DID *HOMO ERECTUS* REACH THE ISLAND OF FLORES?

Gert D. van den Bergh[1], Bondan Mubroto[2], Fachroel Aziz[2], Paul Y. Sondaar[3] and John de Vos[1].

1 National Museum of Natural History, PO Box 9517, 2300 RA Leiden, The Netherlands.
2 Geological Research and Development Centre, Jalan Diponegoro 57, Bandung, Indonesia.
3 Natuur Museum, Rotterdam, The Netherlands

ABSTRACT

On Flores stone artefacts have been found in situ in a fluvial sandstone layer pertaining to the Early to Middle Pleistocene Ola Bula Formation, near Mata Menge in the Ngada District, East Nusa Tenggara Province, Indonesia. Paleomagnetic measurements indicate a transition from reverse to normal magnetic polarity in the 3 m thick interval just underneath the layer containing the artefacts. This transition presumably represents the Matuyama-Brunhes boundary and indicates an age of at least Middle Pleistocene for the artefact bearing layer. This relatively old age strongly suggests that the artefacts are the work of Homo erectus. *The artefacts were found in association with fossil remains of* Stegodon trigonocephalus florensis. *Earlier excavations in the same layer by Verhoeven had already yielded numerous* in situ *artefacts, as well as fossil remains of* S. trigonocephalus florensis *and a giant murid,* Hooijeromys nusatenggara. *An older faunal association occurs at the base of the Ola Bula Formation in a tuffaceous layer with a reversed magnetic polarity. It contains a pygmy* Stegodon *spec. C, a large tortoise and* Varanus komodoensis. *Though distinct in composition, both successive faunas are characteristic for unbalanced endemic island conditions. These results strongly suggest that* Homo erectus *was already able to cross a water barrier to reach the palaeo-island of Flores.*

INTRODUCTION

The discoveries of Pleistocene vertebrates in Flores (East Nusa Tenggara Province, Indonesia) started with the finding of fossil remains of a large-sized animal in December 1956 by the Raja of Nagekeo, Josef Dapangole. The findings were reported to Dr. Th. Verhoeven, a Dutch priest at Mataloko, who subsequently visited the original locality Ola Bula in the Ngada District (Figure 1). Additional fossil material was collected by means of excavations and sent to Leiden, where Hooijer (1957) concluded that all the fossil material could be ascribed to one taxon, *Stegodon trigonocephalus florensis*, a somewhat more advanced but slightly smaller subspecies of the large *Stegodon trigonocephalus* MARTIN from Java.

More fossil collecting in the same area followed, and in 1960 a geological study was carried out by the Geological Survey of Indonesia (Hartono 1961). Interestingly, two milk-molars of a pygmy *Stegodon* were reported, found in the surroundings of Ola Bula, of which the exact stratigraphic position remained unknown (Hooijer 1964). Besides stegodonts also remains of an extinct giant rat were collected at the localities Ola Bula and Boa Leza. This rodent was named *Hooijeromys nusatenggara* by Musser (1981).

In 1970 Maringer and Verhoeven reported the discovery of primitive-looking stone artefacts in association with remains of *S. trigonocephalus florensis* at the localities Mata Menge and Boa Leza. Based on the association with *S. trigonocephalus florensis* these artefacts, described as a number of pebble tools and retouched flakes mostly made of volcanic rock, were thought to be of Middle or Late Pleistocene age. It was speculated that Solo Man might have reached the Lesser Sunda Islands. However, the evidence presented by these authors is generally considered as non-conclusive and it has been argued that it is not known when *Stegodon* became extinct (Bellwood 1985). New geological investigations would be required to prove the age of the artefact-bearing layers.

