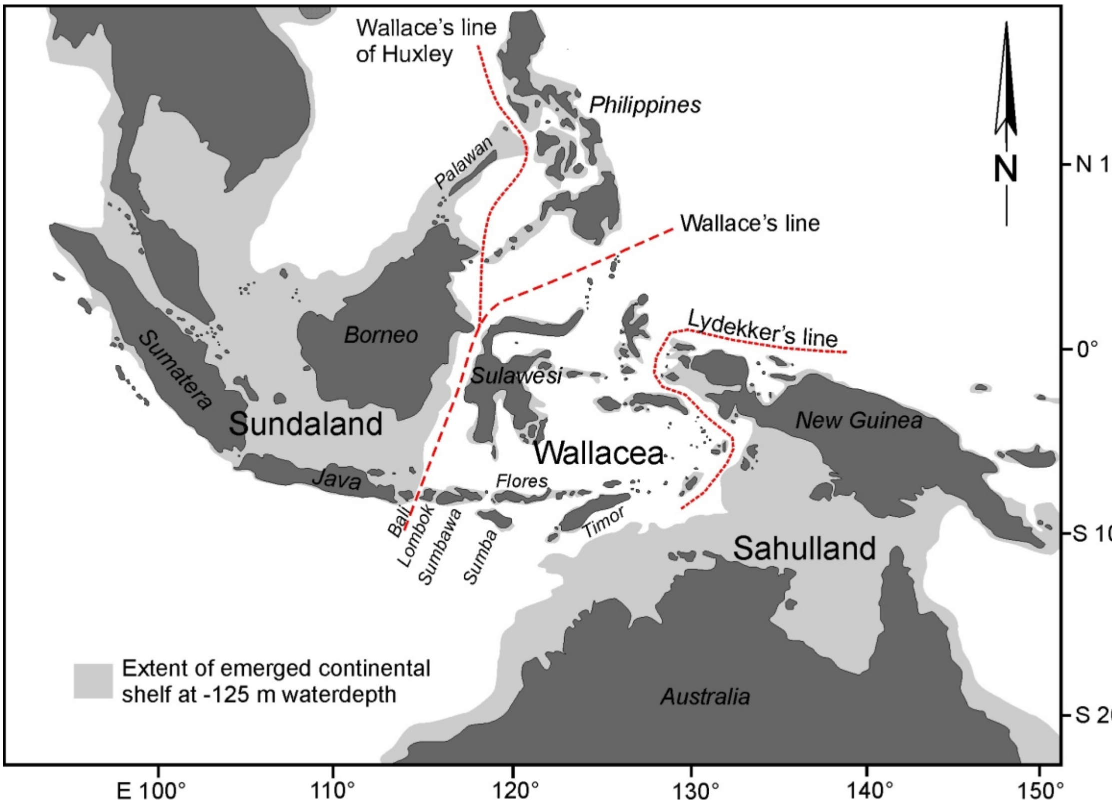

Figure 1.1: General location of Flores in Southeast Asia. Wallace's Line, the major biogeographical boundary in Southeast Asia mainly corresponds with the eastern margin of the Sunda continental landmass. Instead of running south of the Philippines as originally proposed by Wallace, however, the line that runs north between Palawan and the remaining part of the Philippines more accurately follows the eastern boundary of the Sundaic biogeograpic region, as first proposed by Huxley. To the east, Lydekker's Line similarly delineates the Sahul continental margin. The zoogeographic region between these two boundaries, consisting of many oceanic islands, is often called Wallacea.

mainly comprised elephantoids (such as *Stegodon and Elephas*), giant tortoise, rodents and humans. Elephantoids are large, buoyant, strong-swimming herd animals, and are therefore particularly good island colonisers (Johnson 1980; Sondaar, 1977). Giant tortoises are similarly buoyant and can last for extended periods without food or water, while rodents are prolific and can cross water barriers on natural rafts of flotsam.

It was generally thought that pre-modern humans populations lacked the required intellectual, linguistic and technological capacity to make sea crossings, and that the islands of eastern Indonesia were occupied relatively within the last 50,000 years by modern humans, some of whom went on to colonise Greater Australia (Bowdler, 1993; Davidson and Noble, 1992). In fact, Flores also lies on a likely route taken by the first people to reach Australia (Birdsell, 1977; Fig. 1.2).

1.2. History of Soa Basin research

Evidence for early hominin presence comes from the Soa Basin on the upper Ae Sissa River, Central Flores (Fig. 1.3). The basin is about 20 km by 10 km in area and comprises a grassland savannah with numerous small rounded hillocks and occasional deep gorges cut by the Ai Sissa River and its tributaries (Fig. 1.4). It is almost entirely surrounded by mountains and still active volcanoes, and is drained to the northeast by one deeply incised river outlet.

Seminal research in the Soa Basin was undertaken by Father Theodor Verhoeven (Fig. 1.5), a Catholic priest based in Flores and with a passion for archaeology, who had studied Pompeii for his Master's degree in classical history at the University of Leiden. In 1956, the Rajah of Nagakeo in Boawae drew Verhoeven's attention to the large bones exposed by erosion near the abandoned village of Ola Bula. These turned out to be the fossilized bones of *Stegodon*, and the discovery initiated Verhoeven's extensive research on the palaeontology and archaeology of Flores (Hooijer 1957; Verhoeven 1958). He undertook large-scale excavations at Ola Bua and obtained a large assemblage of *Stegodon* remains, but began looking for alternate sites in the Soa Basin after a dispute with the Rajah about the fee for continued work there.

