FACULTY OF HUMANITIES
UNIVERSITY OF COPENHAGEN
Saxo Institute, Department of Archaeology

Poul Erik Lindelof

^{40}Ar/^{39}Ar Dating of the Archaeological Layers in Mata Menge, Indonesia

Ambolopo Volcano (2124m), located east of Soa Basin, Flores. (Photo: P.E. Lindelof).

Master thesis
Academic advisor: Ulla Lund Hansen
Submitted: 18/2/2013

Københavns Universitet
Saxo Instituttet
Forhistorisk Arkæologi

Master thesis: ^{40}Ar/^{39}Ar Dating of the Archaeological Layers in Mata Menge, Indonesia

Author: Poul Erik Lindelof

Institutnavn: Saxo Institute

Name of department: Department of Prehistoric Archaeology

Titel: ^{40}Ar/^{39}Ar Dating of the archaeological layers in Mata Menge, Indonesia

Subject description: Older Palaeolithic archaeology in Southeast Asia. Fieldwork and collecting of material for ^{40}Ar/^{39}Ar dating at Mata Menge, Flores. Picking crystals from the material and doing mass spectroscopy at RUC.

Academic advisor: Ulla Lund Hansen

Submitted: 18. February 2013

Acknowledgement:

Lecturer Michael Storey suggested this project at my visit to Roskilde University in April 2010. The master project should be a continuation of the very successful work by Gitte M. Jensen (now lecturer at Himmelev Gymnasium). I am grateful for Michael's guidance, and I thank Gitte for giving me all her written material. It was planned that I should go to Flores and join the archaeological project headed by Professor Mike Moorwood (Wollongong University, Australia) and Professor F. Aziz (Centre for Geological Survey, Bandung, Indonesia). I thank them for letting me join the project. My main contact before and during my visit in 2011 became, however, Dr. Gert van den Bergh (Wollongong University), whom I sincerely thank for all his help and kindness. In the mean time Dr. Stephanie Flude joined Michael Storey's group and went together with me to Flores. She was a pleasant travel mate. At Roskilde University she has been instrumental for guiding my picking of crystals for the dating analysis. Reader Ulla Lund Hansen became the principle academic advisor for the project and helped, not only with the archaeological content, but also the formal things, such as an agreement with Roskilde University and Wollongong University about the limitations, I was forced to have regarding the description of artefacts found in the 2011 excavation. Fiedlers Foundation generously covered the expenses in connection with my trip to Indonesia.

$^{40}Ar/^{39}Ar$ Dating of the Archaeological Layers in Mata Menge, Indonesia

Resumé (in Danish)

På Java, Indonesien, er der fundet 1,6 millioner år gamle fossiler af Homo erectus. [Dennell 2009]. En række vulkanske øer strækker sig fra Java mod øst. Det drejer sig om Bali, Lombok, Sumbawa, Komodo, Flores og Timor. På øen Flores er der fundet palæolitiske stenredskaber, først af en hollandsk pater, Theodor Verhoeven, i 1953 [Verhoeven 1953]. Han bestemte alderen af stenredskaberne til at være mere end 700.000 år gamle. Siden er der fundet tilsvarende stenredskaber ved mange arkæologiske undersøgelser i dalstrøget Soa Basin midt på Flores. De arkæologiske udgravninger i Soa Basin tog fart efter det spektakulære fund af Homo floresiensis i Liang Bua Hulen på Flores i 2003 [Brown et al. 2004; Morwood et al. 2004, 2005]. Homo floresiensis-fundet går ganske vist kun ca. 74.000 år tilbage, men fundet af en ny menneskerace på den lille ø var mildest talt en overraskelse. Hvad var dens forfædre, og hvor kom de fra? Dette spørgsmål blev kædet sammen med Theodor Verhoevens gamle fund, og der blev sat en udvidet undersøgelse i gang for at opnå en større nøjagtighed af fundenes alder. Dette blev først effektueret af Gitte M. Jensen, studerende hos Michael Storey på Roskilde Universitet, der kunne fastsætte alderen af fund fra udgravningen Wolo Sege i Soa Basin til 1.02 millioner år gamle [Brumm et al. 2010a]. Ser man bort fra Liang Bua Hulen med de meget yngre fund, er Mata Menge i Soa Basin den mest fundrige lokalitet på Flores. Derfor er det netop her vigtigt med en præcis datering. I dette speciale beskriver jeg, hvordan jeg ved $^{40}Ar/^{39}Ar$ dateringer har foretaget den hidtil mest nøjagtige aldersbestemmelse af det vulkanske lag, der ligger over laget med artefakter og dyrefossiler i Mata Menge. Alderen er bestemt til 1.02 millioner år før nu, med en præcision på ca. 2%. Altså samme alder som Gitte M. Jensen fandt i Wolo Sege med samme dateringsmetode. Tidligere dateringer i Mata Menge har været baseret på fissionssporsmetoden, som har en usikkerhed på ca. 20%. Der er selvfølgelig systematiske usikkerheder ved begge dateringsmetoder på grund af muligheden for, at de vulkanske lag og lagene med stenredskaber er dannet ved senere aflejret materiale fra områder tættere ved eller længere borte, hvilket vil blive analyseret nærmere i dette speciale. Desuden vil jeg diskutere sandsynligheden for, at de mennesker, der lavede stenredskaberne i Mata Menge, var Homo erectus. Om de var forfædre til den 900.000 år yngre Homo floresiensis, ved man ikke, da der ikke er fundet menneskefossiler i Soa Basin. Hvilke mulige fremtidige undersøgelser, der er efter min mening vil være interessante, gennemgås til sidst i specialet.

Contents

$^{40}Ar/^{39}Ar$ Dating of the Archaeological Layers in Mata Menge, Indonesia

1. Introduction.. 7
2. The older Palaeolithic Stone Age in Africa.. 10
   2.1 Africa as the melting pot.. 10
   2.2 Out of Africa I.. 11
3. The older Palaeolithic Stone Age in Asia.. 13
   3.1 Asian hominides: Dmanisi, Beijing, and Jakarta... 13
   3.2 The climate in Southeast Asia in the Pleistocene period.. 15
   3.3 Java human fossils and stone artefacts... 17
4. Homo floresiensis... 18
   4.1 The discovery in the Liang Bua Cave.. 18
   4.2 New possible evolution trends on the basis of Homo floresiensis 19
5. Soa Basin Archaeology... 22
   5.1 The Soa Basin excavations.. 22
   5.2 Wolo Sege.. 24
   5.3 Mata Menge... 26
6. Material and Crystals from Mata Menge for Dating.. 32
   6.1 Stratigraphy and sampling of material.. 32
   6.2 Two important potassium-rich volcanic crystals... 36
   6.2 Sieving and sorting of the PL FLO11-01.. 37
   6.3 Choosing sanidine feldspar crystals by XRF.. 39
7. Neutron Irradiation-Induced Decay of Potassium Isotopes... 41
   7.1 Decay of radioactivex elements.. 41
   7.2 Radioactive decay of ^{40}K... 42
   7.3 Accumulation of the decay products in solid materials.. 42
   7.4 Neutron irradiation-induced decay of ^{39}K in a nuclear reactor.................................. 43
8. The Physical Principles of Argon Age Determination.. 46
   8.1 $^{40}Ar/^{39}Ar$ dating method 46

8.2 The step-heating method…… 46
8.3 The isochron consistency…… 47
9. The Argon Mass Spectrometer…… 49
9.1 Crystal mounting…… 49
9.2 CO_2 laser set-up and heating…… 50
9.3 The ultra high vacuum system…… 51
9.4 Mass separation and detection…… 52
9.5 Computer control…… 53
9.6 The measurement procedure…… 55
10. Results on the Sanidine Crystals from Mata Menge…… 56
10.1 Overview of the 24 sanidine crystals in PL FLO11-01 from Mata Menge…… 56
10.2 The 3 most excellent age determinations…… 58
10.3 Earlier dating results in Soa Basin and the present status…… 58
11. Artefacts…… 61
11.1 Published pictures of artefact from Mata Menge…… 61
12. Discussion and Perspectives…… 62
12.1 Geology. The fluvio-lacustrine sediments…… 62
12.2 How do we find the human Pleistocene fossils at Soa Basin or on Flores?…… 62
13. Conclusion…… 65
14. References…… 66
WWW addresses……71
Wordbook and Abbreviations……72

Appendices

A.1 Photos of the Western Baulk of Trench 18…… 75
A.2 Artefacts from Mata Menge…… 81
A.2 $^{40}Ar/^{39}Ar$ Step-Heating Spectrometer Results…… 108

1. Introduction

This master thesis is a result of three weeks participation in the Mata Menge excavation on Flores, Indonesia, in the summer 2011, and of subsequent investigation at Roskilde University of the materials collected at Mata Menge in the winter 2011/12 and mass spectrometer measurements in the summer 2012.

Southeast Asia plays an important role in the human evolution. After the first emigration of Homo ergaster/erectus out of Africa 1.8 million years ago (BP), there are signs that the human evolution in Asia and in Africa/Europe was quite different [Dennell 2009]. The Dmanisi, Zhoukoudian (China) and Java human fossils, as well as artefacts found there, indicates that the Palaeolithic development took a different direction in Asia, and it is still discussed if Homo sapiens developed somewhat independently in Asia. In Java the finds are ~1.6 million years BP [Swischer et al. 1994], and the results of Gitte M. Jensen [Brumm et al 2010a], former student at Roskilde University, and the present master thesis work show, that humans, probably Homo erectus, lived on Flores for more than 1 million years BP. This indicates crossing 19 kilometers of water twice, a surprising achievement of Homo erectus. A much later human branch, Homo floresiensis, lived on Flores for an extended period from 74 ka to 17 ka BP [Aiello 2010]. They were small in stature and seem to have roots much further back than Homo erectus, possibly to Australopithecus africanus [Jungers et al. 2009; Liebermann 2009]. A consensus of all these pieces of confusing information is difficult and makes it highly relevant to study the Palaeolithic artefacts and fossils on Flores, the theme of this master thesis.

