LETTERS

Early stone technology on Flores and its implications for *Homo floresiensis*

Adam Brumm[1], Fachroel Aziz[2], Gert D. van den Bergh[3], Michael J. Morwood[4], Mark W. Moore[4], Iwan Kurniawan[2], Douglas R. Hobbs[5] & Richard Fullagar[6]

In the Soa Basin of central Flores, eastern Indonesia, stratified archaeological sites, including Mata Menge, Boa Lesa and Kobatuwa (Fig. 1), contain stone artefacts associated with the fossilized remains of *Stegodon florensis*, Komodo dragon, rat and various other taxa. These sites have been dated to 840–700 kyr BP (thousand years before present)[1]. The authenticity of the Soa Basin artefacts and their provenance have been demonstrated by previous work[2–6], but to quell lingering doubts[7], here we describe the context, attributes and production modes of 507 artefacts excavated at Mata Menge. We also note specific similarities, and apparent technological continuity, between the Mata Menge stone artefacts and those excavated from Late Pleistocene levels at Liang Bua cave, 50 km to the west. The latter artefacts, dated to between 95–74 and 12 kyr ago[8,9], are associated with the remains of a dwarfed descendent of *S. florensis*, Komodo dragon, rat and a small-bodied hominin species, *Homo floresiensis*, which had a brain size of about 400 cubic centimetres[10,11]. The Mata Menge evidence negates claims that stone artefacts associated with *H. floresiensis* are so complex that they must have been made by modern humans (*Homo sapiens*)[7].

Mata Menge occurs in the 80–120-m-thick Ola Bula Formation, which was deposited between 960 and 700 kyr ago in a fluvio-lacustrine environment, probably by one or more distal volcanic fans entering a lake or small series of lakes[1]. The artefact- and bone-bearing deposits at Mata Menge lie between two tuffaceous silts with ascending zircon fission-track ages of 880 ± 70 kyr and 800 ± 70 kyr BP, respectively[1,4]. The nearby site of Boa Lesa also yielded a fission-track age of 840 ± 70 kyr BP for tuffaceous silt sealing in sandstones containing stone artefacts and *Stegodon* fossils[5,12] (see Supplementary Information). This provides a minimum age for the presence of hominins on Flores.

Our excavations at Mata Menge in 2004–05 (Fig. 2) yielded a total of 487 *in situ* stone artefacts. They had been subject to hydraulic transportation and size sorting—artefacts measuring less than 10 mm in maximum dimension appear to have been 'winnowed' by fluvial flow or wave action[13]. Nonetheless, the minimal degree of edge damage and abrasion to the surface indicate that the artefacts had not been exposed to prolonged water movement (52% fresh/unabraded, 35% slightly abraded and 13% heavily abraded)[14]. This analysis is based on the 507 stone artefacts excavated from Mata Menge in 1994 (refs 6, 12) and 2004–05 (Table 1), which comprise the largest and most securely dated Early Pleistocene assemblage from Island Southeast Asia.

Stone artefact technology at Mata Menge was simple, based on the removal of small- to medium-sized flakes from cobbles and flake blanks. Flakes were struck invasively and non-invasively across core faces by direct freehand percussion using a cobble or recycled core as a hammerstone. Other reduction techniques included the removal of elongated flakes down the edges of cores and flakes ('burination') (Fig. 3f) and anvil-supported percussion (truncation) (Fig. 3d; see also Supplementary Information). Dominant raw materials were moderate to low quality, volcanic/metavolcanic, fluvial cobbles (average maximum dimension: 33.1 ± 14.5 mm; range 15.6–87.2 mm) that were obtained locally and provided raw material for 91% of the artefacts ($N = 459$). In addition, 27 fine-grained chert, 13 chalcedony, four 'chlorite' and four 'opal' artefacts were recorded.

There are five core types in the assemblage: (1) radial cores with flakes struck towards the centre of the core face from a platform edge extending partially or completely around the periphery (Fig. 3a–d, f); (2) single platform cores with flakes removed unidirectionally from a single platform edge; (3) multiplatform cores with flakes removed irregularly from different platform edges; (4) assayed cobbles with one or more amorphous scars interpreted as the result of hominins testing raw materials for flaking quality; and (5) undiagnostic cores with ambiguous flake scar patterns. An average of six flakes were removed from the cores before discard, with the maximum recorded being 26.