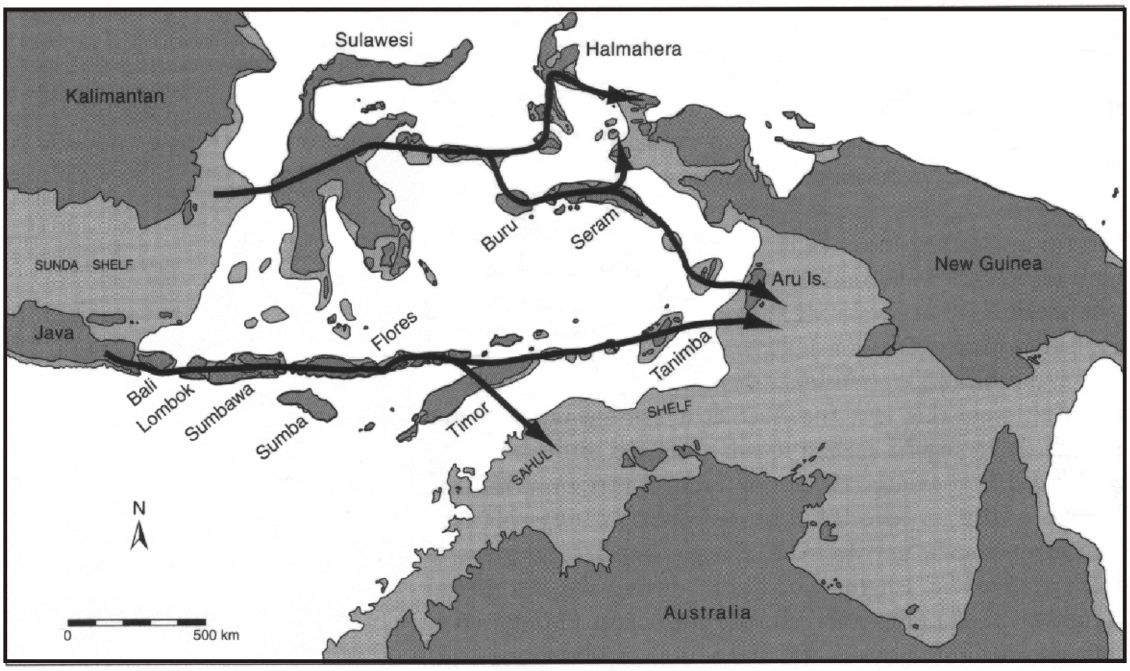

Figure 1.2: Five optimal migration routes across island Southeast Asia for initial human colonisation of Greater Australia (after Birdsell 1977).

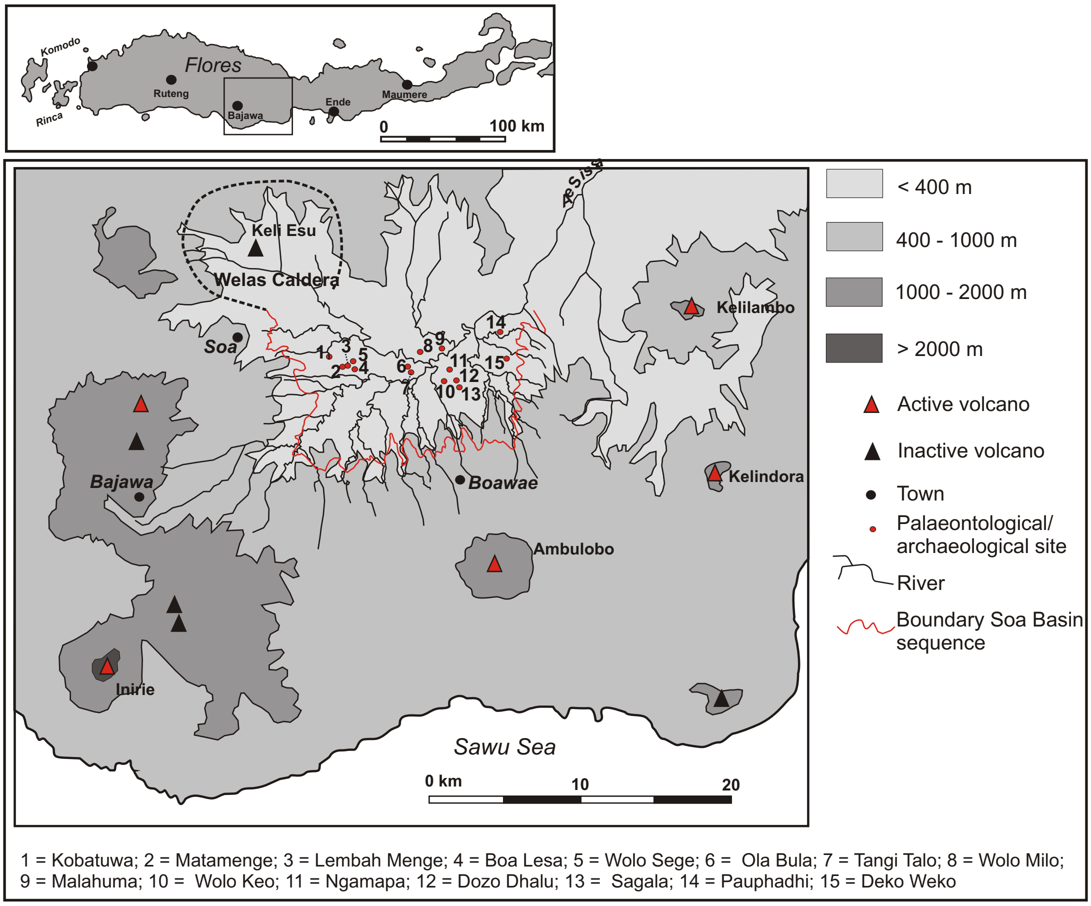

Figure 1.3: Location of palaeontological and archaeological sites in the Soa Basin.

In 1960, the Geological Survey of Indonesia carried out surveys in the basin to clarify the stratigraphic sequence of the fossils beds and collect more materials. The basal material of the Soa Basin was found to be a hard volcanic breccia, which Hartono (1961) termed the Ola Kile Formation. Overlying this, the Ola Bula Formation comprises a series of tuffaceous sandstones and siltstones about 100 m thick. The thickness of some siltstone layers indicates that they were laid down in an extensive body of water. In turn the Ola Bula Formation is capped by Gero Limestone, which was also laid down in freshwater.

The sediments within the Soa Basin indicate that for much of its history it contained a large lake, or series of lakes. Periodically though, a new river outlet would be cut and the area was drained to become grassland savannah. At such times processes of erosion would have predominated, but localised tuffaceous sediments accumulated in rivers, creek and waterholes.

Figure 1.4: General view of the Soa Basin grassland savannah with two local Ngadha hunters (Photo: Doug Hobbs).