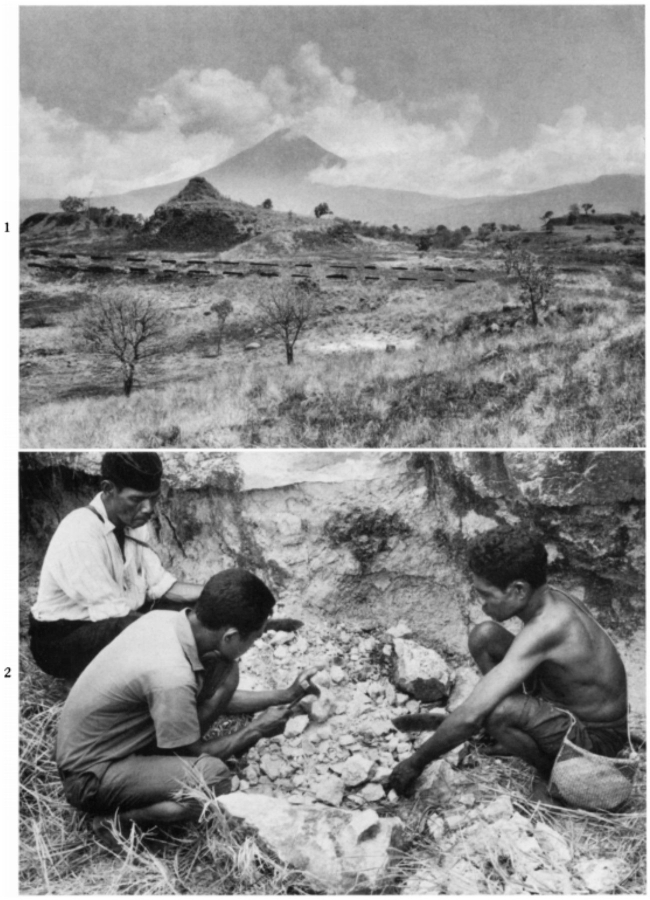
During my stay at Mata Menge, I excavated material from the baulks of trench no. 18 and no. 19. About 10 kg of materials from the trenches are taken to Roskilde University to be investigated. This master thesis deals with a complete $^{40}Ar/^{39}Ar$ dating analysis of 3 kg of volcanic ash material at one particular strategic place in trench no. 18 in the western baulk called PL FLO11-01. It is material taken above a sheet flow layer, which contains a few stone artefacts as well as a few animal (stegodon) fossils. Trench no. 18 (west baulk) has been selected because the sheet flow layer is visible. In the trenches further to the east, the sheet flow layer (see explanations in Wordbook and Abbreviation p. 69) has apparently been eroded away by water and the heavier materials, i.e. fossils and stone artefacts, have sunk to the bottom [van den Bergh et al. 2009]. The layers in trench no. 18 and no. 19 have been formed in a lake, close to the shore and only little disturbed by underwater currents [van den Bergh 2009].

The PL FLO11-01 material has been sieved in 0.25 to 0.5 mm and in 0.5 to 1 mm sieves to obtain grains suitable for magnetic separation in a so-called Frantz Magnetic Separator (see figure 6.9). Of particular importance for dating are hornblende and sanidine feldspar crystals, which are nonmagnetic and contain sufficient concentration of potassium (~1%) to warrant the $^{40}Ar/^{39}Ar$ analysis. We found a sufficient number of sanidine crystals for this analysis by using a Bruker type XRF analyser. 24 sanidine crystals were chosen and sent to neutron irradiation in Oregon, USA, in order to convert ^{40}K to ^{39}Ar.

Based on a series of 20 reference crystals from Alder Creek, USA, we were able to determine the age of seventeen Mata Menge sanidine crystals found above the artefact/fossil sheet flow layer. Various weighted averages are all consistent with an age of 1.02±0.02 Ma (2 σ error, corresponding to 95% confidence). This is within errors the same as the age of the Wolo Sege artefacts, which were determined by Gitte M. Jensen [Brumm et al. 2010]. Together with my age determination these are in fact the only precision age determinations at Soa Basin.

J. MARINGER und TH. VERHOEVEN, Die Steinartefakte aus der Stegodon-Fossilschicht von Mengeruda auf Flores, Indonesien

Tafel I



1. Matamenge im Fossilgebiet von Mengeruda. Im Hintergrund der Vulkan Ambolobo. In der Mitte hügelartige Erosionsreste; davor die bankartige Fossilschicht = = = =
2. Vor der bankartigen Stegodon-Fossilschicht.

Anthropos 65. 1970

Figure 1.1. View of the landscape around Mata Menge and Wolo Sege 1970 and below some of Theodor Verhoeven's assistents excavating at Mata Menge. [Maringer and Verhoeven 1970 a].

The dating results cannot stand alone. The results raise many questions and comments to the earlier discussions about the Soa Basin Palaeolithic finds. Firstly there is the problem of the origin of the sanidine crystals. The crystals are situated in the volcanic layer above the layer containing the artefacts. The possibility exists that the sanidine crystals are brought into the layer by water flow from some distant place [Brumm et al. 2010b]. This could give rise to a significantly older dating than the corresponding crystal's stratigraphic layer position and thus a younger age of the artefacts than stratigraphy suggests. In the layer above the sheet flow layer, there are in the south end of the west baulk of trench no. 18 some irregularities, which may indicate a turbulent flow. However, the otherwise quite homogeneous volcanic layer makes it highly probable that it is formed on the spot in the ancient lake. Also the layer thickness seems to be of the same thickness all over the Mata

Menge excavation. The so-called sheet flow layer below the volcanic layer with the crystals contains both the artefacts and the fossils. It is an inhomogeneous layer and could have been formed from secretion in a flow of water. The artefacts may therefore come from a distant place, and they could be very much older than the dating of the ash layer above suggests. An age of 1 million years is already surprising. It is, however, difficult to believe, based on their wear, that the stones and fossils have been moved more the a few tens of meters [Morwood et al. 1998; O'Sullivan et al. 2001].

The sanidine feldspar dating at Mata Menge and the hornblende dating at Wolo Sege [Brumm et al. 2010] are almost exactly of the same age. The overall stratigraphic layers in the landscape between Wolo Sege and Mata Menge, only with 500 m distance, have been claimed to show a very significant vertical layer distance, incompatible with such a close dating. However, the landscapes (confer with figure 5.2, p. 23) between Wolo Sege and Mata Menge are difficult to reconcile with a large distance in age between the two localities. The differential stratigraphic layer sequences at the two places, where the artefacts are found, are also quite similar.

An archaeological age of 1 million years BP is interesting and raises the question of how the humans (Homo erectus) were able to get across two straits (between Bali and Lombok and between Sumbawa and Flores, see map figure 3.3, p.15), one of which has never been narrower than 19 km in the coldest ice age. A similar question has been raised regarding a possible crossing of the Gibraltar Strait between Morocco and Spain, which is central to the discussion of the human routes [Klein 2005].

So far, no human fossils have been found in the Soa Basin, in spite of extensive excavations for more than fifty years. Figure 1.1 shows an old picture of excavations at Mata Menge. It is likely, that when and if a human fossil is found, it will be similar to Homo erectus. This expectation is based on the type of artefacts found. One interesting outcome of such a future human fossil may be a linkage to the much later Homo floresiensis. Homo floresiensis has traits, which lead back to the very early evolution in Africa (Australopithecus africanus). Considering the span of 900.000 years between the oldest finds in Liang Bua and in Soa Basin, completely independent developments would however not be unexpected.

In the most recent Mata Menge excavation in 2011, more than 2000 palaeolithic stone artefacts have been found. This is comparable to the records from East Africa. Similar numbers of artefact have been found in other of the 14 excavation sites in Soa Basin. Clearly, the Soa Basin has been densely populated with what is suggested to be Homo erectus people [Dennell 2009]. In connection with the very large number of animal fossils from the same period as the stone artefacts, it is quite surprising that no human fossil has been found - not even a tooth. This indicates that the artefacts are found in a different place from where humans have been. In fact it indicates that the stone tools are brought to the sheet flow layer in the lakes by water currents. The humans who produced these artefacts may have lived in a different place, and archaeologists may simply not have come across these places. This indicates to me that a new research and excavation strategy is needed. Firstly one could look for caves in the ground under the lava layer. Electrical current probes are well suited for finding such caves. Another method is by looking down through the lava layers with strong penetrating x-ray radiation. Of course drilling at particularly chosen points in the landscape would be most obvious, and local authorities all over the world use today mobile drills for geological prospecting.

2. The Older Palaeolithic Stone Age in Africa

2.1 Africa as the melting pot

Although the results in this master thesis are concerned with human activity 1 million years ago on the island Flores in Southeast Asia, the first chapter is about Africa. You may ask why? It has become increasingly clear over the last decennium, in particular with the analysis of modern and ancient DNA [Gonder et al. 2007; Bower et al. 2009; Brown et al. 2009] that the roots for human evolution is to be found in Africa [Klein 2005]. The analysis of modern and ancient DNA is complicated, but one of the main reasons for archaeologists to select Africa as a sort of human melting pot is because of the much higher genetic diversity there than on other continents. We can localize the start of the evolution of humans to East Africa, which has been given the name the Oldowan Culture after the Olduvai Gorge. This region I have indicated in figure 2.1 (dark pink). The Oldowan stone industry started at the northern end of the Olduvai Gorge in the Gona area, Ethiopia, 2.5 million years back [Toth et al. 2006].

The human evolution and the human stone industry are difficult to synchronize during the Palaeolithic period from 2.5 million years Before Present (BP) to 12.000 years BP. In some cases there is the possibilities of a common age determination of both fossils and artefacts in the same archaeological layers, but this occurs seldom.

Complete human skeletons before about 500.000 years BP are seldom, but they give nevertheless a fair picture of the development in the early Palaeolithic periods. The human branch of the primates started 6 million years BP, extrapolated back from differences among modern humans' DNA. Today's chimpanzees are the nearest relatives evolved parallel to the human evolution since then. Fossil skeletons of human apes leading to what is defined as humans (Homo) are few, but what was earlier questioned as "the missing link", is today a very probable route of development [Spoor et al. 2007; Simpson et al. 2009; Gilbert et al. 2008].