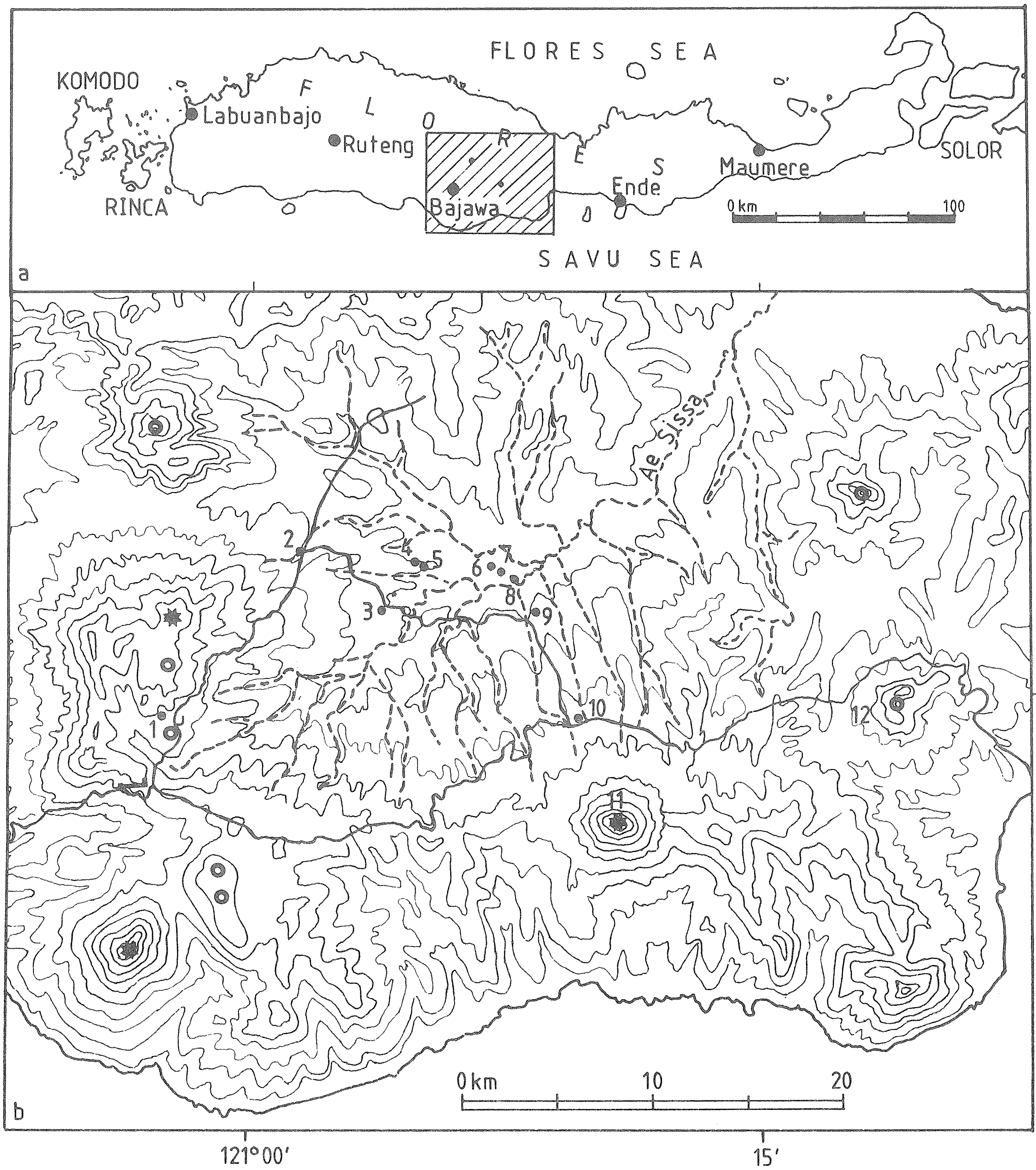

Figure 1: a: Map of Flores showing the location of the study area. b: Map of the study area. Stars indicate active volcanoes, circles indicate inactive volcanoes. Contour interval 200 m. 1: Bajawa, capital of Ngada District; 2: Soa; 3: Menge Ruda; 4: Mata Menge; 5: Boa Leza; 6: Ola Bula; 7: Tangi Talo; 8: Bhisu Sau; 9: Ola Kile (abandoned village); 10: Boawae; 11: Abulobo, active volcano; 12: Kelindora, eroded volcano.

In 1982 a locality near Bhisu Sau was discovered 250 m SE of Ola Bula and 2 km east of Mata Menge, yielding *in situ* fossils of a giant tortoise and a pygmy *Stegodon*. This locality appeared to be older than the Ola Bula excavation of Verhoeven. It has been suggested that the observed faunal succession is the result of the arrival of early hominids to the island of Flores, leading to the extinction of the giant tortoise and the pygmy Stegodon

(Sondaar 1987) and preventing the more recently arrived large-sized stegodonts from dwarfing due to hunting pressure.

In November 1991 and 1992, Indonesian-Dutch joint expeditions were organized to the Soa Plateau with the aim of relocating the excavations made by Verhoeven and of checking the earlier claims of *in situ* artefacts associated with *Stegodon trigonocephalus florensis* (Aziz 1993). Two sections were measured and sampled for paleomagnetic dating, one near Mata Menge and the other at Bhisu Sau/Ola Bula (Figure 1b). Test excavations were made at the most promising sites of Mata Menge and Tangi Talo (Tangi Talo is the name of a small hill at the foot of which the fossil-bearing layer with pygmy stegodonts and tortoises is located; this name is preferred here instead of the name Bhisu Sau, used by Sondaar (1987), which refers to the river valley southeast of this hill). The test excavation near Mata Menge was carried out in the same sandstone layer excavated by Verhoeven (his excavation is still visible as a large pit, 7 by 3 m wide and maximum 2 m deep).

GEOLOGY

All fossil localities mentioned here are located in the Ola Bula Formation, which is up to 80 meters thick. The Ola Bula Formation was deposited in a small basin surrounded by presently still active and inactive volcanoes to the west, south and east (Figure 1b). It lies horizontal and unconformably overlies a slightly tilted sequence of resistent andesitic volcanic breccias, which have been named the Ola Kile Formation (Hartono 1961). The basin has not been much disrupted by tectonic activity since deposition of the Ola Bula Formation and the northern area of the basin is characterized by a slightly undulating plateau dissected by the Ae Sissa River and its tributaries. The rivers have formed steep-walled valleys where they cut the resistant breccias of the Ola Kile Formation. Higher up, the valleys widen where the less resistant Ola Bula Formation crops out. Remnants of conglomeratic terraces are locally present halfway up the valley slopes. In the south, erosion by north-south flowing rivers has shaped the topography into elongated ridges, which merge further south into the footslope of the active Abulobo volcano (Figure 1b). Recent unconsolidated deposits from this volcano cover the older formations along the southern margin of the basin.