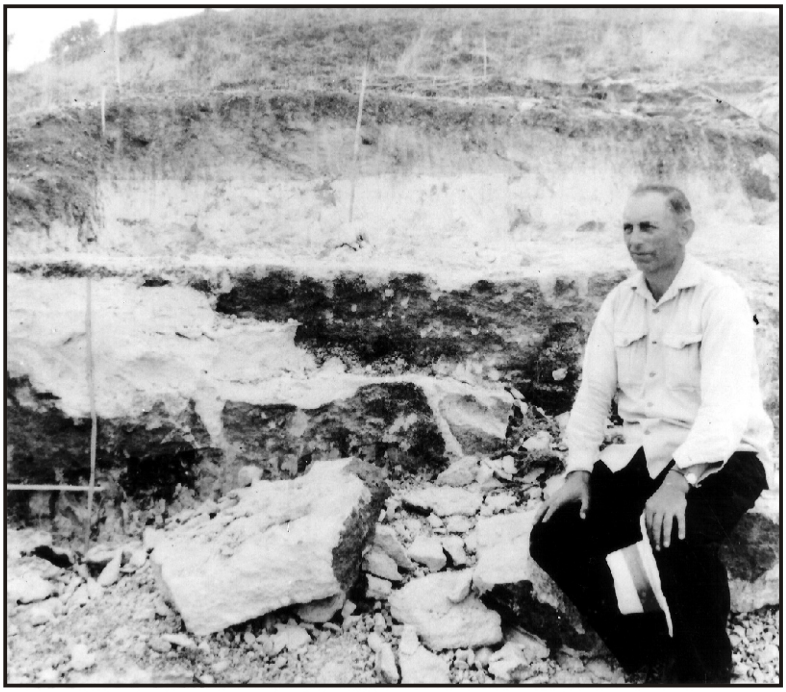

Figure 1.5: Father Theodor Verhoeven excavating at Mata Menge in 1963 (Photo: Theodor Verhoeven).

In 1963, Verhoeven excavated at two newly discovered fossil locales 3.5 kilometres west of Ola Bua - Mata Menge and the nearby site of Boa Lesa. At both these sites, *Stegodon* remains occurred in sandstone layers, sandwiched between layers of tuffaceous silts. For the first time, he also found stone artefacts in the same layers as *Stegodon* fossils. These included flake tools, chopping tools and hand axes (Fig. 1.6). Verhoeven (1968) concluded that early humans and *Stegodon* co-existed on Flores. Because *Stegodon* and *Homo erectus* were known to have lived in Java about 750,000 years ago, he also concluded that the stone tools at Mata Menge were of similar age, and that this species of early human had somehow reached Flores.

Following further excavations in the Soa Basin, Verhoeven and a colleague, Father Johannes Maringer, presented the evidence and implications in a number of papers in the journal *Anthropos* (Maringer and Verhoeven, 1970a, b). Their evidence was ignored by the archaeological establishment because of doubts about his identification of stone artefacts, 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 (Allen, 1991; Bellwood, 1997). The findings were also published in German, which made it even easier for detractors simply to ignore them.

It did not help that Verhoeven had fallen out with H. R. van Heekeren and Dirk Hooijer, two of the major figures in Indonesian archaeology and palaeontology at the time. In 1967, van Heekeren, author of an influential book, *The Stone Age of Indonesia*, had arranged with Verhoeven to visit archaeological sites in Flores, but had come earlier than agreed and at a time when Verhoeven happened to be away. So van Heekeren visited a number of Flores sites by himself before Verhoeven returned. This initiated a major falling out between the two men.

A similar falling out occurred when Hooijer reneged on an agreement to return some Flores *Stegodon* fossils that Verhoeven had sent to him in the Netherlands. Furthermore, both van Heekeren and Hooijer regarded Verhoeven as an amateur, and resented his cooperation with Ralph von Koenigswald, an ambitious palaeontologist with the Geological Survey of the Dutch East Indies, whom they disliked. Such personal animosities and loyalties may have been a major reason for Verhoeven's evidence and claims being long ignored. In fact, it would take another 30 years before further research was undertaken at Mata Menge, when Aziz and Paul Sondaar decided to investigate Verhoeven's claims.

Sondaar had studied palaeontology under Ralph von Koenigswald, was a lecturer at Utrecht University in the Netherlands and had a long-standing research interest in the evolution of animals on islands. In 1980, he organized an expedition to the Soa Basin, revisited Mata Menge and discovered a stratigraphically older site, Tangi Talo (originally named Bhisu Sau), which contained the fossilised remains of pygmy *Stegodon* and giant tortoise (Sondaar, 1987, 2000).

Such dwarfing of large mammals and the increase in size of reptiles and rodents is a noted evolutionary trend on isolated islands generally and had been previously recorded in the Mediterranean, the Americas and elsewhere (e.g. Azzaroli, 1981; Davis, 1985). In fact, the “island-rule”, an idea first proposed by Bristol Foster of the University of British Colombia, states that on islands mammals bigger than a rabbit, including mammoths, elephants, stegodonts, hippos and hoofed animals, tend to shrink to diminutive pygmies, while smaller mammals, as well as reptiles and birds, may get bigger (Lomolino, 2005; Fig. 1.7). A general explanation for this pattern of

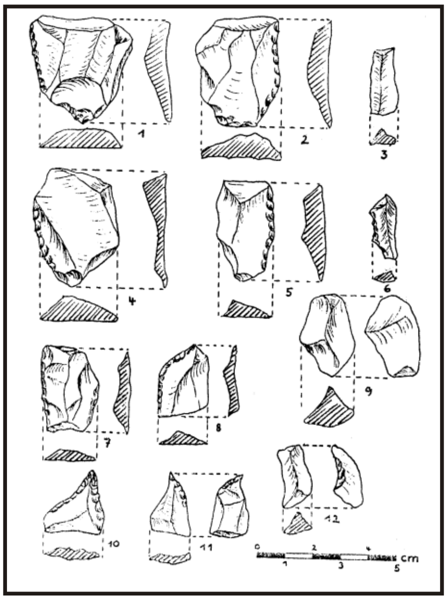

Figure 1.6a, 1.6b: Verhoeven's excavation at Boa Lesa in 1963 yielded Stegodon fossils associated with stone artefacts (Photo: Theodor Verhoeven. Drawing from Maringer and Verhoeven 1970b).

evolution is that when large animals colonise relatively small islands with limited resources, reduced inter-species competition and no predators, smaller individuals will be advantaged by their reduced food requirements and shorter pregnancies. The shrinking of elephants, hippos and deer on Mediterranean islands, such as Malta, Cyprus and Crete, during the Pleistocene are examples of this adaptive downsizing (Schule, 1993).