Radial core reduction of both cobbles and flake blanks or fragments was the most common flaking strategy. Some radial cores were unifacially flaked ($N = 5$) but most were worked bifacially ($N = 36$); the rest ($N = 5$) are unclear. Mata Menge knappers generally proceeded in a series of unifacial removals followed by the removal of flakes from the opposite core face, while further reduction yielded multiplatform cores.

Flakes struck from cores were generally small to medium in size (average maximum dimension: 32.4 ± 12 mm; range 5–70.7 mm) and amorphous in shape (Fig. 3g–i). Most were probably produced and discarded on the spot, but large flakes made from fine-grained materials, such as chert (for example, Fig. 3a), appear to have been carried to Mata Menge from cores struck elsewhere.

Most flakes were discarded without further modification but some exhibited microwear (Fig. 3 h, i; see also Supplementary Information) or retouch, indicating use as tools. Unifacial or bifacial retouch by hard-hammer percussion was identified on 41 volcanic/metavolcanic, two chalcedony and two chert flakes (Fig. 3e). The average maximum dimension of retouched flakes (42.3 ± 12.9 mm; range 21.2–89.4 mm) was significantly larger than that of the scars on the cores (22.8 ± 10.4 mm; range 5.7–72 mm), indicating that the Mata Menge hominins generally selected larger flakes for retouching.

Most of the retouched flakes have unpatterned scars, interpreted as

[1]Department of Archaeology and Natural History, Research School of Pacific and Asian Studies, Australian National University, Canberra, Australian Capital Territory 0200, Australia. [2]Geological Research and Development Centre, Jalan Diponegoro 57, Bandung 40122, Indonesia. [3]Naturalis, the National Museum of Natural History, P.O. Box 9517, 2300 RA Leiden, The Netherlands. [4]Department of Archaeology and Palaeoanthropology, School of Human and Environmental Studies, University of New England, Armidale, New South Wales 2351, Australia. [5]School of Earth and Environmental Sciences, University of Wollongong, Wollongong, New South Wales 2522, Australia. [6]Department of Archaeology, A14, University of Sydney, Sydney, New South Wales 2006, Australia.