The Ola Bula Formation is characterized by white tuffs in the lower part, gradually becoming more sandy higher up (Figure 2). The lower interval is characterized by light colored tuffaceous sediments containing abundant pumice particles. The coarser-grained layers are very poorly sorted and internal structures or erosional features are usually absent. Some of these layers have a muddy matrix and are clearly deposited by mass-flow processes. They may contain angular pebbles of volcanic products. The clastics contain mostly glass (pumice) and plagioclase, but also quartz and hornblende are locally present. Pumice generally contains no macroscopically visible crystals, but if present hornblende and biotite can be distinguished. The source volcano must have produced volcanic products of an andesitic to dacitic composition.

The fine grained layers which alternate with the coarser clastics are silty or clayey and well sorted but may contain pumice fragments as well. The fine grained layers were mostly deposited out of suspension from standing water.

The tuffaceous interval has a thickness of 30 m near Tangi Talo, but becomes thinner towards the west. Near Mata Menge the thickness of this interval is only 10 m and further west the tuffaceous unit wedges out completely. In the western part of the basin deposition has been more interrupted, as evidenced by the frequent development of red palaeosoils in the tuffaceous interval. Where the tuffaceous unit is not developed (west of Menge Ruda, Figure 1b), the upper surface of the breccias of the Ola Kile Formation is strongly mottled due to soil formation processes.

Fossil remains are usually absent in the tuffaceous interval of the Ola Bula Formation, though at one locality (Tangi Talo) fossil vertebrates are abundantly concentrated in one horizon at the boundary between a pumice-containing mass-flow layer and a tuffaceous silty clay layer. The tuffaceous interval is conformably overlain by a sandy interval in which sedimentary structures indicate fluvial environments. The transition between the tuffaceous and sandy intervals of the Ola Bula Formation is gradual. In the fluvial interval well-sorted sandy channel deposits alternate with darker colored grey and brownish fine-grained overbank deposits. The sandstone layers can be traced laterally over hundreds of meters and are usually 1-2 meters thick. They locally contain rounded pebbles and have an erosive base. The sandy layers become finer upwards and stacked fining-upwards layers are also developed. Internal sedimentary structures are often obliterated by bioturbation but parallel laminations and cross-bedding can occasionally be distinguished. Inclined accretionary surfaces, caused by the lateral shifting of channels, have also been observed. Pebbles occurring in the sandstones consist mostly of andesitic or basaltic volcanics, but silicified volcanics also occur. Isolated pumice particles can also be found in the sand