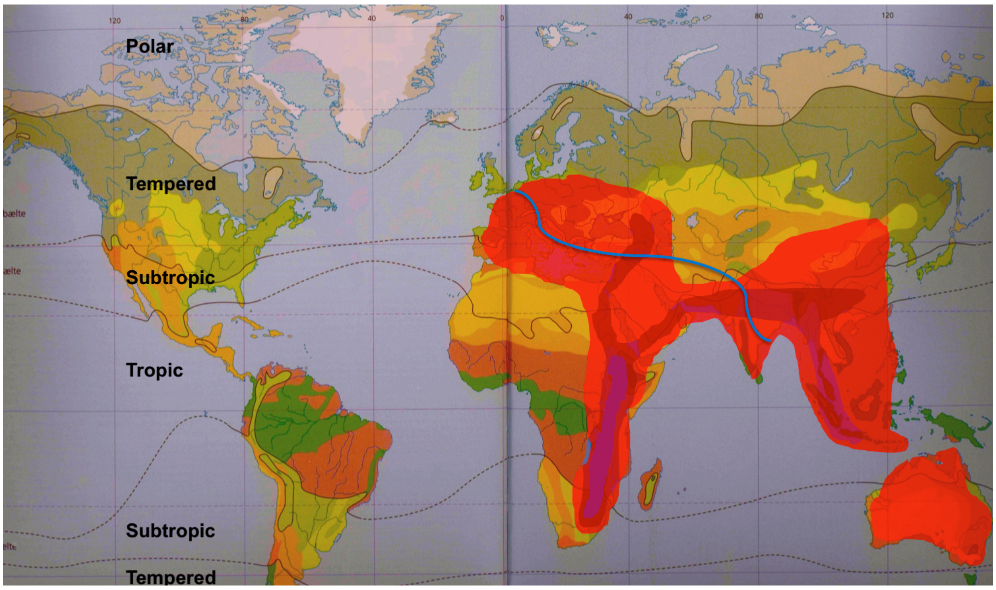


Figure 2.1. Map of the whole World with the climatic zones indicated in colours. Wet and arid region of today is shown in various grades of green and yellow respectively. On top of this climatic map, I have indicated the migration of the humans 2.5-1.8 million years BP (violet), 1.8-1.0 million years ago (dark red) and 1.0-0.04 million years ago (bright red). Up to 1 million years BP the human expansion was limited to the tropic zone. Modified climate map from Andersen et al. [1994].

Figure 2.2 gives one possible evolution diagram [Lieberman 2009; for others see Klein 2005 p. 67]. It is striking how many different branches of hominids, lived together in Africa up to around 1.8 Ma BP. I am not convinced that this picture is completed. Archaeological investigation in East Asia and Southeast Asia is only in its infancy and some of the lineage shown in figure 2.2 and others, which are still to be discovered, may change both, see figure 2.1 and 2.2. One example is Homo floresiensis, which was discovered in 2003 [Morwood 2004; Brown et al. 2004], which will be described in more details in chapter 4. Also a recent example is the discovery of a new branch parallel to Homo neanderthalis in Denisova [Krause et al. 2010; Reich et al. 2010].

An important alternative way of naming the evolution shown in figure 2.2 is to name the African lineage corresponding to Homo erectus (upright man) by Homo ergaster (working man). The sequence Homo habilis – ergaster - erectus is with high probability one of the branches, which has lead to the migration of humans to Flores.

2.2 Out of Africa I

The large scale Palaeolithic migration is often described by two waves of humans moving out of Africa. The first one is described as Out of Africa I [Templeton 2002; Boyd et al. 2005]. It is today defined as beginning around 1.8 million years BP and most accurately defined by the important discoveries in Dmanisi, where the dating (by $^{40}Ar/^{39}Ar$ method) is very trustworthy, and where the human fossils are found to be of late Homo habilis type and some of Homo ergaster (or erectus) type [Jöris 2008]. This may indicate a very early migration out of Africa, which may have parallels to Homo floresiensis, which will be discussed shortly in this thesis. In connection with my thesis work it has been interesting to compare these findings with the Asian findings.

Looking at the map of the World figure 1.1 two routes of the migration between 1.8 and ~1.0 million years BP is seen. One route is going north towards Dmanisi and the other route towards the east with the oldest settlement on Java (~1.6 million years BP), but also spreading out towards China (Beijing). One attempt to explain this double migration is that the routes Homo erectus take are either north or south of the Red Sea.

The routes to Europe only start after 1 million years BP, and it seems, that the original Homo erectus wave does not reach Europe. The first major wave of humans towards Europe is Homo Heidelbergensis, which is a developed form of Homo erectus. Homo Heidelbergensis has larger brain and more refined stone fabrication technique including an advanced Auchelean hand axe technology [Klein 2005].

The stone industry of the palaeolithic humans found in Dmanisi lack completely the Auchelean hand axe technology. This is also the case for the stone artefact findings at Beijing (Zhoukoudian) [Shen et al. 2009] and Java (Trinil & Sangiran) [Swischer et al. 1994; Zain et al. 2011]. The drawn blue line in figure 1.2 indicates the so-called Movius separation line, beyond which we find no hand axes in the older Palaeolithic Stone age. Alltogether the stone tool technology beyond the Movius line is found to be fairly primitive and some authors draw a parallel to the African Oldowan technology.

The reason for the Movius separation line has been much debated in the literature [Lycett 2009]. One suggestion is that the migration from Africa started before the handaxes was introduced. One could therefore imagine that this happened only once, say at 1.8 Ma BP and not at a later time where the handaxes were common tools. It is hard to believe that the migration "Out of Africa 1" was only a single event. Another possibility is that the right type of stone material didn't exist in the region the humans moved through. At a few places this may be so, but not on such a wide region. It has been suggested that the large abundance of bamboo, which existed in these areas, made the hand axe technology superfluous. Based on ethnographic research, it has been observed that tools made of bamboo tree are very sharp. This last hypothesis is hard to prove since no 1 million years old bamboo tools have been found so far.

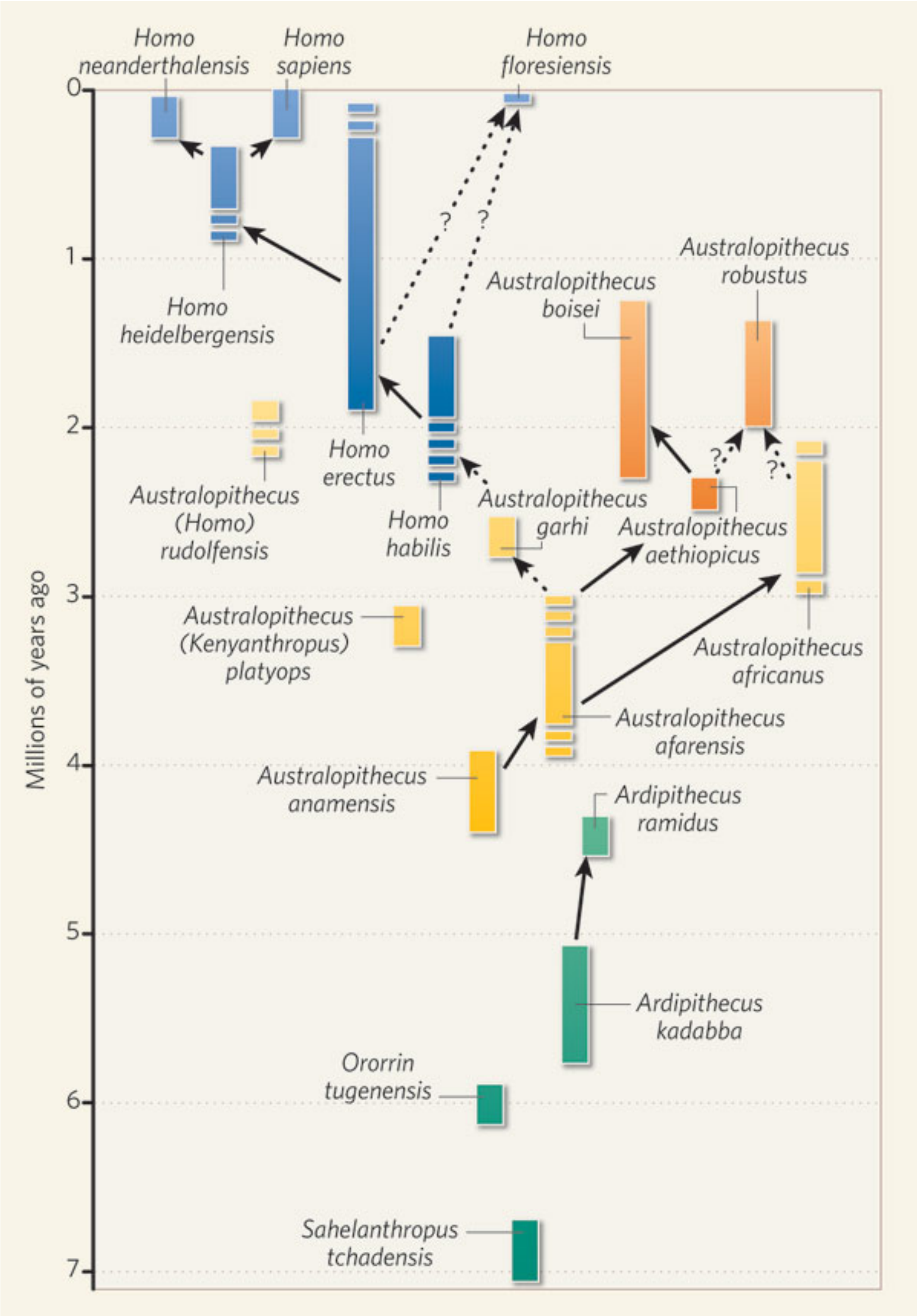


Figure 2.2. The human evolution as most palaeoantropologists see it today. All documenting fossils before 1.8 million years BP have been found in Africa. DNA analyses of modern humans show that by far the most types of DNA are found in Africa, showing the longer development there and consequently most mutations have taken place there. [Liebermann 2009].