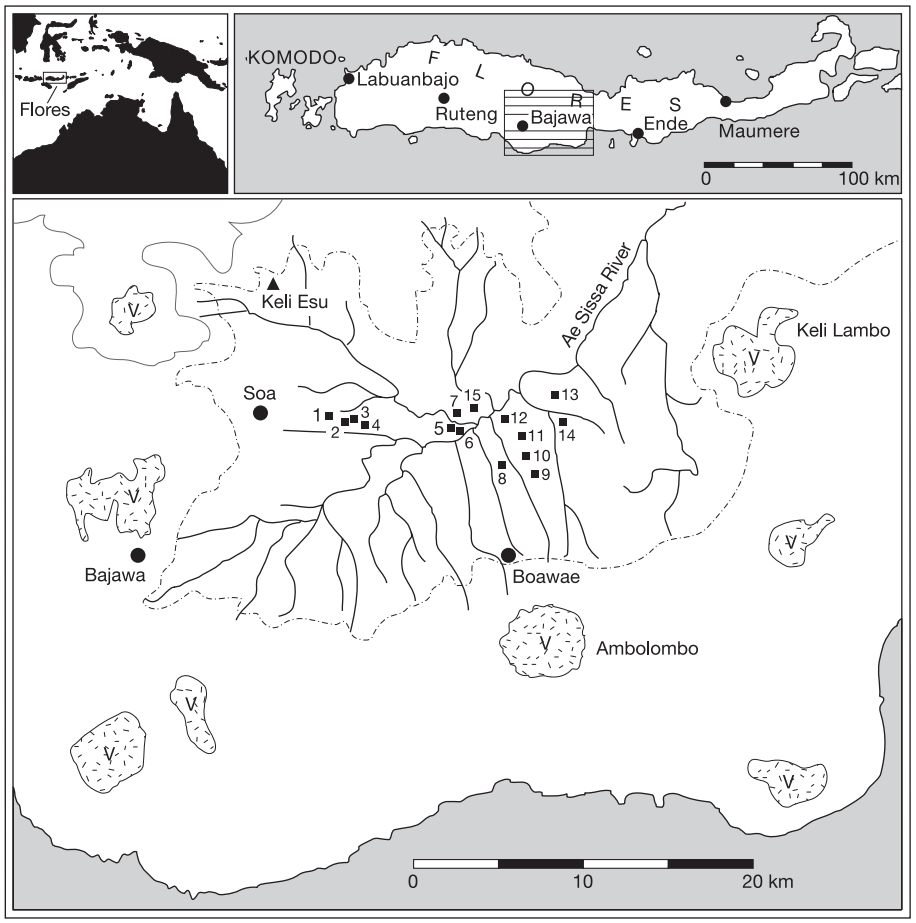

Figure 1 | Early and Middle Pleistocene sites in the Soa Basin of Flores. 1, Kobatuwa; 2, Mata Menge; 3, Lembahmenge; 4, Boa Lesa; 5, Ola Bula; 6, Tangi Talo; 7, Wolo Milo; 8, Wolokeo; 9, Sagala; 10, Dozu Dhalu; 11, Kopowatu; 12, Ngamapa; 13, Pauphadhi; 14, Deko Weko; 15, Malahuma. The dashed areas indicated with a V represent volcanoes. The broken line indicates the approximate boundary of the Ae Sissa River drainage basin.

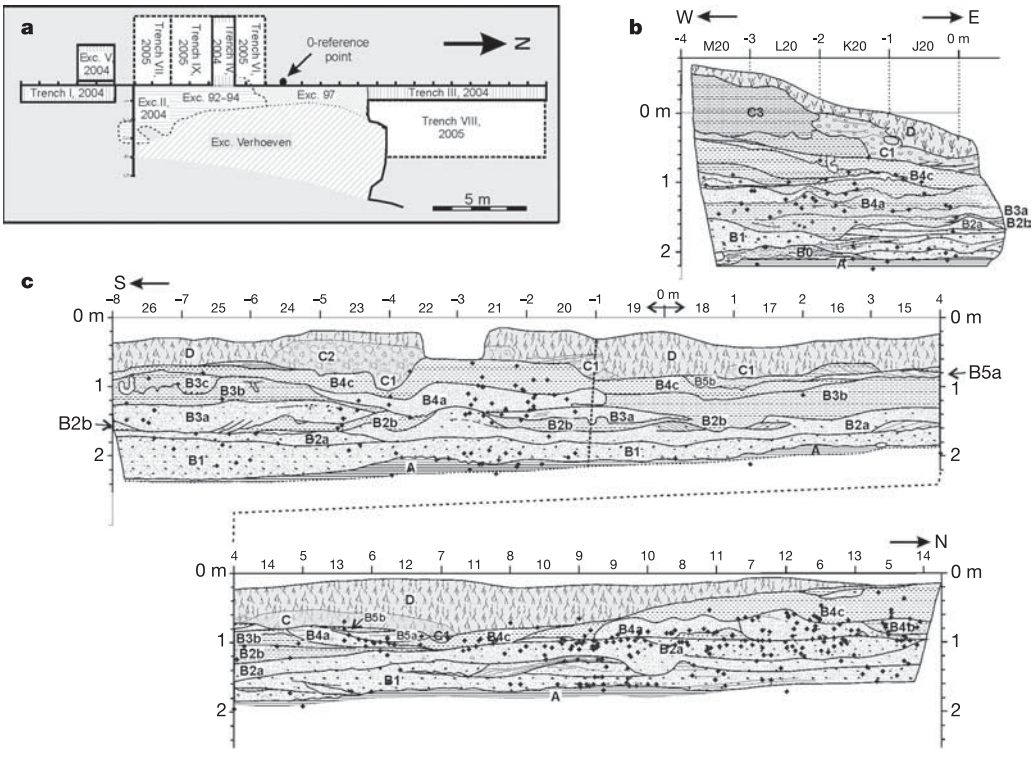

Figure 2 | Stratigraphic profiles and excavations at Mata Menge. **a**, Plan view of the excavation, showing the 2004–05 trenches and the extension of previous excavations. **b**, Profile of the north baulk of trench VI. **c**, Profile of the west baulks of excavation II/97 and trench III. Three distinct units can be distinguished: A is pink tuffaceous mudstone containing stone artefacts but no fossils; B is an alternation of well-consolidated grey tuffaceous sandstone and white/grey tuffaceous siltstones; C is an alternation of poorly consolidated pebbly sands and pink tuffaceous silts, largely overprinted by topsoil (D). Squares indicate the projected positions of stone artefacts.