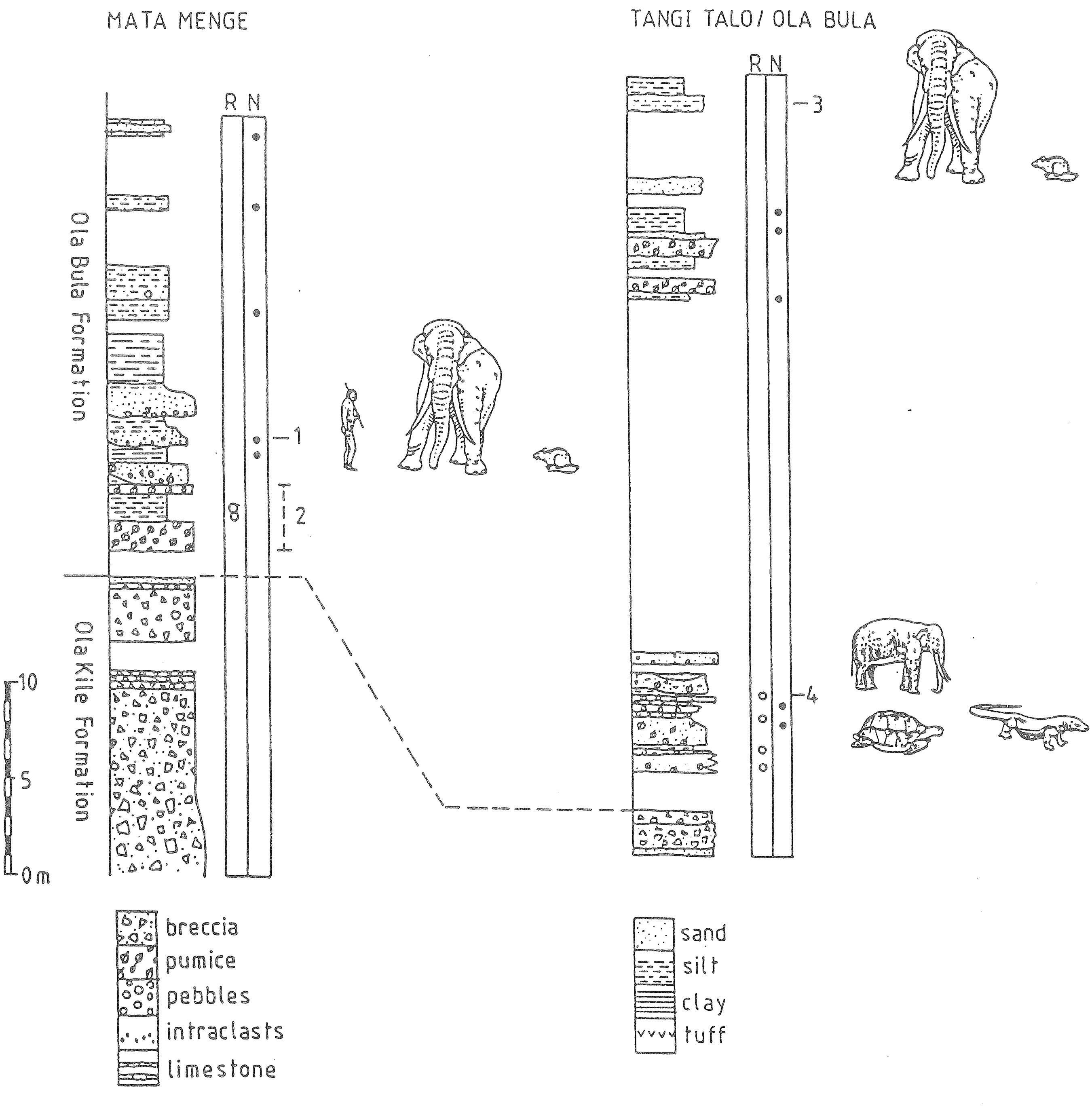

Figure 2: Two sections measured at Mata Menge (left) and Tangi Talo/Ola Bula (right). Magnetic polarity (N = Normal, R = Reverse) of several sampled horizons is indicated to the right of each section. 1: Fossiliferous sandstone layer at Mata Menge which has yielded artefacts and Stegodon *fossils. 2: Pink/white mottled paleosoil developed on pumice containing tuffs. 3: Fossiliferous layer at Ola Bula excavated by Verhoeven. 4: Fossiliferous layer at the base of the hill of Tangi Talo near Bhisu Sau. For explanation of the fossil faunas see text.*

stone layers, but not so abundantly as in the underlying tuffaceous subunit of the Ola Bula Formation.

The sandstones and siltstones frequently contain casts of fresh-water mollusca (*Melanoides*) and of fossil plant remains (mostly grasses but also some badly preserved wood fragments). Near the top of the exposed sequence thinly-bedded lacustrine limestones are developed, which are here included in the Ola Bula Formation as well. In the northwestern part of the basin these limestones have been largely eroded away but locally they crop out at the tops of small rounded hills emerging above the plains.

Individual limestone layers are usually no more than 10 cm thick. They consist of micritic limestone (mudstone), locally with siliciklastic grains of volcanic origin admixed. On the top surfaces of individual limestone layers polygonal cracks can occasionally be noticed which have been later filled in with sparitic calcite. Oogonia of characea, ostracods and freshwater mollusca can be found in these limestones. These limestones were deposited in small lakes which occasionally dried up.

The Ola Bula Formation is interpreted as representing the foot-of-slope deposits of one or more interfingering volcanic aprons. These volcano-clastic deposits covered a palaeo-relief developed on the eroded surface of the Ola Kile Formation. Initially a period of strong volcanism supplied large quantities of pumice and other volcanic products towards the basin. Because the tuffaceous interval thickens towards the southeast, the volcanic source of these tuffaceous products must have been located in this direction as well. The Kelindora, an eroded volcano 15 kilometers east-northeast of the Abulobo (Figure 1b), seems to be the most likely source of these volcanic products. The tuffaceous material was largely transported into the basin by means of unchanneled mass-transport processes (debris-flows and hyperconcentrated stream-flow processes). When the volcanic activity ceased the deposition in the basin became dominated by fluvial processes. Eventually, shallow fresh-water lakes could develop in the small basin, possibly due to a rise in ground-water during a period of high sea level.

Hartono (1961) already reported that the non-vertebrate fossils from the Ola Bula Formation are largely indicative of a fresh-water environment (ostracods, charophytes and mollusca), though some marine foraminifera (*Cymbaloporella* sp. and *Cytherella* sp.) were found as well, suggesting that during deposition of the Ola Bula Formation the basin had an elevation of near sea level. Nowadays the top of the Ola Bula Formation is located at an elevation of over 200 m above sea level, which means that the area must have been uplifted considerably during the later part of the Quaternary. The general absence of coastal plains and the presence of uplifted coastal terraces on Flores (Ehrat 1925) indicates that this uplift has continued up to present times.

PALEONTOLOGY AND ARCHAEOLOGY

Tangi Talo

Near Tangi Talo 80 fossil specimens were recovered from the top of a 30 cm thick white tuffaceous layer containing abundant pumice fragments, which is overlain by a white fine-grained tuff (4 in Figure 2). The fossils occur in an approximately 10 cm thick interval at the slightly undulating boundary between both layers. Most of the excavated material consists of giant tortoise and pygmy *Stegodon* remains. Besides, the sediment inside a tortoise carapace also yielded 6 teeth of *Varanus komodoensis* OUWENS, of which several vertebrae were found as well in the same layer. The pygmy *Stegodon* has been preliminary designated as *Stegodon* spec. C and is clearly distinct from *Stegodon sompoensis* HOOIJER from south Sulawesi (van den Bergh *et al.* 1992). The material is at present under study and it remains to be seen whether the Flores pygmy is specifically or subspecifically distinct from the pygmy *Stegodon timorensis* SARTONO from Timor.

The association of a pygmy *Stegodon* and a giant tortoise is characteristic of an unbalanced endemic island fauna. This means that mammalian carnivores are lacking and only a few vertebrate genera are present. The genera able to reach islands are usually herding herbivores which are good swimmers, such as hippos, proboscideans and cervids (Sondaar 1977). As is well known, tortoises are also excellent island colonizers.