Such are the evolutionary forces at work, that insular dwarfing can happen very quickly, as illustrated by the rapid dwarfing of red deer on Jersey in the Channel Islands, 25 km from the coast of France. These deer became reduced to one-sixth of their body weight in less than 6000 years, during the last interglacial period around 120,000 years ago (Lister, 1989).

Often because of the absence of large mammalian predators and the paucity of resources, reduction in body size is accompanied by a reduction in the size of the brain, an energy-expensive organ to maintain, while bone fusion and shortening in the limbs result in heavier built legs with stouter bones: speed is sacrificed for increased stability. In addition, animals on islands commonly develop more efficient ways of chewing and digesting food. The bovid *Myotragus,* on the island of Majorca near Spain, provides a well-known example of such insular evolutionary changes. During some five million years of isolation, the body of *Myotragus* shrank by 60% and the brain by 50%. In addition, its canine teeth were lost, its molars developed higher crowns and cusps, and its incisors became ever growing like those of rodents (Kohler *et al.*, 2006).

On the other hand, small animals that colonise relatively large islands can adaptively radiate to fill empty niches, and some may become bigger in the process. This trend is evident in the evolutionary

Figure 1.7: Endemic fauna on Malta included pygmy elephant, pygmy hippo, giant tortoise and a large goose. These animals well illustrate the unbalanced nature of island faunas, the size changes that often occur and the vulnerability of animals which have evolved in island isolation – once modern humans arrived on the island about 11,000 years ago, endemic species quickly became extinct (From Andrew Leith Adams, Notes of a Naturalist in the Nile Valley and Malta, 1870, Edinburgh).

histories of lemurs on Madagascar (Fig. 1.8), rodents in the Bahamas, marsupials in Australia and flightless birds in New Zealand. In the case of lemurs, DNA evidence shows a single colonising species made the crossing from Africa, but subsequently radiated into a wide range of habitats and morphologies – including a now extinct giant form about the size of a gorilla, and others that looked like sloths, koalas and monkeys (Feagle, 1998; Mittermeier *et al*., 1995).

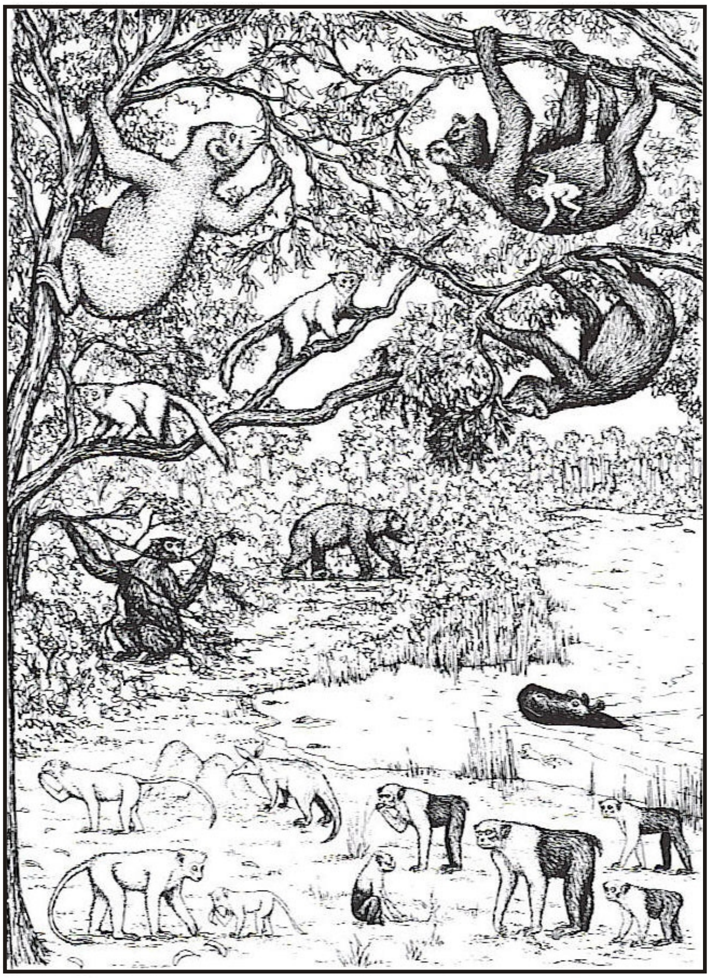

Figure 1.8: Endemic fauna on Madagascar. Mammals that managed to reach the island from Africa and evolve in situ included hippos, civets, mongooses, cat-like carnivores, rodents and lemurs - with most being early offshoots from their evolutionary lineages. Lemurs, in particular, have undergone spectacular adaptation and radiation from one colonising species. This early primate was once widespread across Africa, but is now only found in Madagascar. Since humans arrived on the island about 2300 years ago, at least two species of giant tortoise, three species of pygmy hippo, two species of elephant bird and 17 species of lemur have become extinct (after Mittermeier et al., 1995).

Both evolutionary trends – downsizing of relatively large animals and adaptive radiation of relatively small animals are epitomised on Flores. In isolation, the *Stegodon* represented at Tangi Talo dwarfed to become the smallest known species of the genus, and developed additional and higher ridges on molar teeth for more efficient chewing of coarse foods (van den Bergh, 1999). The small number of animal species on the island also allowed niche-filling opportunities: rodents adaptively radiated and some increased in size (e.g. *Hooijeromis nusatenggara*), while Komodo dragons were able to occupy the position of top predator/scavenger, and survive long-term on an island that would not support large mammalian carnivores – possibly by preying on pygmy *Stegodon* (Diamond, 1987).