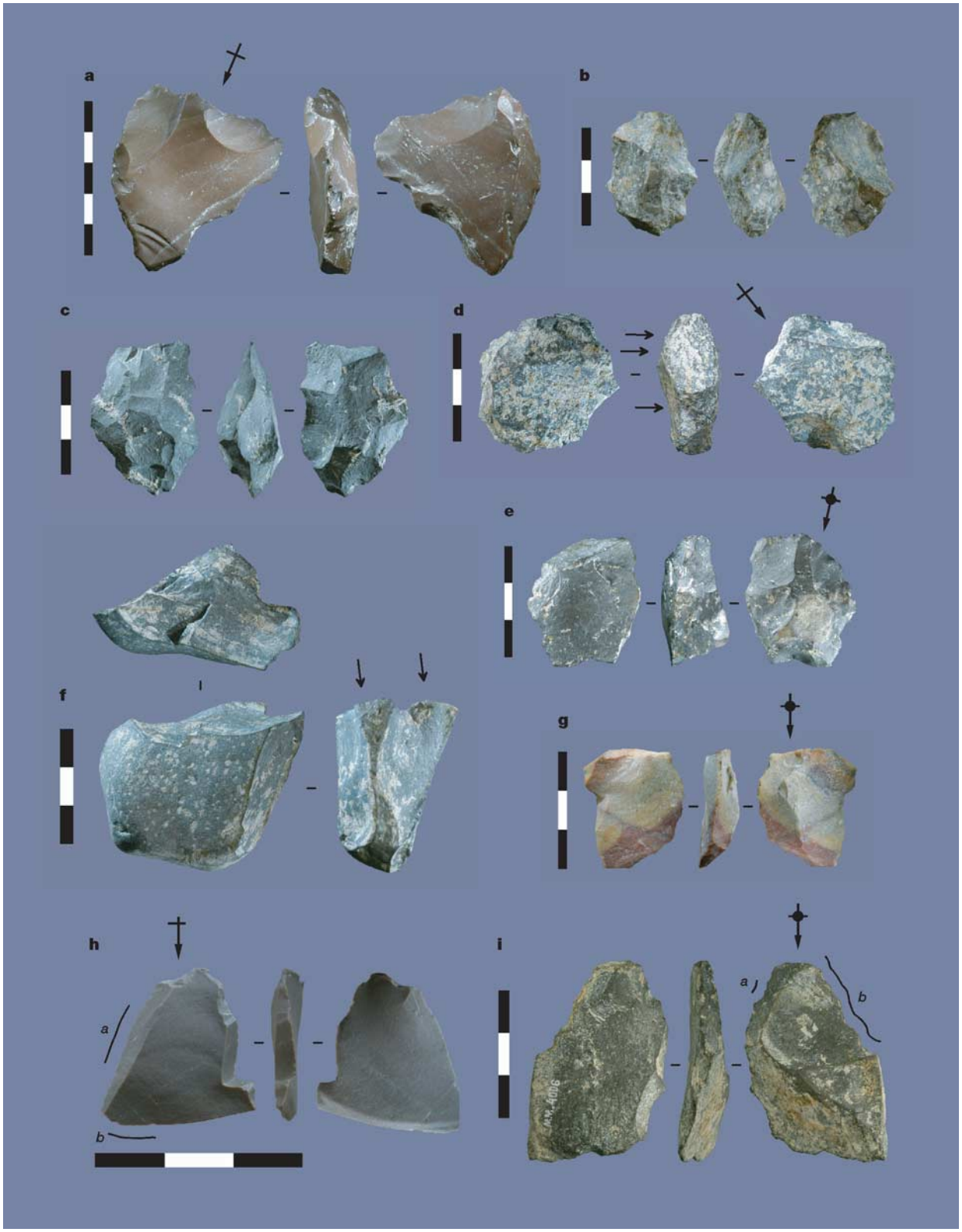

Figure 3 | **Stone artefacts from Mata Menge.** **a**, **b**, Chert bifacial radial cores; **a** is made on a flake. **c**, **d**, Volcanic/metavolcanic bifacial radial cores; **d** is made on a flake and features three truncation scars (indicated by small arrows). **e**, Volcanic/metavolcanic retouched flake. **f**, Volcanic/metavolcanic cobble radial core with two 'burination' scars (indicated by arrows). **g**, Chert flake. **h**, Chert flake with microwear in the form of edge rounding (*a*) and edge scarring (*b*). **i**, Volcanic/metavolcanic flake with microwear including abrasive smoothing and a grainy polish (*a*) and small scars and striations (*b*). Scale bars are in 10-mm increments.