In the vicinity of Tangi Talo, angular volcanic clasts can be found in some debris-flow deposits from the lower tuffaceous interval of the Ola Bula Formation, but none can be positively identified as an artefact.

Mata Menge

Near Mata Menge only large sized *Stegodon* fossils were excavated by extending the original excavation of Verhoeven. Amongst this material is a 1.9 m long tusk with a proximal diameter of 11 cm, a upper last molar, a femur, a humerus, a tibia and four vertebrae, all of which can be ascribed to *Stegodon trigonocephalus florensis*. In association with these fossils several *in situ* artefacts were excavated from the same layer.

All this material comes from a well-consolidated fluvial sandstone layer 1.5 m thick (Figure 3). The layer has

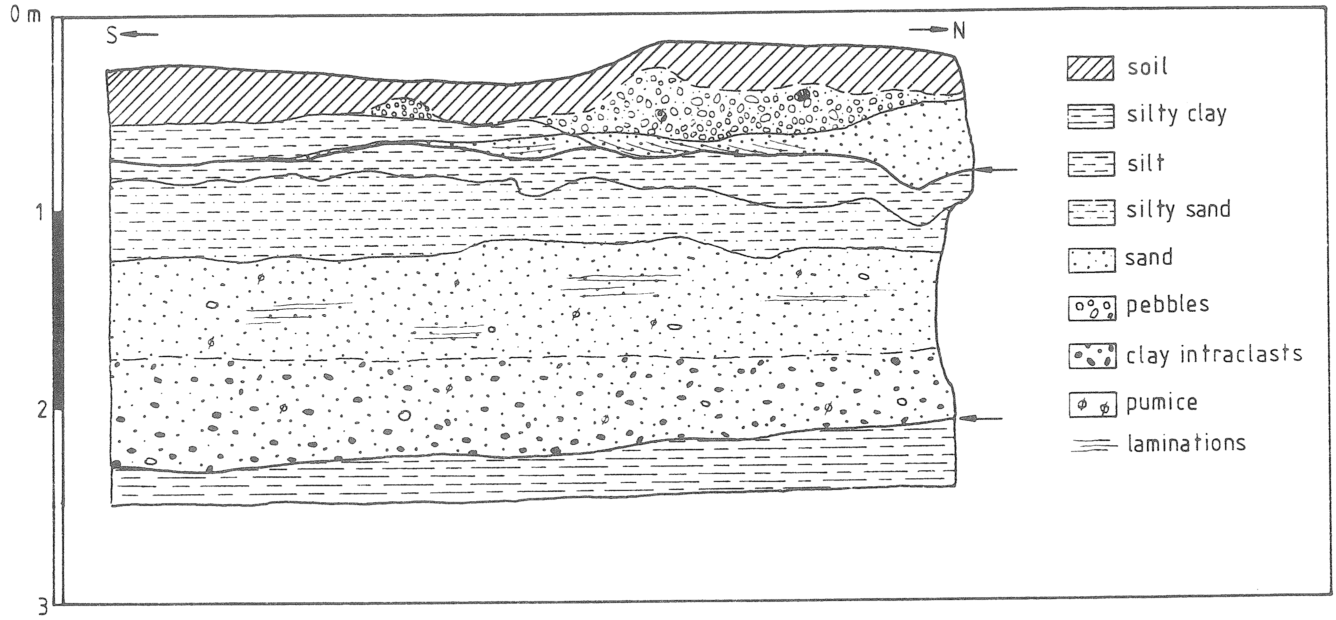

Figure 3: Profile of the eastern excavation wall at Mata Menge, showing the internal layering of the artefact and fossil-bearing layer. The profile corresponds with the zero reference line indicated in Figure 4, between points D and I. Arrows mark the two erosional surfaces defining the layer. Depths of objects indicated in Figure 4 correspond with the scale bar to the left. The boundary between the silt and sand intervals is locally sharp, but mostly gradual due to bioturbation. This boundary is inclined downwards towards the spectator (in western direction). 3 meters west of the profile this boundary occurs at a depth of around 1.45 m below the zero reference point.

an erosional base (lower arrow in Figure 3) and the lower part contains intraclasts of the underlying silty clay. In the lower part the grain-size is coarse to medium grained with a few rounded pebbles. Upwards the sandstone grades into siltstone. This siltstone is bounded by an erosional surface (upper arrow in Figure 3) from a younger fluvial fining-upward layer. The layering shown in Figure 3 dips approximately 20 degrees in an eastern direction (towards the spectator). The silty interval at the top thickens in the same direction and was probably deposited out of suspension in a (partly) abandoned channel.

Stegodon fossils occur throughout the layer, but tend to be rather fragmented in the lower sandy interval, while from the upper silty interval complete bones were recovered, which, however, are in a rather poor state of preservation. Freshwater gastropods and plant remains occur throughout the layer. In addition some small bones and teeth of the giant rat *Hooijeromys nusatenggara* were unearthed as well as teeth of a small crocodile. The fauna from Mata Menge is poor in vertebrate species (only three), at least two of which (the *Stegodon* and the rat) are endemic. Again, this strongly points to an island environment.

Artefacts

During our test excavation at Mata Menge in 1992, four artefacts were unearthed. They are made of fine-crystalline basalt. They vary in size from 34 to 67 mm. The smallest two are small flakes with only fresh breaks. The other two are made of rounded basaltic pebbles with one or more fresh breaks. One of these shows a percussion bulb. It lacks retouch on the sharp edges, suggesting waste material.