The development of pygmy elephantoids and giant murid rodents on Flores thus seemed to represent a classic insular evolutionary process. The problem was that at Tangi Talo the remains of large-bodied *Stegodon* were exposed in the same section as strata containing pygmy *Stegodon* fossils, but they were higher and therefore younger. This seemed contrary to predicted evolutionary trends on islands.

Figure 1.9a, 1.9b: Excavations at Mata Menge by the Indonesian-Dutch team in 1994 found in situ stone artefacts and Stegodon fossils together. Here a Stegodon tusk and stone flake lie in close proximity (Photo: Gert van den Bergh).

In 1984, Sondaar invited Aziz to his excavations at Corbeddu Cave on the Mediterranean island of Sardinia, where he had discovered the remains of extinct mammals, including large-bodied deer, and part of a strange-looking human upper jaw, about 18,000 years old. Sondaar concluded that the deer on Sardinia had not reduced in size over time, as those on the nearby island of Crete had done, because there had been a predator present – humans.

A long-retired Verhoeven also visited the Corbeddu Cave excavations in 1985. Further intrigued by his claims that *Homo erectus* had reached Flores, Sondaar obtained funding for a research project to study the stratigraphy of the fossil-bearing formations on Sulawesi and Flores. He now wanted to know if the arrival of hominins had been responsible for the extinction of pygmy *Stegodon* and giant tortoise on Flores, and whether the large-bodied *Stegodon* that subsequently recolonised the island had not then reduced in size over time because of the presence of human hunters.

Sondaar realised that here was a real opportunity to examine the impact of early humans on a pristine island.

During field trips to Flores in 1992 and 1994, Sondaar, Aziz, John de Vos and Gert van den Bergh undertook two excavations – the first at Mata Menge, where they recovered the remains of large-bodied *Stegodon* fossils in the same strata as possible stone artefacts (Fig. 1.9); the second at Tangi Talo, which contained abundant evidence for pygmy *Stegodon*, giant tortoise and Komodo dragon, but apparently no stone artefacts**.** Sondaar *et al.* (1994) also took a series of rock samples for palaeomagnetic dating of both sites, and initiated research at another site Dozu Dhalu, where they found a single stone artefact (Fig. 1.10) in the same strata as the remains of large *Stegodon* and Komodo dragon (Sondaar *et al.*, 1994*;* van den Bergh *et al.*, 1996: 32-4; van den Bergh 1999: 249).

This Indonesian–Dutch team concluded on the basis of the paleomagnetic results that Tangi Talo, with pygmy *Stegodon*, giant tortoise and no stone artefacts, was about 900,000 years old, while the site of Mata Menge, with large-bodied *Stegodon* and stone artefacts, was 'slightly less than' 730,000 years old'. The stone tool evidence clearly pointed to the arrival of humans as the cause of this faunal turnover. This would be the first record of an early species of human causing extinctions; a trait thought to have been the exclusive province of modern humans. Unfortunately,

Figure 1.10: In 1994, a single stone artefact was excavated at Dozu Dhalu in a sandstone layer stratigraphically several metres below an accumulation of large Stegodon remains (Photo: Gert van den Bergh)

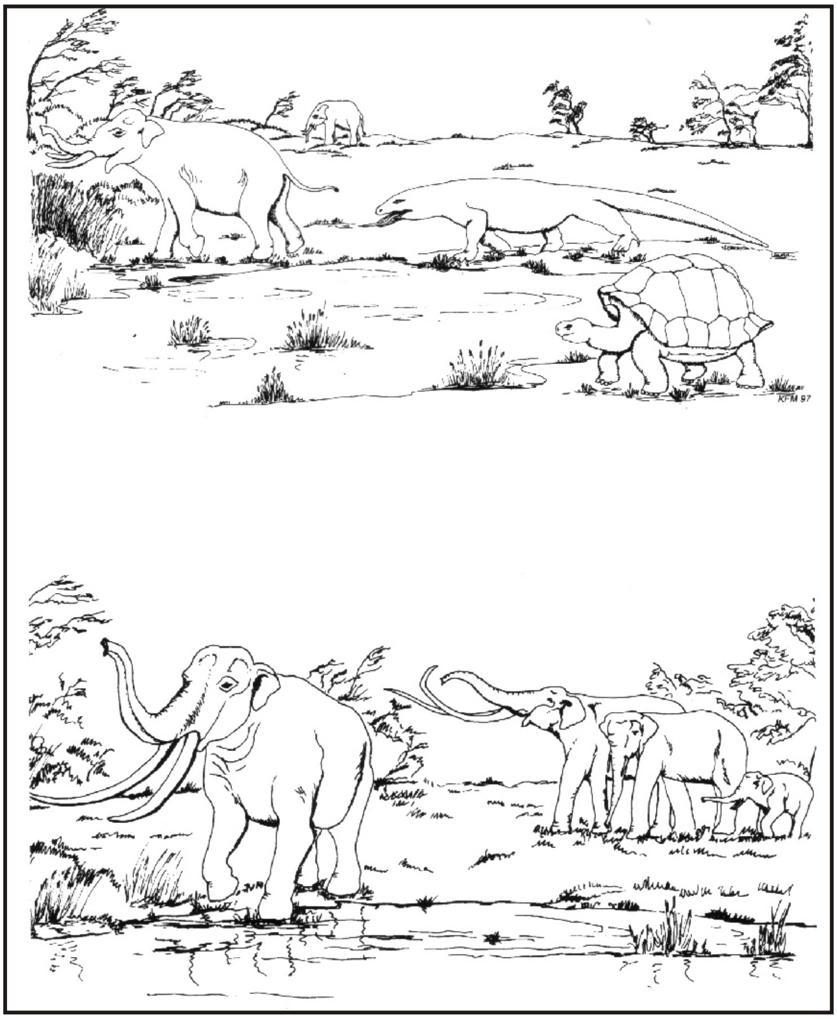

Figure 1.11: Fauna in the Soa Basin 900,000 years ago included pygmy Stegodon and giant tortoise (Top). By 880,000 years ago, these had been replaced by large-bodied Stegodon in association with the first proxy evidence for hominins – stone artefacts (Drawing: Kathy Morwood).

these conclusions were published in fairly obscure venues and, because their team did not include researchers with stone artefact expertise, most in the archaeological community remained dubious about the identification of Middle Pleistocene 'stone artifacts' at Mata Menge.