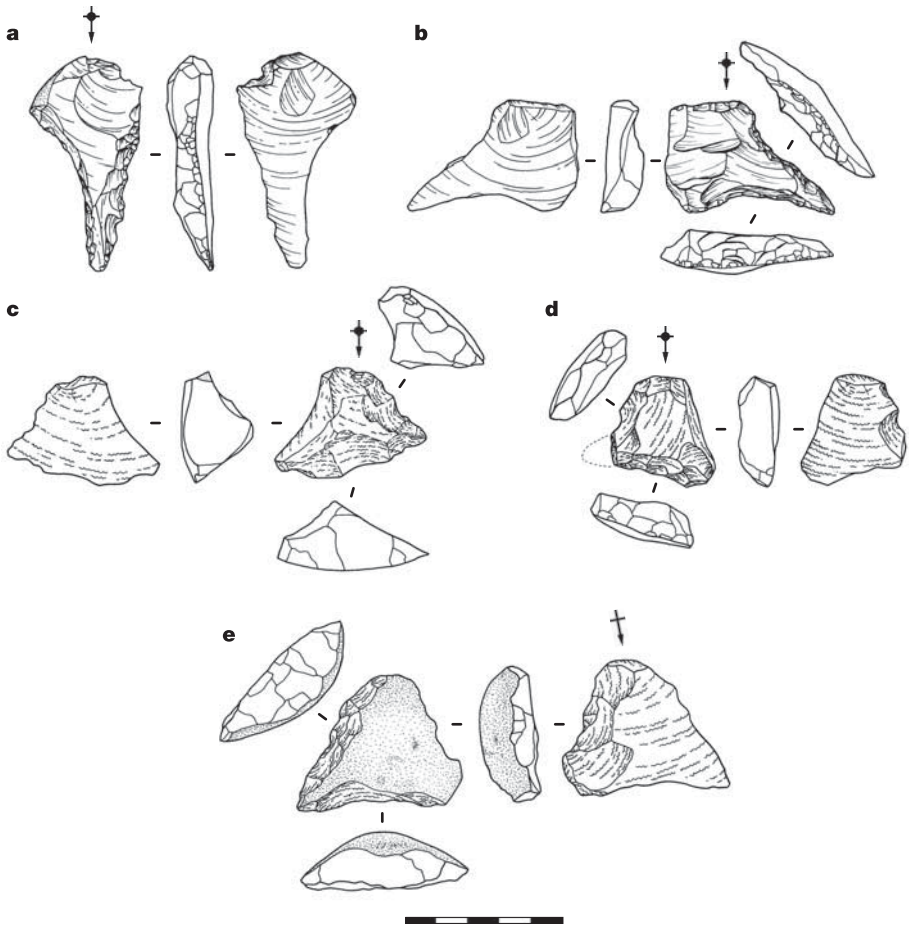

Figure 4 | Perforators from Mata Menge and Liang Bua. a, Chert perforator from between spits 60 and 71, sector VII, Liang Bua. **b**, Chert perforator from sector IV, spit 55, Liang Bua. **c–e**, Volcanic/metavolcanic perforators from stratified Early Pleistocene sediments at Mata Menge. Scale bar, 50 mm.

the result of casual rejuvenation of used edges, but five have extensive unifacial retouch forming a pointed projection on the margin or distal end (Fig. 4c–e). Similar deliberately shaped 'perforators' were also excavated at Boa Lesa[15].

Despite being separated by 50 km and at least 700,000 yr, there are remarkable similarities between the stone artefact assemblage from Mata Menge and that found with *H. floresiensis* at Liang Bua[16] (Table 1). For instance, both assemblages show an emphasis on the use of volcanic/metavolcanic fluvial cobbles as raw materials, along with the transportation of flake blanks for use as cores. Core reduction strategies at Mata Menge and Liang Bua are also very similar, with special emphasis on freehand reduction of cores both bifacially and radially. In fact, small, invasively reduced radial cores from the two sites are virtually indistinguishable. In addition, single platform cores, multiplatform cores, cores with 'burination' scars from the production of elongated flakes, 'truncated' flakes and cores indicating anvil-supported percussion and 'perforators' occur in both assemblages (Fig. 4). The maximum dimensions of flake scars on Mata Menge and Liang Bua cores are also very similar (Fig. 5; see also Supplementary Information). This is notable given that Liang Bua cores were more often on flakes, whereas Mata Menge cores were predominantly cobbles and hence tend to be bigger.