During our recent excavation at Mata Menge in April-May 1994, more artefacts were recovered *in situ* from the same layer. This time an area of approximately 10 square metres of the 1.5 m thick artefact-bearing sandstone layer was excavated. The excavation was carried out in 10 cm spits and positions of all excavated fossils and artefacts were recorded (Figure 4).

The artefacts mostly represent flakes. One is made of chert, the remainder (over 15 specimens of varying quality) are made of fine-crystalline basalt. One flaked core with a maximum dimension of 7 cm was found in the

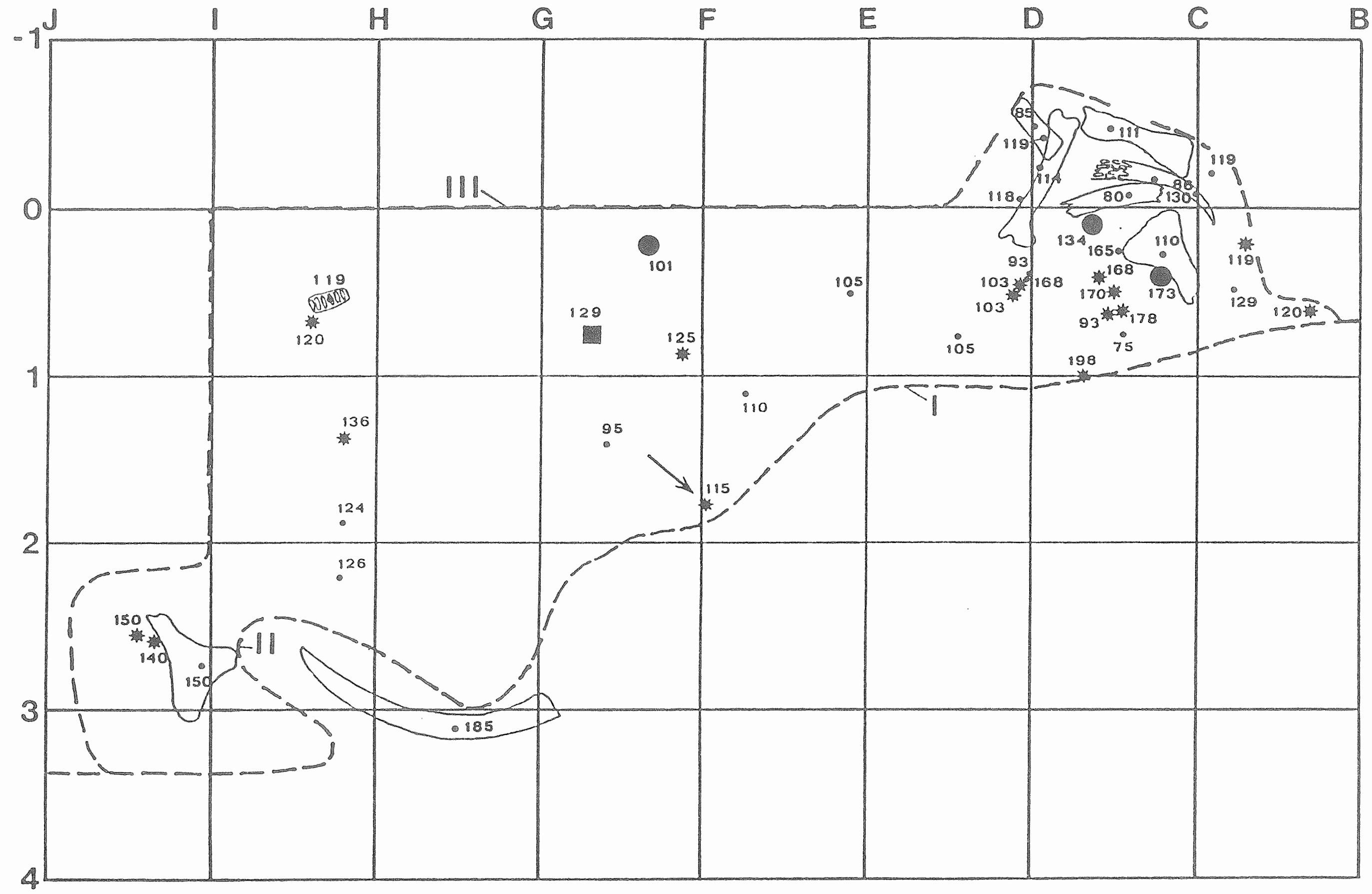

Figure 4: Horizontal plan of the Mata Menge excavation, showing the location of the various artefacts and fossils. The highest point of each object as it was found in situ *is indicated in cm below the zero reference line of Figure 3. Small dots: fossil fragments; stars: flakes; large dots: pebble tools; square: core. The location of the retouched flake depicted in Figure 5 is indicated with an arrow. I: Wall of the original Verhoeven excavation. II: Wall of the 1992 test excavation. III: Wall of the 1994 excavation.*

lower part of the silt deposits depicted in Figure 3. Eight flakes and one pebble tool with a maximum dimension of 8 cm also came from the silts, which contain no other natural pebbles. This strongly indicates an allochthonous origin for these pieces. These flakes appear fresh and have sharp edges, while the flakes from the basal sandstone interval show rounding due to transport. This suggests that the flakes in the silts were brought in by means other than water transport.