3. The Older Palaeolithic Stone Age in Asia

3.1 Asian hominides: Dmanisi, Beijing and Jakarta

The first expansion of the homonides is believed to take place after the second generation of Homo habilis [Klein 2005]. In Africa this generation is called Homo ergaster and spans a period from about 1.8 to 1 Ma BP. At this time there was also a change in the stone artefact industry. Mary Leakey [see Toth et al. 2006] distinguished between the Oldowan and the Deveoped Oldowan cultures, but today the situation even in Africa is much more complex. At approximately 1.8 Ma BP there was a significant evolution change with the appearance of a more advanced, bifacial stone technology. This was the beginning of a more moden human – like genus, Homo ergaster/erectus followed by a dramatic migration of these outside Africa. The Turkana Boy fossils found at the Turkana Lake in the Olduvai Gorge exemplify the Homo ergaster/erectus. This complete skeleton found in 1980 [Klein 2005] marked a revolution in our understanding of the development of mankind. Many similar human skeletons have since been found at the Olduvai Gorge and gives a picture of an upright tall man with a low forehead. Richard Leakey suggested at a meeting in Stony Brook this [WWW3]: “A Homo ergaster or erectus, which walked into this university auditorium and took place on the first row, would by everybody in the auditorium be taken as a new professor at Stony Brook”. But there are of course significant differences to the later Homo sapiens. Most noticeable the brain size is between 700 cm^3 and 1100 cm^3 [Gilbert et al. 2008], whereas modern humans have brain sizes of 1300-1500 cm^3.

At the time when Homo ergaster appeared in East Africa, the stone artefact technology changed. The tools were suddenly much more elaborated with bi-facial technology leading to sophisticated hand axes, which became the landmark of the Auchelean technology. This dominated the human stone technology for more than 1 million years in the Middle East and in Europe [Inizian et al. 1992].

Figure 3.1. Fossiled skull of a typical Homo erectus. This is the Sangiran 17 find from a cave in the middle of the Indonesian island Java. The brain volume is 1000 cm^3. It is dated to be from about 1 million years BP. The fossil is on the exhibition at the Archaeological Mueum in Jakarta. [Photo P.E. Lindelof].

Homo ergaster expanded out of Africa and many of their traits have been found in human fossils in many areas outside Africa. The expansion went via the Middle East in three distinct directions defined by significant discoveries of human fossils in Georgia, Indonesia and South China. The finds in Dmanisi, Georgia are dated 1.8 million years BP [Jöris 2008]. The earliest human fossils found there have traits of Homo habilis, but most are very similar to Homo ergaster in Africa. However this human line outside Africa is called Homo erectus (not ergaster). Homo erectus has also been found at Zhoukoudian south of Beijing, dated to be from about 1.2 million years ago [Shen et al. 2009] and several 1 million years old Homo erectus fossils have been found on the Indonesian island Java. Figure 3.1 gives an example. The oldest fossil of Homo erectus was discovered at Sangiran Dome on Java, and it has been dated to around 1.6 million years BP [Swischer et al. 1994]. One of the most surprising hallmarks of this early expansion (called Out of Africa I) lies in the stone artifacts found together with the human fossils. It is everywhere in the world on a more primitive level, than in Africa at the same time. The complete lack of the handaxes in Asia is one interesting example of this. After this massive invasion of Homo erectus into Asia, the next big invasion came around 50.000 years BP by Homo sapiens, who apparently wiped out Homo erectus. Generally, this migration of Homo sapiens is referred to as Out of Africa II [Klein 2005]. Figure 3.2 shows an artist's view of Homo erectus.

Figure 3.2. An artist's view of 3 Homo erectus individuals in a landscape, which is very much like the landscape in the Soa Basin today, which is seen on the photos figure 4.1 and the front picture of the master thesis. The painting is at the Archaeological Museum in Jakarta. [Photo P.E. Lindelof].

3.2 The climate in Southeast Asia in the Pleistocene period

The climate in the Indonesian archipelago is dominated by the monsoon weather. This weather system is determined by the massive Asian landmasses north of Equator, which heats up the air during April-September and sends warm and dry air towards the south. The situation is opposite in the October-March period, where the wind goes south and sends colder air and more rainful conditions [Atlas Indonesia Dan Dunia 2002].

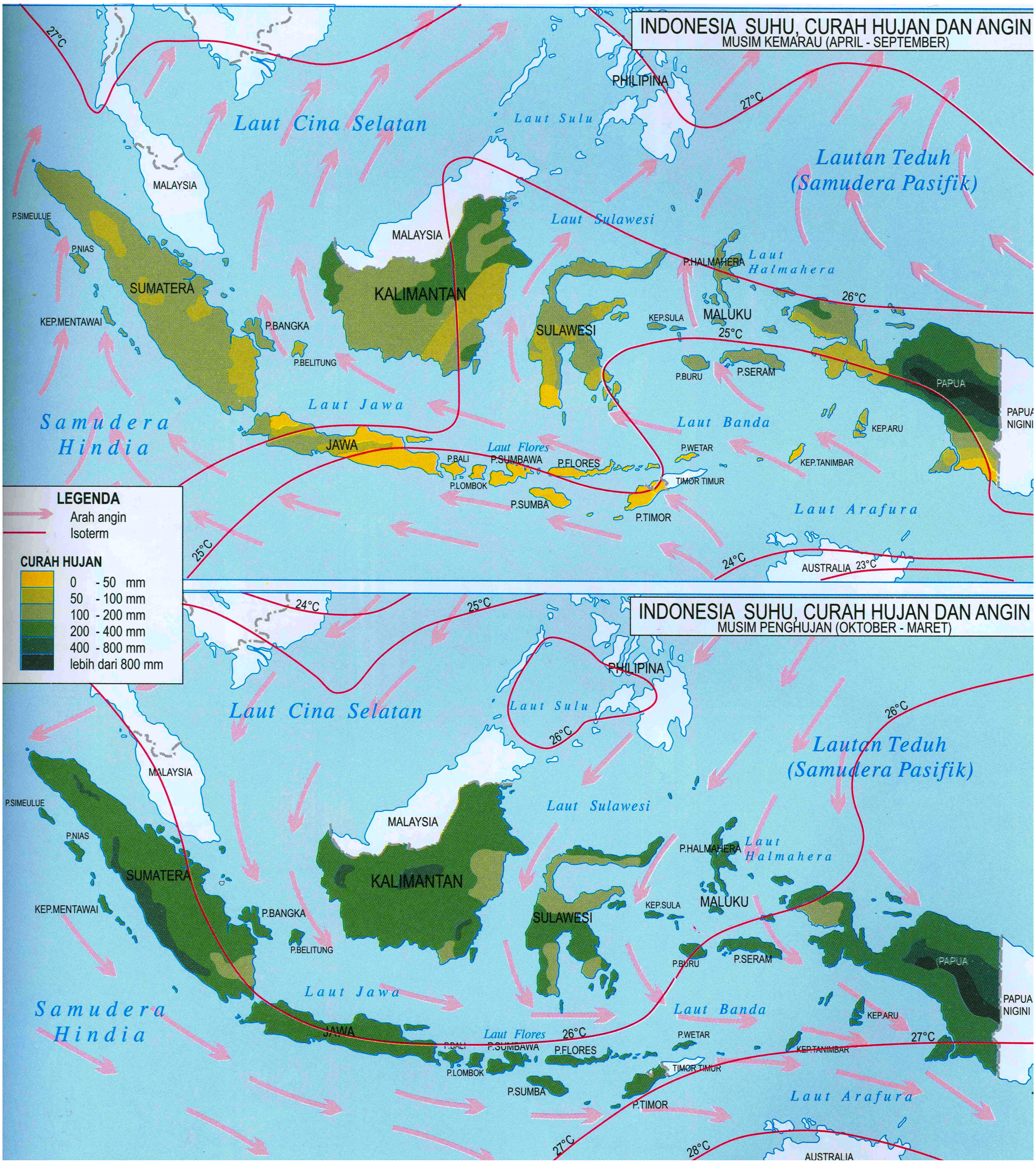


Figure 3.3. (a) and (b). Map of Indonesia summer and winter. Temperature, rainfall and ocean currents. [Atlas Indonesia Dan Umum 2002].

The monsoon creates a gradient in temperature from North to South during April to September and vica versa during the winter as seen on figure 3.3. As a result of these gradients, strong currents in the ocean also change directions. These annual oscillations are reflected in the rainfall on the islands, as seen in the colour codes of figure 3.3. It leads to relatively dry winters. These annual variations are likely to have been ruling the climate as long as the hominids have existed in the area.

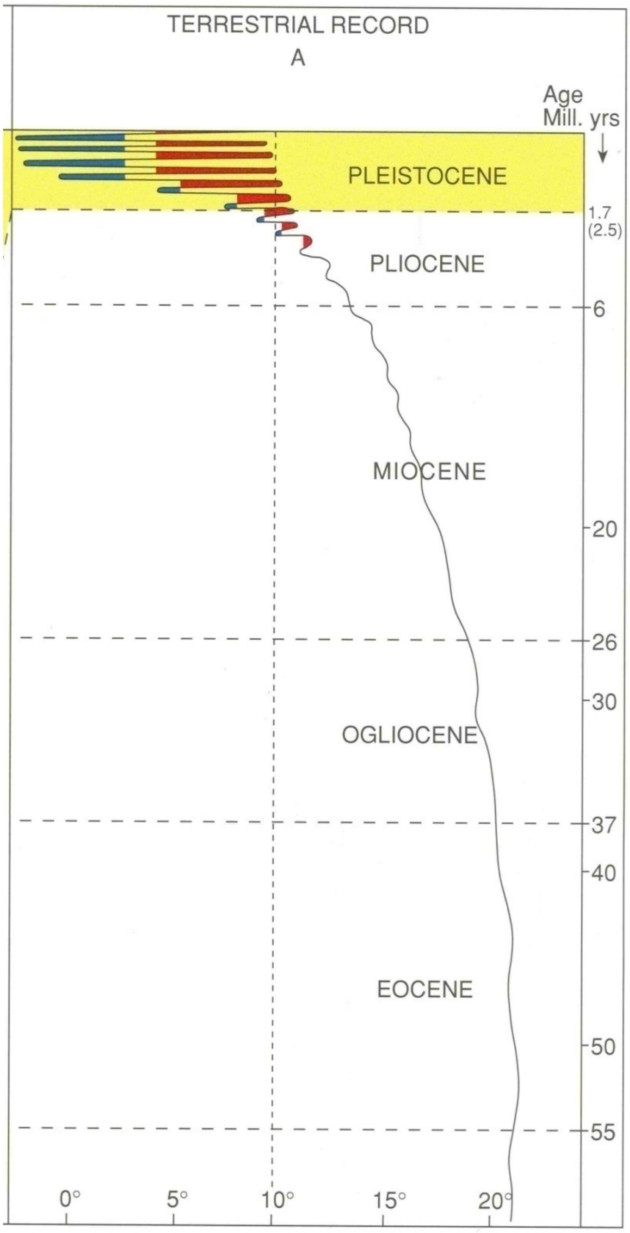


Figure 3.4. The average temperature of the World the last 65 million years. These data are the result of ocean drillings, where in particular the relative concentration of the isotope ^{18}O is an indicator of temperature. From the start of the Pleistocene period 1.7 million years ago (some reckon the Pleistocene period from 2.5 million years BP), the ice age oscillations dominate the weather. [Andersen et al. 1994].