Differences between the assemblages include the fact that heat-fractured artefacts only occur at Liang Bua, whereas only one possible example of bipolar reduction of flake edges (relatively common at Liang Bua) was recorded at Mata Menge. Overall—and in spite of

Table 1 | Artefact types and frequencies from Mata Menge and Liang Bua

	Liang Bua		Mata Menge	
Type	*N*	Percentage	*N*	Percentage
Flake	3,264	90	294	57.9
Retouched flake	177	4.8	46	9.1
Radial core	103	2.8	46	9.1
Single platform core	2	0.1	7	1.3
Multiplatform core	25	0.6	10	1.9
Undiagnostic core	3	0.1	5	0.9
Assayed cobble	5	0.1	11	2.1
Cobble hammerstone	2	0.1	2	0.3
Radial core/hammerstone	0	0	1	0.1
Multiplatform core/hammerstone	2	0.1	2	0.3
Bipolar artefact	31	0.8	?	–
Cobble manuport	0	0	1	0.1
Shatter fragment	0	0	33	6.5
Heat-fractured piece	12	0.3	0	0
Undiagnostic/unidentified artefact	0	0	49	9.6
Total	3,626	100	507	100

The data from Liang Bua are derived from sector IV, spits 23–85.

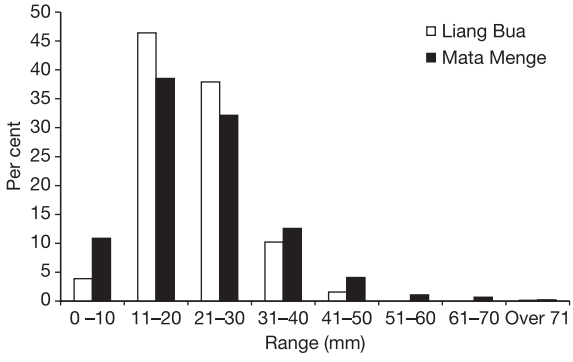

Figure 5 | Scar dimensions on Mata Menge and Liang Bua cores. The Liang Bua data come from spits 45–55, sector IV.

differences in sample size (Table 1)—a long-term technological theme involving the reduction of cores bifacially and radially, and the manufacture of a suite of technically and morphologically distinctive artefacts, is evident on Flores from at least 840 kyr ago right up to the disappearance of *H. floresiensis* 12 kyr ago[8,9]. In contrast, the first skeletal evidence currently available for modern humans on the island, at Liang Bua around 10.5 kyr BP, is associated with various changes and additions to the stone artefact record, including an increased emphasis on the use of chert and the appearance of new stone artefact types (for example, edge-glossed flakes, grinding stones), as well as the first evidence for symbolic behaviour, such as personal ornaments (for example, beads), pigments and formal disposal of the dead[9].

The stone artefact assemblages from Mata Menge and the Pleistocene levels of Liang Bua are remarkably similar. We still do not know the species identity of the Mata Menge knappers, as no associated hominin remains have been recovered so far, but the age of the site clearly precludes modern humans. At Liang Bua, however, the skeletal remains of at least nine individuals are represented in finds from the Pleistocene levels, and all diagnostic elements are of *H. floresiensis*[9]. The most parsimonious explanation for this is that the stone artefacts from Mata Menge and Liang Bua represent a continuous technology made by the same hominin lineage. Pronouncements that *H. floresiensis* lacked the brain size necessary to make stone artefacts[17] are therefore based on preconceptions rather than actual evidence.

Received 1 August 2005; accepted 1 February 2006.