In addition, two retouched flakes made of chert came from the sandstone layer overlying the fossiliferous layer. This material is being studied now and will be described in a later paper. One basalt flake is shown in Figure 5; from the location marked by an arrow in Figure 4. The results confirm the earlier claims made by Maringer and Verhoeven (1970), who describe numerous retouched stone tools excavated from the same site.

AGE

Stratigraphic correlations

The fossil bearing layer at Tangi Talo is stratigraphically 31 m below the *Stegodon trigonocephalus florensis* layer of Ola Bula in which Verhoeven carried out his excavations (3 in Figure 2). The Ola Bula excavation has never yielded pygmy *Stegodon* spec. C or giant tortoise remains among the many fossils of *S. trigonocephalus florensis* originating from this layer (Hooijer 1957, 1972). Neither were *in situ* artifacts ever reported from the Ola Bula excavation. However, based on the presence of *Stegodon trigonocephalus florensis* at Ola Bula and Mata Menge it has already been suggested that these localities are both younger than the one near Tangi Talo (Sondaar 1987). This is confirmed by the lithostratigraphic correlations, the Tangi Talo locality being

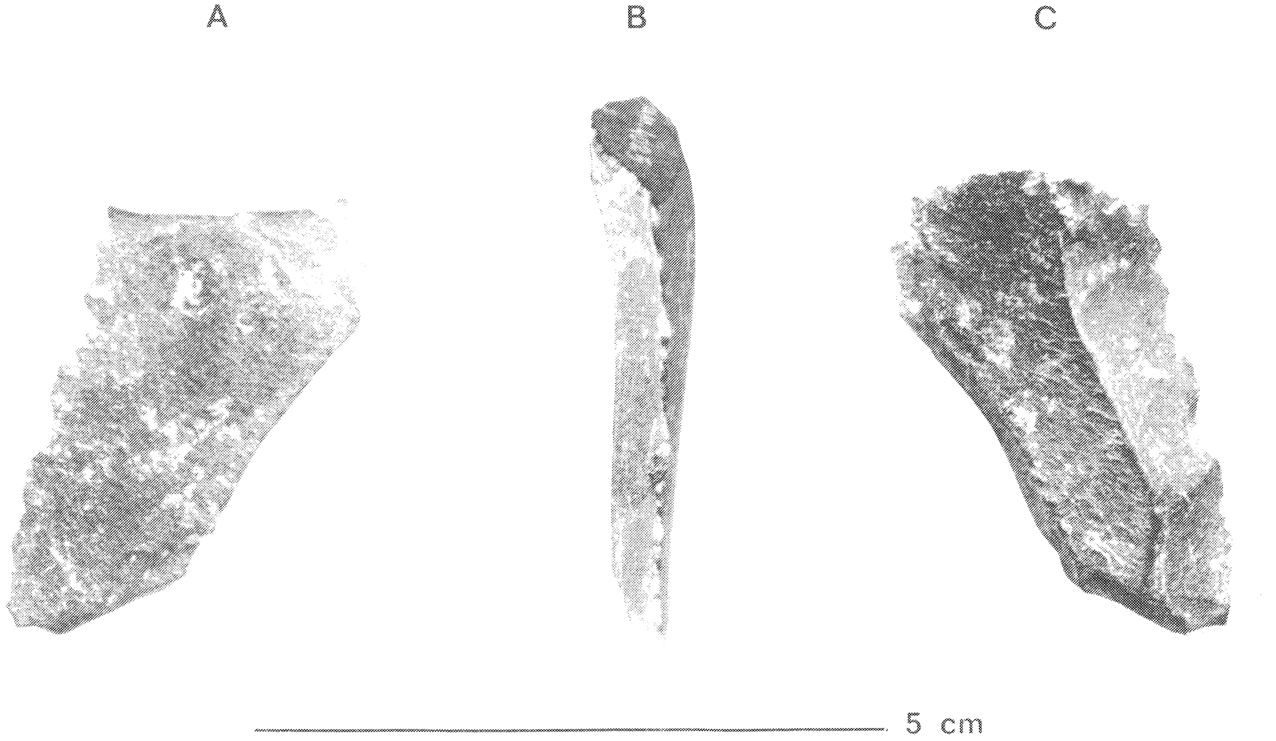

Figure 5: Small basalt flake, excavated from the siltsone interval in the Mata Menge excavation (see Figure 4 for the original location). Note the presence of the percussion bulb (A, B) and retouched edge (B). Natural size.

situated in the lower tuffaceous member of the Ola Bula Formation and the other fossil localities all pertaining to the upper fluvial member.

Paleomagnetic dating

The paleomagnetic results obtained by B. Mubroto (Figure 2) provide new evidence which supports such an interpretation. Samples from 19 levels in both measured sections were taken in order to determine the remanent magnetization. From each layer 5 to 6 oriented core samples were drilled, or an oriented block sample was cut using non-magnetic tools. The block-samples were further prepared in the laboratory. The Natural Remanent Magnetization was determined using a Schönsted DSM-2 spinner magnetometer. A stepwise alternating field demagnetization method was applied in steps of 5-20 mT up to a maximum peak field of 100 mT in order to examine the stability of magnetization. Three of the sampled horizons did not yield reliable demagnetization results and have been omitted further. From each of the other layers 4 to 6 samples gave satisfactory demagnetization curves and the average declination and inclination was calculated from these measurements.