At Aziz's prompting, however, Mike Morwood analysed the assemblage of stone fragments excavated from Mata Menge and showed that most were definitely artifacts. This study, published with Sondaar, Aziz, de Vos and van den Bergh, put on record the definite existence of stone artefacts at the site (Morwood *et al.*, 1997). It also led directly to the next phase of research in the Soa Basin.

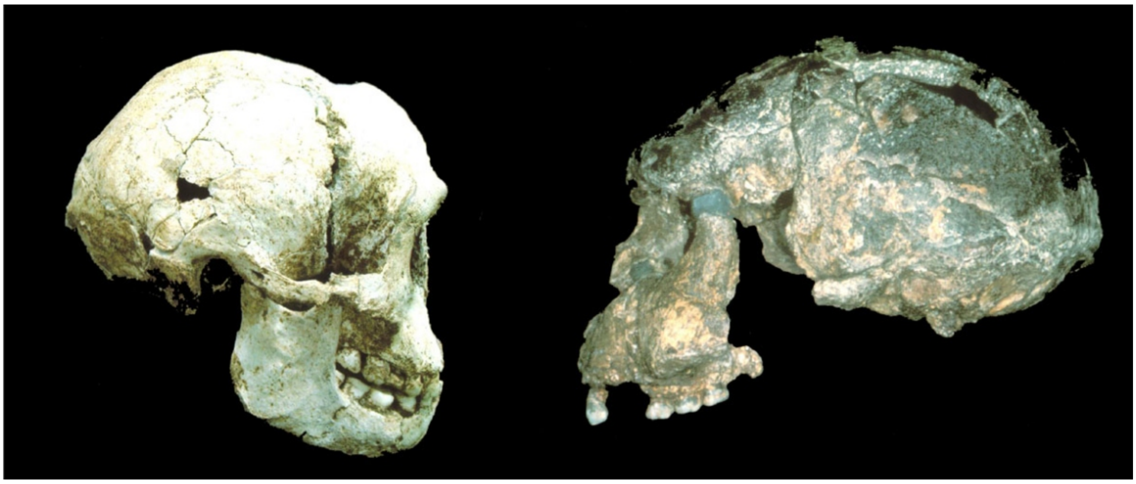

Figure 1.12: Skull of Homo floresiensis from Liang Bua, Flores, compared with Homo erectus from Sangiran, Java. Some very primitive morphological traits of the Flores population indicate that their lineage predates that of H. erectus (Photo: Peter Brown).

1.3. Our research

In 1996, we made a brief trip to Flores to visit Mata Menge and Tangi Talo. Our aim was to record the stratigraphies at both sites in detail and to collect well provenanced samples that could yield radiometric ages for the deposits. Fission track dating of these samples subsequently showed that the pink tuffaceous silt underlying the main accumulation of fossils and artefacts at Mata Menge was 880,000 years old while an overlying white tuff was about 800,000 years in age (Morwood *et al.*, 1999). We also obtained a fission track age of 900,000 years for the white tuffaceous silt containing the fossils at Tangi Talo. This tallied exactly with the palaeo-magnetic age determinations previously obtained by Sondaar *et al.* (1994).

Getting credible radiometric dates from these two sites provided the makings of a paper for '*Nature*' in which we argued that humans, presumably *Homo erectus*, had reached Flores between 880,000 and 800,000 years ago, a time that seemed to coincide with the extinction of pygmy *Stegodon* and giant tortoise, and their replacement by large *Stegodon* **(**Morwood *et al.*, 1998; Fig. 1.11). In turn, this paper provided the basis for a successful grant application to the Australian Research Council (ARC) for a project entitled '*Archaeology and palaeontology of the Ola Bula Formation, central Flores, Indonesia*' to begin larger scale investigations in the Soa Basin.

The project, which ran from 1998 to 2001, included extensive surveys and use of aerial photographs to map the geology of the entire basin; the recording of 16 *Stegodon* fossil sites and associated column sections; fission track dating of 17 sediment samples representing all major strata and fossil sites; large-scale excavations at Dozu Dhalu, Boa Lesa, Tangi Talo and Kopowatu; the taking of sediment samples from fossil sites for palynological analysis; and an ethnoarchaeological study of the Ngadha. Much of this work has already been published (e.g. Morwood *et al.*, 1999; Morwood 2001, 2002; O'Sullivan *et al.*, 2001; Polhaupessy, 2001; Suminto *et al.*, 2002; Sudarmadi, 2000; van den Bergh *et al.*, 2001); but not the geological map of the Soa Basin, the excavations at Tangi Talo, detailed accounts of the Mata Menge excavation, or the most recent investigations at Boa Lesa.

Our next project funded by the Australian Research Council, '*Astride the Wallace Line'*, ran from 2003 to 2006 and aimed to tackle the following questions in two main study areas, Java and Flores.

- When did hominins first arrive?
- When and why did early hominins, such as *Homo erectus*, become extinct?
- When and how did fully modern humans first appear?
- When and why did people start cultivating plants and domesticating animals?
- When and why did technological changes, such as the introduction of ground tools, pottery and metal occur, and what were their impacts?
- What major environmental changes occurred during the time span of hominin occupation, and what were their impacts?

This project included excavations at Sembungan in Central Java and Song Gupuh in East Java; the dating of fossils sites at Punung and Bumiayu in Java; excavations at Liang Panas and Liang Bua in West Flores; and excavations at Mata Menge, Kobatuwa and Wolo Sege in the Soa Basin of central Flores. The associated discovery of an endemic human species, *Homo floresiensis* (Fig. 1.12), at Liang Bua has already been published and extensively publicised (e.g. Brown *et al.*, 2004; Falk *et al.*, 2005, 2007; Moore and Brumm 2007; Morwood *et al.*, 2004, 2005; Morwood and Oosterzee 2007; van den Bergh *et al.*, 2008; Westaway *et al.*, 2007). The find has also given a whole new significance to the Soa Basin evidence for Early Pleistocene hominins, who are likely to have been ancestral to the Liang Bua 'hobbits' (Brumm *et al.*, 2006). In fact, the main aim of our excavations at Mata Menge in 2004, 2005 and 2006 was to find skeletal evidence for the hominin species present on Flores over 800,000 years ago. We were not successful in finding hominin skeletal evidence at the site, but did find flaked stone artefacts associated with the remains of large-bodied *Stegodon* in a layer of pink tufaceous silt that yielded a fission track age of 880,000 years. This now provides the earliest evidence for hominins on the island.