A drop in temperature worldwide has taken place and has accelerated during the Pleistocene period. At the same time oscillations in the World's temperature have become stronger and stronger in the Pleistocene period as seen in figure 3.4. These oscillations have been well documented by studying drilled cores in the oceans in many places and for the last 150.000 years in the icecore drillings in Greenland and the Antarctics. Stalactites in caves in Indonesia and China have added to the detailed oscillations in the temperature in these regions [Andersen et al. 1994]. There is hardly any doubt that these violent variations in the weather conditions in the Southeast Asia (and other places) have influenced the migration of hominids, but the lack of knowledge of the movement of the palaeolithic hominids (as we believe: the Homo erectus) on a 10.000 years scale is insufficient to make a comparison.

A result of the ice ages indicated in figure 3.4 is that the water level in the oceans oscillates synchroneously with typically 130 meters differences. At the coldest parts of the ice ages many of the Indonesian islands have been connected, so animals and hominids could migrate unhindered between what today are islands. A few straits between the Indonesian islands have such deep water that they have never dried out. This is for instance the case with the water between Komodo Island and Bali. A number of connected waters, named the Wallace line, have in the Pleistocene period always been at least a 19 km hindrance for migration. To get to Flores or to Australia from the Java has been possible only by swimming or by boat (or by accident) [Dennell 2009 p. 431].

3.3 Java human fossils and stone artefacts

Java is one of the places on Earth with the highest population density. Perhaps this might also have been the case in the older Palaeolithic period. In two archaeological areas, Trinil and Sangiran, 8 fossil crania of Homo erectus and other skeleton parts have been excavated. Figure 3.1 shows the fossil skull, Sangiran 17, estimated to be about 1 million years old. The Homo erectus skeletons are roughly similar to the Homo ergaster skeletons in East Africa. The Homo erectus crania are thicker than that of ergaster, and the volume of the crania found in Indonesia have increased in size from about 800 cm^3 (~1.6 Ma BP) to 1100 cm^3 (~200.000 years BP, the youngest Homo erectus so far found). Such a gradual development is not recorded in East Africa to my knowledge, where Homo ergaster developed into Homo heidelbergensis. Most of these human fossils are found in the lower wet region of Java, but Robin Dennell [2009, p. 149] suggests that the Homo erectus actually lived higher up in the montains, but that the fossils are only preserved in the lower, wetter parts of the island. Stone arifacts are however also mostly found in the lower parts of Java and this seems to contradict Robin Dennell’s claim. The artefacts are fairly primitive and look in many respects as artefacts from the Oldowan period. Very little development of tools appears to have taken place on Java, and the hand axes, which are so abundant in Africa, does not exist here. All this raises question on the evolution of Homo erectus.

The Palaeolithic landscape on Java has been formed by a series of volcano eruptions as well as the formation of lakes in this older Palaeolithic period, very similar to Flores. The tools, which have been found on Flores, will be discussed in a later chapter and in appendix A2, where some of the stone artefacts found in Mata Menge, Flores are on display.

4. Homo Floresiensis

4.1 The discovery in the Liang Bua Cave

The most important find, though not the oldest palaeolitic find on Flores, Indonesia, is the so-called Hobbit, a very small hominid fossil. It was found in 2003 in the Liang Bua Cave just north of Ruteng, Flores. Later, fossils of 16 individuals have been discovered. Excavations have, however, been ongoing in the Liang Bua Cave for a long period of time [Verhoeven 1953]. The trenches in the Liang Bua Cave, figure 4.1, had up to 2003 revealed interesting (though unpublished) Neolithic and Mesolithic finds, as old as 11.000 years. In 2003 the trenches reached a depth of 3 m and it was believed that at this depth the basic geological floor had been reached.

It was the merit of an Indonesian-Australian group [Brown et al. 2004; Morwood et al. 2004] that the excavations continued beyond the apparent geological floor and into a very hard sandstone material. In a depth of 6 m these efforts were rewarded with the find of new layers with human fossils and stone artifacts. An almost complete, partly fossilized, skeleton of a young women, who was 1.04 m high and 17.000 years old, surprised the archaeological community and lead to a violent dispute on the interpretation of the find. Today, however, part of 16 fossilized skeletons has been found. Only one skull has been excavated, though. These skeletons are dated to be between 17.000 and 74.000 years BP [Roberts et al. 2009]. In the same layers stone artifacts have been found. In some adjacent layers the artifacts were dated to be up to 94.000 years BP. The dating of the layers with the skull was based on the ^{14}C-method [Andersen et al. 1947; Lippy 1955] and gave the age of 17.000 years BP. The dating of the deepest layers could not be done with ^{14}C-method and were done by OSL (optical stimulated luminescence) and by ^{238}U-^{230}Th method. The error in these dating methods is at least 15%. $^{40}Ar/^{39}Ar$ dating and the fission track method have not yet been attempted in the Liang Bua Cave.

Figure 4.1. The Liang Bua Cave on Flores, Indonesia. The Homo floresiensis fossils were found in the deep trenches to the left on the photo. [Photo P.E. Lindelof].

4.2 New possible evolution trends on the basis of Homo floresiensis

The immediately most striking feature with Homo floresiensis is its small height of only a little more that 1 m. It is easy to see that the fossilized human was not a child. In particular the skull showed some reminiscence of Homo erectus and the first conclusions were that it was a result of insular dwarfing of Homo erectus. Such dwarfing is not uncommon among animals. In fact Flores has one wellknown example of this, namely the pygmy stegodon (elephant). Small Homo sapiens exists, the most wellknown example is the pygmae in the Calahari Desert in Africa, which is believed to have grown small by isolation. People on Flores today are also small, as illustrated in figure 4.2, and a statistically record of how small they are has recently been published. It shows that the average heights of some local groups of people are in the 120-150 cm range. Whether this is another example of insular dwarfing is unknown, but illustrates the little evolutionary importance that should be placed on the smallness of Homo floresiensis [Berger et al. 2008].

Figure 4.2. Small people on Flores. Picture taken near the two Caves at Cunca Wulang 15 km southeast of Labuan Bajo on Flores of Calis' mother, who has a typical height of women on Flores, and me. [Photo taken by my guide, Calis].

Studies of the almost complete skeleton (LB1) of Homo floresiensis as well as all the minor parts of skeletons of Homo floresiensis found in the Liang Bua Cave give today, 10 years after the first find, some very interesting similarities to not only Homo erectus (& ergaster) and Homo habilis, but all the way back to e.g. Australopithecus africanus shown previously in the diagram figure 2.2.

The cranium, LB1, is shown in figure 4.3 (a) and (b) from the front and from the side. It is essentially small in the same proportion as the skeleton, but the volume of the brain is relatively small, only 400 cm^3 and the ratio of the brain volume to overall weight is very close to the Australopithecus africanus and much smaller than Homo erectus. In perspective, the stone artefacts from Homo floresiensis do not appear to be more primitive than the stone artefacts from Homo erectus. The appearance of the cranium resembles Homo erectus with prominent brow ridges. But the jaws are sticking forward and the chin is withdrawn similar to Homo habilis. But the endocast (imprint of the inner side of the skull) taken with a CT scanner shows several distinct differences from Homo erectus. According to Dean Falk the imprint of the front lobes is most similar to Autralopithecus africanus [Falk et al. 2005; Falk 2011].

A very interesting study of the feet and hands clearly ties Homo floresiensis to the very early Homo habilis or late Australopithecus [Jungers et al. 2009]. The arms are long and the legs short. The feet are extremely long, almost as a chimpanzee. Figure 4.4 illustrates the ties to Australopithecus. Figure 4.4 shows the tibia and femur of the LB1 leg and at the top two perpendicular pictures of the (left) foot. The 5 metatarsal bones in the foot are measured relative to each other. In figure 4.5 (a) (length of metatarsal bone no. I/ length of metatarsal bone no. III) is plotted against (length of metatarsal bone no. I/ length of metatarsal bone no. II). In figure 4.5 (b) (Proximal phalanx V/ length of metatarsal bone no. V) is plotted against (Proximal Phalanx II/ length of metatarsal bone no. II) for 133 Homo sapiens individuals and for 64 chimpanzee individuals. The corresponding values for LB1 Homo floresiensis are shown as a star. Homo floresiensis is in both these cases closest to the chimapanzee and the LB1 value is in fact very close to the value for Australopithecus africanus. This is just one example of the various ratios taken on the Homo floresiensis skeleton, showing a close similarity with the late Australopithecus individuals (in particular homo africanus). The teeths of the LB1 cranium are somewhat different from Australopithecus africanus, resembling the small teeths observed on Homo erectus and Homo sapiens.

Homo floresiensis is a complicated hominid, which is not easily categorized in the scheme of human evolution. It has been argued that it is a spin-off from Homo erectus, locally in the Indonesian archipelago and perhaps gradually ending its existence with the appearance of Homo sapiens after ~50.000 years BP. Another possibility, which has most recently been favoured in the literature, is that Homo floresiensis represents a direct migration from Africa 2 million years ago and most closely linked to Homo habilis or even Australopithecus africanus. The extensive search on Flores for Palaeolithic sites, where this master thesis is only a small addendum, must be seen in this light. As I shall comment more on later in my thesis no other palaeolithic fossils like those from Liang Bua have so far been found anywhere on Flores or elsewhere in the world.

Figure 4.3 (a) and (b). The fossil cranium of Homo Floresiensis. Exhibited at Jakarta Archaeological Museum. [Photo P.E. Lindelof].