The lower part of the Ola Bula Formation at the section Tangi Talo/Ola Bula is dominated by reverse polarities, including the layer which has yielded pygmy *Stegodon* spec. C and tortoise remains. Two of the six levels in the lower part however, have normal polarities (Figure 2). At present it is not clear whether these latter two normal polarities represent a short normal event, perhaps the Jaramillo Event at around 0.9 myr, or whether a secondary normal-magnetic overprint has not been successfully removed in these samples. In any case, the reversed polarities in the same interval indicate that this part of the sequence is at least older than the Matuyama-Brunhes boundary at 0.73 myr (Mankinen and Dalrymple 1979).

Above the reverse-dominated basal interval at Tangi Talo/Ola Bula there is an 18 m non-exposed interval in which no samples were taken. Above this non-exposed interval three sampled levels with normal polarities occur, situated 5-10 m below the excavation level of Verhoeven at Ola Bula. It follows that at least a transition from reversed to normal polarity should occur in the non-exposed interval. This transition most likely represents the Matuyama-Brunhes boundary as will be argued below.

At Mata Menge the Ola Bula Formation is thinner developed than near the type section at Ola Bula. At Mata Menge the lower part of the formation is 23 m thick from its base to the base of the limestone member (the equivalent litho-stratigraphic interval is at least 36 m thick in the Tangi Talo/Ola Bula section 2 km to the east). Near Mata Menge a transition from reversed to normal polarity takes place in between a 3 m thick palaeosoil overprinted on pumice-containing tuffaceous sediments (2 in Figure 2) and the top of the silty clay layer underlying the artefact-bearing sandstone layer. Samples from the middle of the palaeosoil provided a reversed polarity. The magnetic transition above this palaeosoil most likely represents the Matuyama-Brunhes boundary at 0.73 myr and not an older reversed-normal transition, based on paleontological evidence. It is unlikely that the Mata Menge artefact layer with *Stegodon trigonocephalus florensis* would be older than 1.2 myr, because *Stegodon* has its oldest occurrence on Java in the Ci Saat faunal stage (Sondaar 1984), which has an age of around 1.2 myr (Leinders et al 1985) (see also this volume, page 15: Ed.). As stated by Hooijer (1972), the *S. trigonocephalus* subspecies from Flores is more advanced in molar ridge-formula and hypsodonty than the Javanese subspecies, which is known from the Kedung Brubus fauna (de Vos *et al.* 1982). The Kedung Brubus fauna has an absolute age of between 0.8 and 0.7 myr (see van den Bergh *et al.* this volume). As it is unlikely that the Flores *Stegodon* from Mata Menge is older than its more primitive relative or even ancestor from the Kedung Brubus fauna, the observed transition from reverse to normal polarity in the Flores sections probably does not represent the base of the Jaramillo Event either. This renders one interpretation as the most likely one, namely that the transition represents the lower boundary of the Brunhes Epoch.

Because of the depositional hiatus indicated by the palaeosoil, the artefact bearing layer should be considered slightly younger than 0.73 myr, though there are no indications (such as a major erosional contact) that the hiatus would be larger than a few hundred thousands of years. The palaeosoil probably corresponds with a period of reduced deposition rates along the western margin of the basin, which is more distant from the volcanic source of sediment as compared to the Tangi Talo section.

DISCUSSION AND CONCLUSIONS

The faunal succession of Flores is represented in Figure 6. The paleomagnetic results suggest a late Early Pleistocene age for the Tangi Talo fauna and an early Middle Pleistocene age for the Mata Menge fauna. Considering the relatively old age of the latter, it must be concluded that the stone artefacts found in association with the Mata Menge fauna were the work of *Homo erectus*. An early Middle Pleistocene age for these artefacts is clearly too old for *Homo sapiens*.

	Tangi Talo	Mata Menge
Geochelone spec.	+	
Varanus komodoensis	+	
Stegodon spec. C (pygmy)	+	
S. trigonocephalus florensis		+
Hooijeromys nusatenggara		+
crocodile		+
stone artefacts		+

Figure 6: Faunal list for the Tangi Talo and Mata Menge terrestrial vertebrate faunas from Flores.

The new data here presented strongly suggest that *Homo erectus* was the first hominid to cross Wallace's line to the island of Flores at the beginning of the Middle Pleistocene. The colonization of the island by humans coincides with a faunal turnover on the island. An unbalanced endemic island fauna with a giant tortoise, a pygmy *Stegodon* and *Varanus komodoensis* was replaced by an endemic island fauna including *Stegodon trigonocephalus florensis* and a large murid *Hooijeromys nusatenggara,* this latter being associated with artefacts, indicating human presence. *Homo erectus* was apparently able to cross small water barriers already during the Middle Pleistocene.

ACKNOWLEDGEMENTS

This research was financially supported by the Netherlands Foundation for Tropical Research (WOTRO, grant W75-319), the Geological Research and Development Centre at Bandung, Indonesia, and the National Museum of Natural History at Leiden. We thank the Indonesian Institute of Sciences (LIPI) for the clearances to conduct research in Indonesia. We wish to express our gratitude to Iwan Kurniawan, Slamet Sudjarwadi and Reinier van Zelst, who joined the excavations. We are grateful to Emil Waso Ea, Musa Bali and the other local residents of Boawae, Ola Kile and Menge Ruda for their help and assistance in the field. Reinier van Zelst prepared Figure 5.

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