The papers and geological map contained in this volume are hard-won results from excavations and surveys undertaken between 1998 and 2006. In combination with previous publications on the Soa Basin, they confirm the scientific significance and potential of this unique area. Hopefully, information presented here will also promote further geological, palaeontological and archaeological research in the Soa Basin, and help ensure that parts are preserved in the face of rapid population growth on Flores and increasing pressure to develop its agricultural potential.

References

Allen, H. (1991). Stegodonts and the dating of stone tool assemblages in island S.E. Asia. *Asian Perspectives* 30, 243-66.

Azzaroli, A. (1981). About pygmy mammoths of the Northern Channel Islands and other island faunas. *Quaternary Research* 16, 423-25.

Bellwood, P. (1997). *Prehistory of the Indo-Malaysian Archipelago*. Honolulu: University of

Hawaii Press.

Birdsell, J.H. (1977). The recalibration of a paradigm for the first peopling of Greater Australia. In *Sunda and Sahul,* (eds Allen, J., *et al*.), pp. 113-68. Academic Press, London.

Bowdler, S. (1993). Sunda and Sahul: a 30-kyr BP culture area. In *Sahul in review*, (eds M.A. Smith, *et al*.), pp. 60-70. Dept. of Prehistory, Research School of Pacific Studies, Australian National University.

Brown, P., T. Sutikna, M. J. Morwood, R. P. Soejono, Jatmiko, E. Wahyu Saptomo & Rokus Awe Due. (2004). A new small-bodied hominin from the Late Pleistocene of Flores, Indonesia. *Nature* 431, 1055-1061.

Brumm. A., F. Aziz, G. D. van den Bergh, M. W. Moore, M. J. Morwood, D. R. Hobbs, I. Kurniawan & R. Fullagar (2006). Lower Pleistocene stone artefacts from Mata Menge, Flores: implications for the behaviour of *Homo floresiensis. Nature* 441, 624-628.

Davidson, I. & W. Noble. (1992). Why the first colonisation of the Australian region is the earliest evidence of modern human behaviour. *Archaeology in Oceania* 27(3), 135-42.

Davis, S. (1985). Tiny elephants and giant mice. *New Scientist* 105, 25-27.

Diamond, J.M. (1987). Did Komodo dragons evolve to eat pygmy elephants? *Nature* 326, 832.

Erb, M. (1999). *The Manggaraians: a guide to traditional lifestyles*. Times Editions, Singapore.

Falk, D., Hildebolt, C., Smith, K., Morwood, M.J., Sutikna, T., Brown, P., Jatmiko, Wayhu Saptomo, E., Brunsden, B. & Prior, F. (2005). The brain of *Homo floresiensis*. *Science* **308**, 242–245.

Falk D, Hildebolt C, Smith K, Morwood M.J., Sutikna T, Jatmiko, Saptomo EW, Imhof H, Seidler H. & Prior, F. (2007). Brain shape in human microcephalics and *Homo floresiensis*. *Proceedings of the National Academy of Sciences of the United States of America* 104: 2513-2518.

Fleagle, John G. (1998). *Primate Adaptation and Evolution*. 2nd edition, Academic Press.

Hartono, H.M.S. (1961). Geological investigation at Olabula, Flores: Bandung, Indonesia, Djawatau Geologi, 40 p.

Hooijer, D.A. (1957). Three giant prehistoric rats from Flores, Lesser Sunda Islands. *Zool. Meded. Mus. Leiden* 35 (21), 128-33.

Ithara, M., Watanabe, N., Kadar, D. & Kumai, H. (1994). Quaternary stratigraphy of the hominid fossil bearing formations in the Sangiran area, central Java, in Frunzen, J.L., ed., *100 years of Pithecanthropus: The Homo erectus problem*. Frankfurt, Forschungsinstitut Senckenberg, pp. 123–128.

Johnson, D.L. (1980). Problems in the land vertebrate zoogeography of certain islands and the swimming powers of elephants: *Journal of Biogeography* 7, 383–398

Kohler, M. and Salvador Moya-Sola (2006). 'Reduction of brain and sense organs in the fossil insular bovid *Myotragus*'. *Brain, Behaviour and Evolution* 63(3): 125–40.

Lister, A. M. (1989). 'Rapid dwarfing of red deer on Jersey in the Last Interglacial. *Nature* 342, 539–42.

Lomolino, M.V. (2005).'Body size evolution in insular vertebrates: generality of the island rule'. *Journal of Biogeography* 32, 1683–99.

Maringer, J. & Th. Verhoeven. (1970a). Die steinartefakte aus der Stegodon-fossilschicht von Mengeruda auf Flores, Indonesien. *Anthropos* 65, 229-247.

Maringer, J. & Th. Verhoeven. (1970b). Note on some stone artifacts in the National Archaeological Institute of Indonesia at Djakarta, collected from the Stegodon-fossil bed at Boaleza in Flores. *Anthropos* 65, 638-39.

Mittermeier, Russell A., Ian Tattersal, William R. Konstant & Stephen D. Nash. (1995). *Lemurs of Madagascar*. Conservation International Guide Series.

Moore, M.W. & Brumm, A. (2007). Stone artefacts and hominins in island Southeast Asia: new insights from Flores, Eastern Indonesia. *Journal of Human Evolution* 52, 85-102.

Morwood, M.J., Aziz, F., van den Bergh, G.D., Sondaar, P.Y. & J. de Vos. (1997). Stone artefacts from the 1994 excavation at Mata Menge, West Central Flores, Indonesia. *Australian Archaeology* 44, 26-34.

Morwood, M.J., O'Sullivan, P., Aziz, F. & Raza, A. (1998). Fission track age of stone tools and fossils on the east Indonesian island of Flores. *Nature* 392, 173–176.