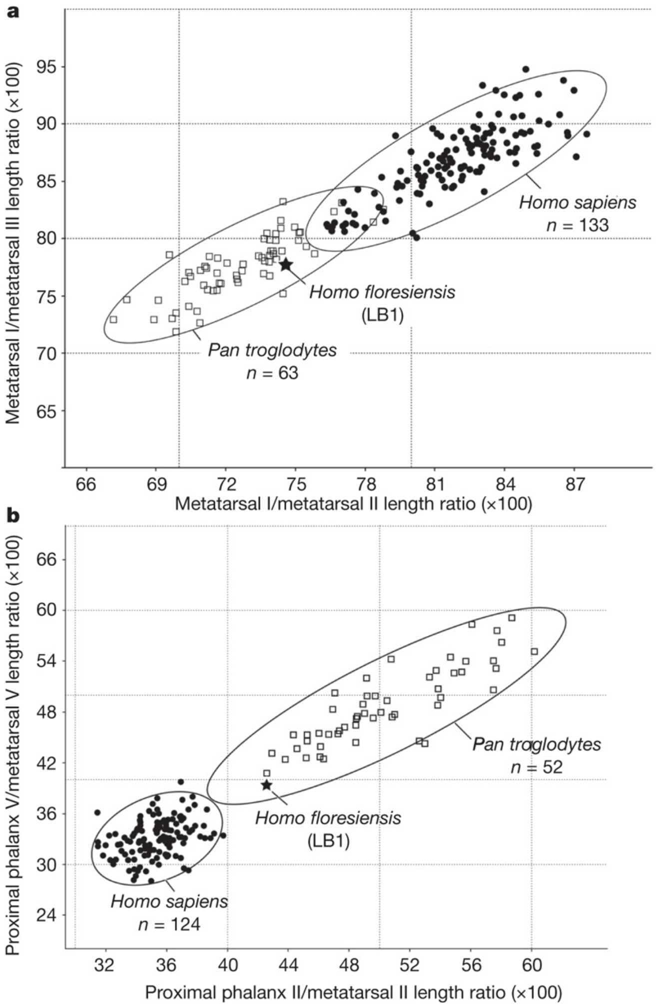


Figure 4.4. The foot and long leg bones of Homo floresiensis. Two projections of the left foot and its associated right tibia and left femur. [Jungers 2009].

Figure 4.5 (a) and (b). Comparison between ratios of various metatarsals (a) and ratios of phalanx and metatarsals (b) of chimpanzees and Homo sapiens with Homo floresiensis. [Jungers 2009].

5. Soa Basin Archaeology

5.1 The Soa Basin excavations

In the central part of Flores north of Bajawa there is a 10 by 20 km area encircled by many active and inactive volcanoes. It has the name Soa Basin and is situated roughly 50 km east of Ruteng and the Liang Bua Cave described in the last chapter. Figure 5.1 sketches the landscape and the position of the volcanoes [Aziz et al. 2009; Morwood et al. 2009; Morwood 2009]. This area has 14 sites where abundant Palaeolithic artifacts have been found. Apart from the Liang Bua Cave, this is the only area on Flores, where Palaeolithic archaeology has been studied. The area may have been attractive in the Palaeolithic period thanks to the moderate temperature in the highland (~300-400 M) and being a fertile volcanic landscape with many lakes. In turn this area seems to have attracted many different animals several million years back. The monsoon rain brings up to 1 m of water to the Soa Basin during the winter and several lakes are formed and drained towards the northeast by the Ae Sissa River. The climate was a little warmer and more humid in the middle Pleistocene period than today and the Ae Sissa River was apparently occasionally blocked by volcanic lava creating more extensive lakes. At the shores of various lakes archaeologists have during excavation found abundant fossil bones of animals and many hominid artefacts dated to different Palaeolithic periods [van den Bergh et al. 2009].

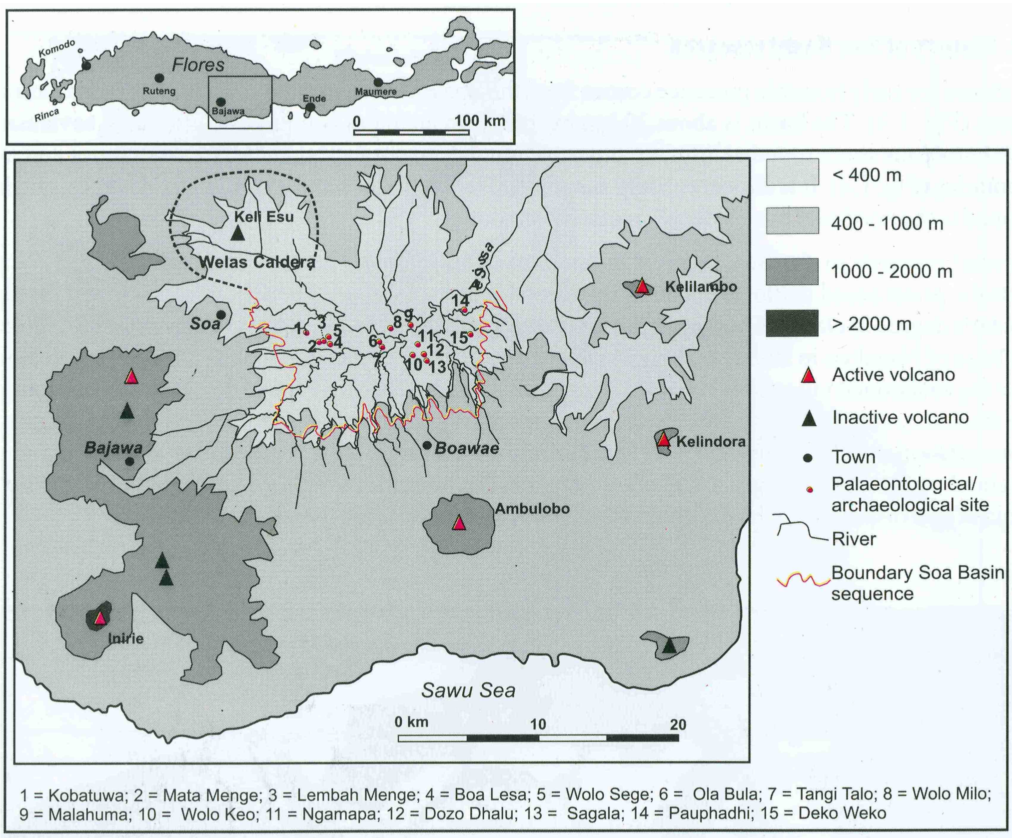


Figure 5.1. Archaeological map of Soa Basin with the 15 excavation sites which are studied by several archaeological groups. [Aziz et al. 2009].

A few places in Soa Basin (e.g. Boa Lesa, Ola Bula and Mata Menge) were studied back as early as 1956-1970 by the Dutch pater Theodor Verhoeven [Verhoeven 1953; Maringer et al. 1970a;

Maringer et al. 1970b]. Theodor Verhoeven's excavations revealed both fossil animals like stegodon elephants and many hominid artefacts. By geological reasoning he estimated the finds to be more than 700.000 years old. After him many archaeologists have studied the area and although the number of finds have since been many-doubled, our understanding of how and when the hominids lived in this area is only slightly improved. About ten years ago the interest was declining, but the discovery of Homo floresiensis in 2003 suddenly created a massive interest among World archaeologists for Flores and in particular for Soa Basin. An important step forward was the precise dating of the Wolo Sege artefacts by the Danish student Gitte M. Jensen [Brumm et al. 2010a], who determined the layer just above the artefacts at Wolo Sege to be almost precisely 1 million years old (1.02 ±0.02 Ma BP). My master thesis is a continuation at Mata Menge of her work.

The Soa Basin is a complicated geological formation shaped by the many volcanic eruptions, earch quakes and streaming as well as static water [Muraoka et al. 2002; Sucipta et al. 2006]. Figure 5.2 illustrates the nature of the Soa Basin area by a photo taken from a 50 m high local hill west of Mata Menge towards the Kelilambo Volcano east of Soa Basin shown on the map, figure 5.1. Geological investigations have revealed two major eruption periods in the Pleistocene period. The first is named Ola Kile and determined to happen 2.5 to 2 million years ago and covering the Soa Basin area with 10-100 m of ash. The next important eruptive period is 1.5 to 1 million years ago with similar thicknesses of ash and named the Ola Bula formation. The ash has, with roughly the same thickness, covered areas of several km^2. The reason that the landscape looks so uneven as seen in figure 5.2 is due to rivers and lake formations, which moved many meters of ash and soil from the landscape. The most highly resistant andesitic breccias stand back as mesas in the landscape and we can easily see plateaus on the photo corresponding to the original flat volcanic depositions. The maximum height differences in the landscape are about 50 m, which is presumably also the maximum depth of the Palaeolithic lakes [van den Bergh et al. 2009].

Figure 5.2. View from the hill behind Mata Menge towards the volcano Kelilambo in the east direction. The Mata Menge excavation is seen as orange tents in the lower left corner of the photo. Wolo Sege is in the middle in front of Kelilambo. The Wolo Sege excavation was behind the dark trees to the left of the hill looking like an inverted soup plate. (Photo: P.E. Lindelof).

The geology of the Soa Basin is complicated and in spite of a considerable effort back to the work of the Japanese geologist Hirofumi Muraoka [2002, 2006], geologists are still not in a position to make a coherent picture of the layer chronology of the Soa Basin. The geologists attempt to find similar layers at different positions and thereby correlate their ages. This is locally combined with the fundamental law of archaeology and geology that the oldest layer in a vertical sequence is the lowest, and the age of the artefacts in turn are determined by their context. However sediments formed by water flow locally perturb the time ordering of the layers and makes the most straightforward interpretation of the geological chronology dubious. For this reason chronology of archaeology and zooarchaeology in Soa Basin also becomes difficult.

There are some interesting basic hints in the finds from the different excavation sites in Soa Basin: At Wolo Sege stone artefacts are found, whereas no animal fossils have been observed. Oppositely at Tangi Talo (see figure 5.1) animal fossils are found but no stone artefacts. The Wolo Sege excavation is 6 m below Mata Menge and the lake was probably too deep for animals to dwell there. The Tangi Talo is 60 m above the Mata Menge, and it is likely that there is no streaming water to this place, so no stone artefacts have been brought there.