1. O'Sullivan, P. B. *et al.* Archaeological implications of the geology and chronology of the Soa basin, Flores, Indonesia. *Geology* **29,** 607–610 (2001).
2. Maringer, J. & Verhoeven, Th. Die steinartefakte aus der *Stegodon*-fossilschicht von Mengeruda auf Flores, Indonesien. *Anthropos* **65,** 229–247 (1970).
3. Sondaar, P. Y. *et al.* Middle Pleistocene faunal turn-over and colonisation of Flores (Indonesia) by *Homo erectus*. *C.R. Acad. Sci.* **319,** 1255–1262 (1994).
4. Morwood, M. J., O'Sullivan, P. B., Aziz, F. & Raza, A. Fission-track ages of stone tools and fossils on the east Indonesian island of Flores. *Nature* **392,** 173–176 (1998).
5. Morwood, M. J. *et al.* Archaeological and palaeontological research in central Flores, east Indonesia: results of fieldwork 1997–98. *Antiquity* **73,** 273–286 (1999).
6. Morwood, M. J., Aziz, F., van den Bergh, G. D., Sondaar, P. Y. & de Vos, J. Stone artefacts from the 1994 excavation at Mata Menge, west central Flores, Indonesia. *Aust. Archaeol.* **44,** 26–34 (1997).
7. Lahr, M. M. & Foley, R. Human evolution writ small. *Nature* **431,** 1043–1044 (2004).
8. Morwood, M. J. *et al.* Archaeology and age of a new hominin from Flores in eastern Indonesia. *Nature* **431,** 1087–1091 (2004).
9. Morwood, M. J. *et al.* Further evidence for small-bodied hominins from the Late Pleistocene of Flores, Indonesia. *Nature* **437,** 1012–1017 (2005).
10. Brown, P. *et al.* A new small-bodied hominin from the Late Pleistocene of Flores, Indonesia. *Nature* **431,** 1055–1061 (2004).
11. Falk, D. *et al.* The brain of LB1, *Homo floresiensis*. *Science* **308,** 242–245 (2005).
12. van den Bergh, G. D. 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 Geol.* **117,** 1–419 (1997).
13. Schick, K. D. *Stone Age Sites in the Making: Experiments in the Formation and Transformation of Archaeological Occurrences* (BAR International Series 319, Oxford, 1986).
14. Shea, J. J. Artifact abrasion, fluvial processes, and "living floors" from the Early Paleolithic site of 'Ubeidiya (Jordan Valley, Israel). *Geoarchaeology* **14,** 191–207 (1999).
15. Maringer, J. & Verhoeven, Th. Notes on stone artefacts in the National Archaeology Institute of Indonesia at Djakarta, collected from the *Stegodon*-fossil bed at Boaleza in Flores. *Anthropos* **65,** 638–639 (1970).
16. Moore, M. W. *The Design Space of Lithic Technology*. Thesis, Univ. New England (2005).
17. Culotta, E. New 'hobbits' bolster species, but origins still a mystery. *Science* **310,** 208–209 (2005).

Supplementary Information is linked to the online version of the paper at www.nature.com/nature.

Acknowledgements Excavations at Mata Menge, funded by an Australian Research Council Discovery grant to M.J.M, were undertaken from 26 August to 29 September 2004 and 16 August to 23 September 2005. The work was done under GRDC survey/research permission letter 57/45.04/BMG/2004 to the Governor of NTT Province, Kupang. We received support from the Ngadha Regency Administration and Head of the Bajawa Culture and Tourism Office, I. Yusuf. Other participants included P. M. D. Moi, I. Botha, E. Yan Patriani, S. Sudjarwadi and 20 Ngadha people led by K. Podhi. The Secretary of Desa Mengeruda, G. Leo, provided further support. We also thank Ngaliman and Dadang for preparing the topographic map of the Mata Menge area, and J. Tode Solo for assistance in the field. The Department of Archaeology and Natural History, Research School of Pacific and Asian Studies, Australian National University funded A.B. S. O'Connor and D. Boyd are thanked for their support.

Author Contributions A.B. conducted the analysis and interpretation of the Mata Menge assemblage. F.A. and G.D.v.d.B. planned and directed the excavations in association with M.J.M. G.D.v.d.B. described the stratigraphy and prepared Fig. 2. D.R.H. was responsible for aspects of the archaeological fieldwork and prepared Fig. 1. I.K. assisted with the palaeontological research. M.W.M. assisted with the Mata Menge analysis, conducted the Liang Bua analysis and prepared Figs 3–5. R.F. conducted the microwear analysis.

Author Information Reprints and permissions information is available at npg.nature.com/reprintsandpermissions. The authors declare no competing financial interests. Correspondence and requests for materials should be addressed to A.B. (adam.brumm@anu.edu.au) or M.J.M. (mmorwood@pobox.une.edu.au).