Morwood, M.J., F. Aziz, Nasruddin, D.R. Hobbs, P. B. O'Sullivan & A. Raza (1999). Archaeological and palaeontological research in central Flores, east Indonesia: results of fieldwork, 1997-98. *Antiquity* (June) 73(280), 273-286.

Morwood, M.J. (2001). Early hominid occupation of Flores, East Indonesia, and its wider significance. In I. Metcalf, J. Smith, I. Davidson & M.J. Morwood (eds), *Faunal and floral migrations and evolution in SE Asia-Australasia*. Swets and Zeitlinger, The Netherlands, pp. 377-388.

Morwood, M.J. (2002). The role of museums in ecotourism and heritage protection. In Sudijono and F. Aziz (eds), *Towards ahead: geological museums in a changing world*, pp. 21-30. Geological Research and Development Centre, Special Publication 27, Bandung.

Morwood, M.J., P. O'Sulivan, E.E. Susanto and F. Aziz (2003). Revised age for Mojokerto 1, an early *Homo erectus* cranium from East Java, Indonesia. *Australian Archaeology* 57: 1-4.

Morwood, M.J., R. P. Soejono, R. G. Roberts, T. Sutikna, C. S. M. Turney, K. E. Westaway, W. J. Rink, J.-x. Zhao, G. D. van den Bergh, Rokus Awe Due, D. R. Hobbs, M. W. Moore, M. I. Bird & L. K. Fifield (2004). Archaeology and age of a new hominin from Flores in eastern Indonesia. *Nature* 431, 1087-1091.

Morwood, M.J., P. Brown, Jatmiko, T. Sutikna, E. Wahyu Saptomo, K. E. Westaway, Rokus Awe Due, R. G. Roberts, T. Maeda1, S. Wasisto & T. Djubiantono (2005). Further evidence for small-bodied hominins from the Late Pleistocene of Flores, Indonesia. *Nature* 437, 1012-1017.

Morwood, M.J. and P. van Oosterzee (2007). *The discovery of the Hobbit: the scientific breakthrough that changed the face of human history*. Random House. Sydney, Australia.

O'Sullivan, P.B., M.J. Morwood, D. Hobbs, F. Aziz, Suminto, M. Situmorang, A. Raza & R. Maas. (2001). Archaeological implications of the geology and chronology of the Soa basin, Flores, Indonesia. *Geology* 29 (7), 607–610.

Polhaupessy, A.A. (2001). Vegetation and environment of the Soa basin, central Flores. *Majalah Geologi Indonesia* 16(3), 135-145.

Schule, Wilhelm. (1993). 'Mammals, vegetation and the initial human settlement of the Mediterranean Islands: a palaeoecological approach'. *Journal of Biogeography* 20, 399–412.

Sondaar, P.Y. (1977). Insularity and its effect on mammal evolution. In: M.K. Hecht, P.C. Goody & B.M. Hecht (eds.), *Major patterns in vertebrate evolution*. New York: 671-707.

Sondaar, P.Y. (1987). Pleistocene man and extinctions of island endemics. *Memoires du societé geologique de France*. Nouvelle série 150, 159-63.

Sondaar, P.Y., G.D. van den Bergh, B. Mubroto, F. Aziz, J. de Vos & U.L. Batu, (1994). Middle Pleistocene faunal turnover and colonization of Flores (Indonesia) by *Homo erectus*. *Comptes rendues Ac. Sci. France*, série II, 319, 1255-1262.

Sondaar, P.Y. (2000). Early human exploitation of islands. In *The Ryukyu Islands – the arena of adaptive radiation and extinction of island fauna*. (eds H. Otsuka, H. Ota and M. Hotta). Tropics 10(1) (Special Issue). The Japanese Society of Tropical Ecology, pp. 203-229.

Sudarmadi, T. (2000). An ethnoarchaeological study of the Ngadha, a megalithic culture in central Flores, Indonesia. M.A. thesis. University of New England, Australia.

Suminto, Aziz, F., Polhaupessy, A.A., Morwood, M.J., Hobbs, D.R. & Nasruddin (2002). Startgrafi dan kandungan fosil vertrata Formasi Ola Bula di Cekungan Soa, Flores. *Bulletin Pusat penelitian dan Pengembangan Geologi* 22, 49-62.

van den Bergh, G.D., B. Mubroto, F. Aziz, P.Y. Sondaar & J. de Vos (1996). *Did Homo erectus* reach the island of Flores? In: Bellwood, P. (ed.), *Indo-Pacific prehistory Association Bulletin* 14, 27-36

van den Bergh, G.D. (1999). The Late Neogene elephantoid-bearing faunas of Indonesia and their palaeozoogeographic implications. A study of the terrestrial faunal succession of Sulawesi, Flores and Java, including evidence for early hominid dispersal east of Wallace's Line. *Scripta Geologica* 117, 1-419.

van den Bergh, G.D., Vos, J & M.J. Morwood (2001). Elephantoidea in the Indonesian region: new *Stegodon* findings from Flores. In *The World of elephants. Proceedings of the Ist International Congress*. G. Cavarretta, P. Gioia, M. Mussi, M.R. Palombo (eds). Consiglio Nazionale delle Ricerche – Roma, pp. 623-627.

van den Bergh, G.D., Rokus D.A., Morwood, M.J., Sutikna, T., Jatmiko, Saptomo, W. (2008). The youngest *Stegodon* remains in Southeast Asia from the Late Pleistocene archaeological site Liang Bua, Flores, Indonesia. In: M.R. Palombo (ed.) Insularity and its Effects. Quaternary International, 182, 16-48.

van Oosterzee, P. (1997). Where worlds collide: the Wallace Line. Reed Books.

Verhoeven, Th. (1958). Pleistozane funde in Flores. Anthropos 53, 264-65.

Verhoeven, Th. (1968). Pleistozane Funde auf Flores, Timor und Sumba. In: Anthropica, Gedenkschrift zum 100. Geburtstag von P.W. Schimdt, pp. 393-403. Studia Instituti Anthropos 21, St Augustin bei Bonn.

Westaway, K.E.., Morwood, M.J., Roberts, R.G., Zhao, J.-x., Sutikna, T. Saptomo, E.W., & Rink J. (2007). Establishing the time of initial human occupation of Liang Bua, western Flores, Indonesia. Quaternary Geochronology 2, 337-343.