Several dating methods are used in the Soa Basin, but one can question their reliability. The volcanic layers come of course in the first place in a stratigraphic order. But streaming water may carry the ash away to a different place, where it could very well be situated on a younger layer and the stratigraphy therefore reversed. An intermediate sheet flow layer could therefore also be younger that a layer on top formed by deposition. Another scenario would be that the sheet flow layer comes from elsewhere and therefore could be older that the layers below and above, which would lead to a relatively older sheet flow sediment and artefacts. No investigation of the grain size distribution in the various layers has been attempted. This might tell the extent of the sheet flow. Adam Brumm [Brumm et al. 2006, 2009] remarks that the artefacts at Mata Menge are not weared or grinded by being moved around in the water, so he concludes that the movement of the artefacts is over short distances. I will return to this later. The relation between the archaeological finds and the living places of the hominids are therefore in general not convincing. Did the hominids actually drop the artefacts right at the spot where we find them? Hardly.

5.2 Wolo Sege

The Soa Basin area has been flooded with lava in two timely separated volcanic eruptions in the Pleistocene period. The socalled Ola Kile is the first, which as reported in the literature ended 1.86±0.12 million years ago [O'Sullivan 2001]. This age is determined by the fission track method, but recent $^{40}Ar/^{39}Ar$ dating has given a considerably older age for the Ola Bula layer. Therefore the Ola Kile may also be older than the fission track gives, perhaps closer to 2 million years ago. The excavation at Wolo Sege only 500 m from the excavation site Mata Menge has yielded an $^{40}Ar/^{39}Ar$ dating of the layer just above the sheet flow layer with artefacts of 1.02±0.02 million years.

As everywhere in the Soa Basin landscape water flow has changed the thicknesses of the original volcanic layers very dramatically. The volcanic layers are in both Ola Kile and Ola Bula periods roughly 100 m, but at particular points in the Soa Basin water has eroded the layers to only a few meters, allowing the archaeologists to dig completely through the layers and given valuable stratigraphic information to the Soa Basin archaeology. The very hilly landscape is the result of the water erosion, where some volcanic layers are more resistant to water erosion than others. The two photos figure 5.3 and 5.4 illustrates this at Wolo Sege. In figure 5.3 a trench is seen which stretches all the way from the archaeological site in the bottom of the Wolo Sege valley to the top of the adjacent hill seen in the middle of the photo, figure 5.2. The trench cut the surface of the many meters thick andesitic Ola Bula layers. Actually Wolo Sege means in the Indonesian language a soup plate (perhaps an inverse one), which picturize this place in the landscape. Figure 5.4 shows the excavation at the lower end of the trench figure 5.3.

Figure 5.3. Trench which cuts through the Ola Bula andesitic formation from the archaeological gull and up to the top of the Wolo Sege mesa top. (Photo: P.E. Lindelof)

The vertical excavation cut, figure 5.4 (a), gives a few tuff and ash layers emmediately above the Ola Kile formation and a sheet flow layer from an intermediate period between the ash fall out. This layer sequence is illustrated in figure 5.4 (b). Stone artefacts are found in this sheet flow layer and the $^{40}Ar/^{39}Ar$ age determination by Gitte M. Jensen [Brumm et al. 2010a] gives the interesting result of 1.02 Ma, which, as I will discuss later, was difficult to correlate with the earlier dating results. The about 50 stone tools found at Wolo Sege are similar to what has been reported from Mata Menge (see later).

Although Wolo Sege has in its sheet flow layer hominid stone artefacts, opposite to all other excavations in Soa Basin there are no animal fossils in this layer or in the volcanic tuff layer emmediately above or below. It will be difficult to claim that these fossils have disappeared due to circumstances and it is therefore concluded that no animals have been present here in the first place. As already mentioned the sheet flow layer is 6 m below the Mata Menge sheet flow layer, and it is tempting to conclude that the lake has been fairly deep here, so the stegodon elephants and other terrestrial animals have not stayed at this place. The Hominid artefacts, on the other hand, were presumably brought to the place by the streaming water; from where we don't know. According to Brumm et al. [2010b] the tools are not water-polished and they are therefore presumably shrown not very far away.


a b

Figure 5.4. Wolo Sege. (a) The streaming water has dug the gull. The important archaeological layer is the sheet flow layer roughly in the middle of the cut (grey signature in the figure (b) to the right). 1.5 m below the floor in this gull seen in (a) is the interface between the Ola Kile and the Ola Bula. The material for the $^{40}Ar/^{39}Ar$ age measurement [Brumm 2010] is taken just above the sheet flow layer. The layers indicated by the inserted patterns in (b) are from the top: Topsoil, Ash/sand, Sheet flow, Ash/sand *(Photo: P.E. Lindelof)*

5.3 Mata Menge

The excavation at Mata Menge (see map figure 5.1) is the basis for this master thesis. It has been investigated for more than 50 years. More than 2000 stone artefacts have been dug out of the ground and many more animal fossils have been taken to the museums in Bandung on Java. In the 15 excavation places spread over the Soa Basin there have so far never been observed any human fossils. The stone tools are very similar over the total Soa Basin and they are also claimed [Brumm 2010b] to be very similar to those from Liang Bua. It is therefore difficult to draw conclusions about the cultural evolution over the long period from 1 Ma Bp to 0.1 Ma BP. The concentration of the excavations on Flores to Soa Basin gives a useful detailed archaeological and geological picture. But perhaps more effort to other parts of Flores beside Soa Basin and Liang Bua could give important additional information.

Figure 5.5. The Excavation area 2011 of Mata Menge. Trench 18 is far to the right (north-south branch of the L-shaped trench. The photo is taken southward. The orange tents in figure 5.2 have been removed. (Photo: P.E. Lindelof).

In 2011 the excavation by the Bandung-Wollongong team was done in a new semi-modern way, where the topsoil and part of the volcanic pumice-tuff layer were peeled off by a bulldozer over 2000 m^2 before the detailed digging of trenches began (200 m^2 trench area). The most advanced way would of course be to peel off layer-by-layer of the whole archaeological region in sequences of e.g. 10 cm. This would have given very detailed geological and archaeological information, but was probably considered too expensive. In stead 130 local workers excavated 31 trenches in 2011.

There were clear indications that the ash was fallen into water, since the precise stratigraphic layer sequence corresponding to a sequence of eruptions, were not clearly visible. During pauses of thousands of years in the Ola Bula volcanic eruption one million years ago, the lake-stream or river removed part of the volcanic layers. But there were also periods where materials were brought to the lake/river and deposited there. Figure 5.5 is a photo of the 2011 excavation area seen from north. The trench (no. 18) to the very right in this photo was the trench I investigated during my three weeks stay in Indonesia.

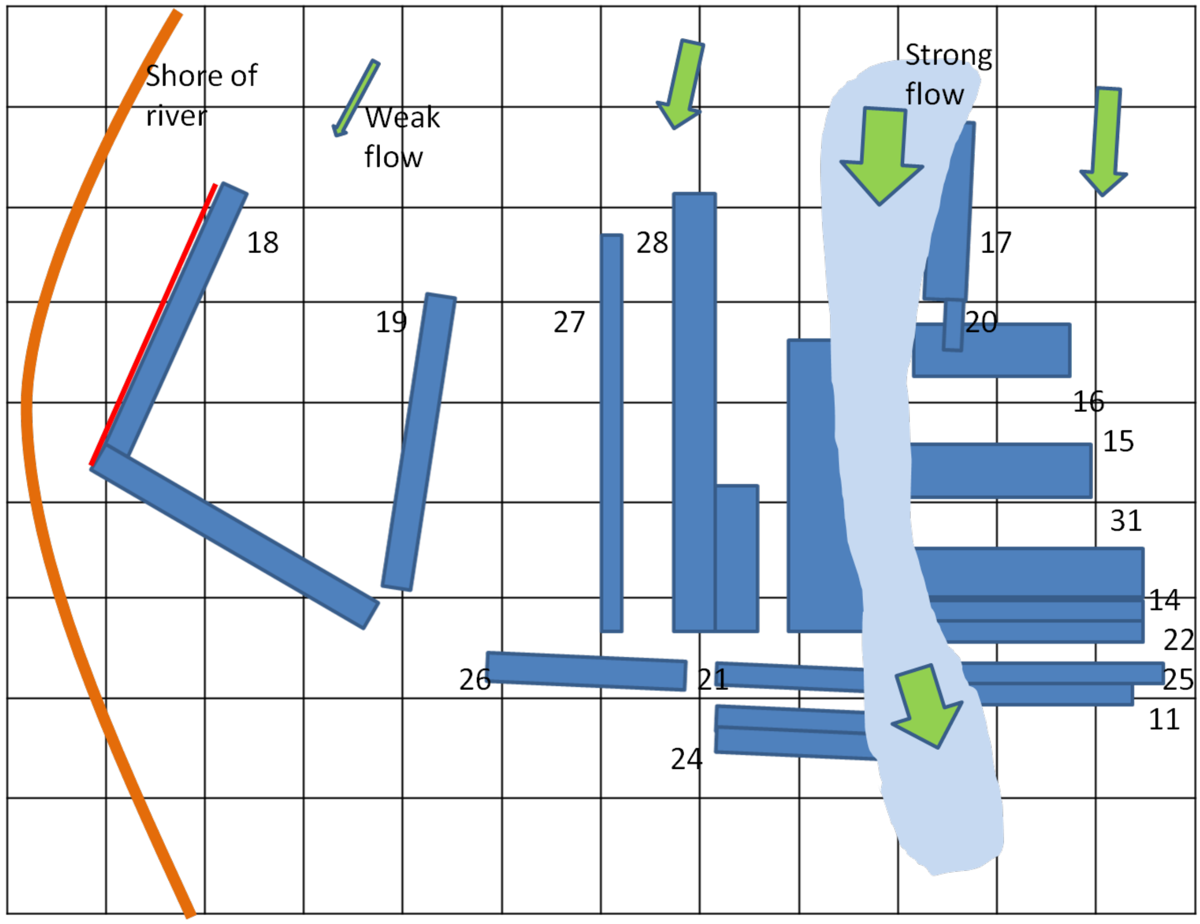
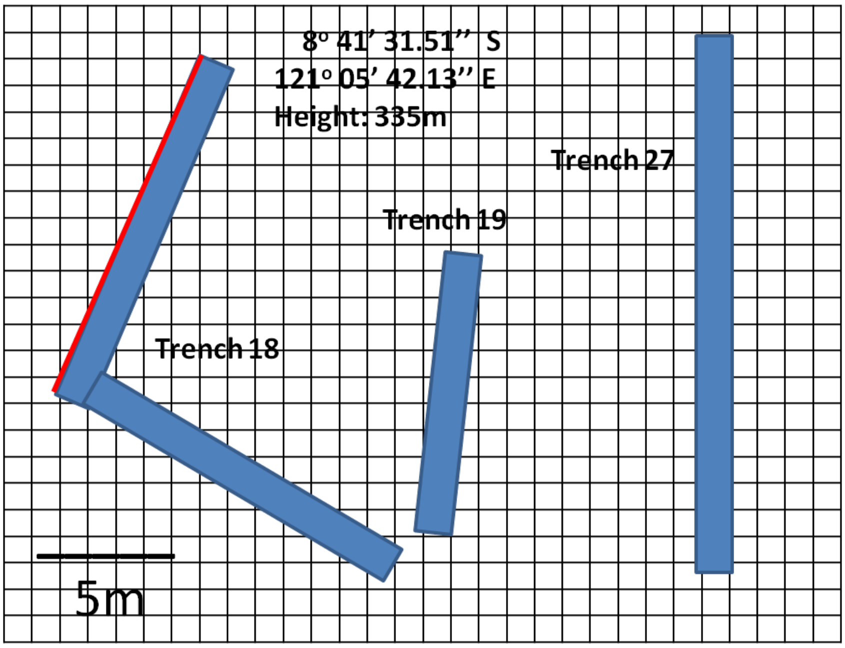
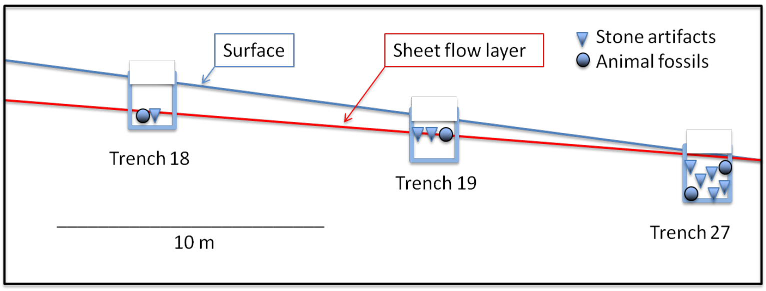


Figure 5.6. Drawing of the 2011 Mata Menge excavation. The blue rectangles are the various trenches. The squared paper is with 5x5 m^2 units. The brown parabolic shaped line to the left is my suggestion of the shore of the lake or river. The flow strength in the river/lake is attempted given by the size of the green arrows. In the middle of the excavation there were apparently a very violent stream at some point, which removed all artefacts and fossils. It is easy to recognize the trenches here with the photo figure 5.6. Trench 18 (to the left) was the trench, which I investigated, in particular the west baulk indicated with the red line. A complete photomontage of the west baulk of trench no. 18 is shown in appendix A1. There were a few finds there. I took samples (3 kg) in 3 places in trench 18 to be able to do dating at Roskilde University, but only one of the batches has so far been studied in detail and described here. (Gert van den Bergh did the measurement, which is the basis of this drawing,).

The streaming water at particular places left sediments on the bottom of the lake and sometimes the stream removed these sediments again. An interpretation would be that there was at first a stream, which deposited very fine-grained material as well as artefacts and fossils in a sheet flow layer. Then the current of water increased and removed all materials as shown in the middle of figure 5.6 (the light blue area). Further towards the shore to the left in figure 5.6 the stream was less violent, and only the very fine-grained materials were carried away. The artefacts and fossils stayed in a sheet flow layer. At the shore of the lake, i.e. at trench 27 (partly) and trench 19 and 18 the sheet flow layers are intact. This is illustrated in figure 5.7 (b). The artefacts and fossils are somewhat spread out in trench 27 and more so in the deeper parts of the river (trench 28, 14,15,16 etc.). In trench 19 the artefacts and fossils are as already mentioned strictly limited to the sheet flow layer as seen in figure 5.7 (b). Also in trench 18 the sheet flow layer was intact, but here the number of artefacts and fossils are much lower. Above the shoreline the fossils have deteriorated and there are very few artefacts, because no stream leads them there. Unfortunately I was not allowed by the archaeological leader of the excavation to record or even see the artefacts. Figure 5.7 (b) is a sketch of the distribution of artefacts and fossil bones on the basis of information from the Indonesian archaeologists.



a



b

Figure 5.7. Map showing the west end of the Mata Menge excavation in 2011. The coordinate of trench 18 is shown in the figure. The red line indicates the part of trench 18, which has been studied in this master thesis. On the same length scale a sketch of the 3 trenches are shown with the fossil animal bones and the artefacts indicated. In trench no. 18 and 19 the artefacts are strictly limited to the sheet flow layer according to the Indonesian archaeologist Iwan Kurniawan, whereas in the more eastern trenches, where the sheet flow layer has been subseuqntly removed by water, the artefacts are found in a much wider layer of tuff/ash/sand.

During the 3 months excavation 2011 in Mata Menge 1500 artefacts and more than 3000 fossils were excavated. Several fossils give a vivid picture of the natural life at the lakeshore. A selection of the finds was kindly shown to me by the indoneian archaeologists. They showed me the fossils of stegodons (elephants). A 2.5 m long tusk was found. This long tusk is close to the record length ever found among these 1 million years old animals. Also many of the characteristic stegodon mandible molars were found in Mata Menge, while I was there. An example is shown in figure 5.8. Of particular interest were several broken pieces from one stegodon, indicating that the bones were broken in the shallow water, possibly by the tramping elephants. Other fossilized animals were found such as frogbones and the lower jaw of a komodo dragon displayed in figure 5.9.

Figure 5.8. Digging out a stegodon (elephant) mandible molar characteristic of the 1 million years old animal. (Photo: P.E. Lindelof).

Stone artefacts from Mata Menge published by Maringer et al. [1970a and 1970b] are displayed in appendix A2. The Indonesian archaeologists at Mata Menge told me roughly how the artefacts were situated in the layers of the various trenches as shown in figure 5.7. The position of the artefacts in the trenches were attempted measured in the 2011 excavation using a total station, but unfortunately the GPS data were wrong and placed in impossible positions outside the trenches.

🡐 5 cm 🡒

Figure 5.9. Fossilized lower jaw of a komodo dragon found in Mata Menge in July 15, 2011 by Iwan Kurniwan. (Photo: P.E. Lindelof).

Further west of the 2011 excavation a trench was dug right up to the ~370 m high hill (35 m above Mata Menge). The photo figure 5.10 (a) shows this trench, with the Mata Menge yellow tents in the distance to the right in the picture. This trench is way above the ancient level of the lake and the layers are very sharply seen in figure 5.10 (b), reflecting each individual volcanic eruption. However, at this level there are no stone artefacts found. The artefacts have a natural concentration in the sheet flow layers. Also there are no fossils here because the dry conditions mean that they will deteriorate rather quickly and not fossilize. Still it would be interesting to make accurate $^{40}Ar/^{39}Ar$ dating analysis on each layer here, since this could help intepret the finds in the rivers/lakes.

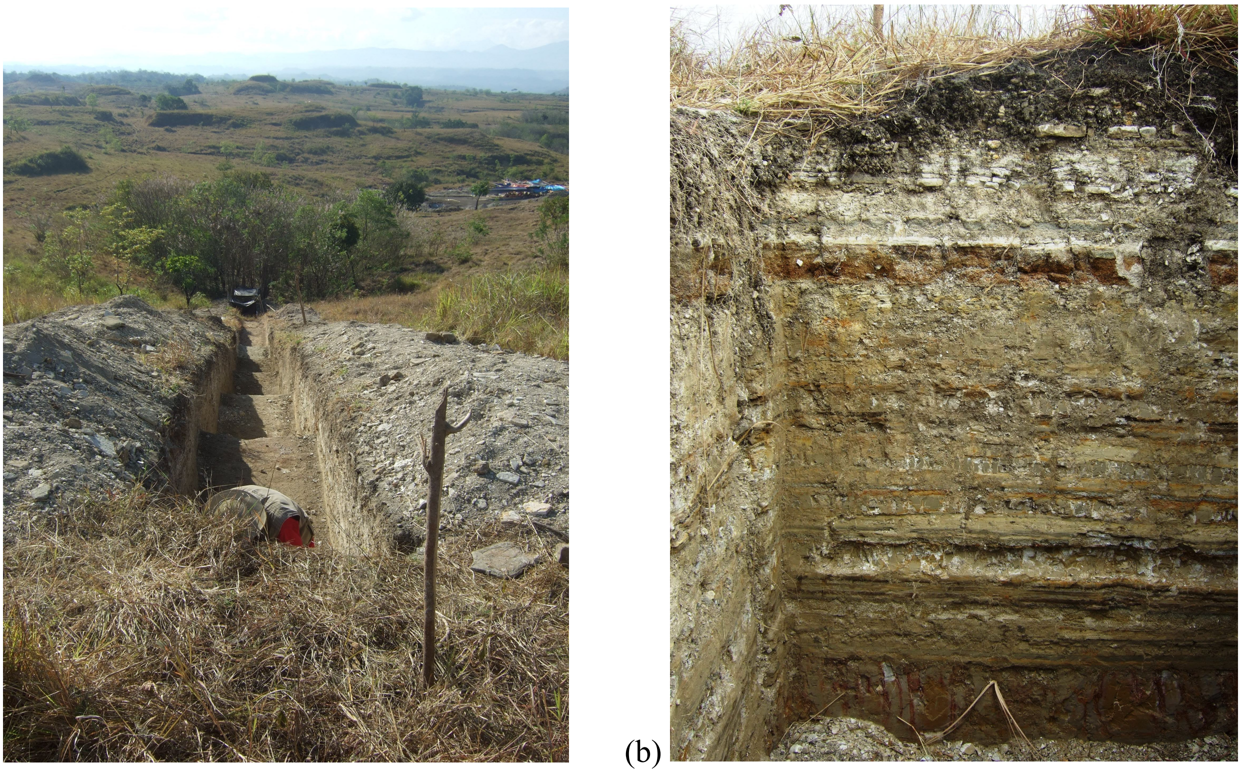
(a)  (b)

Figure 5.10. (a) Trench from Mata menge towards the western hill, (b) Layer structure at the top of the trench in (a). (Photos: P.E. Lindelof).