Available online at www.sciencedirect.com
ScienceDirect
Journal of Human Evolution 52 (2007) 85–102

Stone artifacts and hominins in island Southeast Asia: New insights from Flores, eastern Indonesia

Mark W. Moore [a,*], Adam Brumm [b]

[a] *Department of Archaeology and Palaeoanthropology, School of Human and Environmental Studies, University of New England, Armidale, New South Wales, 2351, Australia*
[b] *Department of Archaeology and Natural History, Research School of Pacific and Asian Studies, Australian National University, Canberra, ACT, 0200, Australia*

Received 27 February 2006; accepted 4 August 2006

Abstract

This study reexamines the current understanding of Pleistocene stone-artifact assemblages in island Southeast Asia. A differentiation has long been made between assemblages of large-sized ‘‘core tools’’ and assemblages of small-sized ‘‘flake tools.’’ ‘‘Core tool’’ assemblages are often argued to be the handiwork of early hominin species such as *Homo erectus*, while small-sized ‘‘flake tool’’ assemblages have been attributed to *Homo sapiens*. We argue that this traditional Southeast Asian perspective on stone tools assumes that the artifacts recovered from a site reflect a complete technological sequence. Our analyses of Pleistocene-age artifact assemblages from Flores, Indonesia, demonstrate that large pebble-based cores and small flake-based cores are aspects of one reduction sequence. We propose that the Flores pattern applies across island Southeast Asia: large-sized ‘‘core tool’’ assemblages are in fact a missing element of the small-sized flake-based reduction sequences found in many Pleistocene caves and rock-shelters. We conclude by discussing the implications of this for associating stone-artifact assemblages with hominin species in island Southeast Asia.

Keywords: Island Southeast Asia; Mata Menge; Liang Bua; Stone artifacts; Flores; Early hominins; Reduction sequence

Introduction

> My own research has told me very clearly that what one researcher calls a middle Pleistocene chopper could well be a discarded waste core less than 10,000 years old (Bellwood, 1997: 57).

Movius (1943, 1944, 1948) observed over 60 years ago that the artifact types marking Old World Paleolithic sites are mostly absent from sites in the Pleistocene Far East. Old World typological schemes are said to be inappropriate east of the ‘‘Movius Line’’ (Coon, 1966: 47–48), a boundary drawn from northwest to southeast from the Himalayas to the northern tip of the Bay of Bengal west of the Ganges-Brahmaputra delta (Swartz, 1980). Archaeologists working east of the Movius Line have devoted much effort to defining types with chronological and stratigraphic meaning comparable to those that have been the mainstay of stone-artifact comparisons elsewhere (Boriskovsky, 1966; Solheim, 1969; Yi and Clark, 1983; Huang, 1987; Jia and Huang, 1991; Schick, 1994; Ranov, 1995; Hou et al., 2000; Keates, 2002; Corvinus, 2004). However, as meaningful, fine-grained typological categories have proven elusive (Schick, 1994; Keates, 2002; Corvinus, 2004), many archaeologists have turned to gross morphological differences between assemblages. An important distinction to emerge in island Southeast Asia is the dichotomy between large-sized, pebble-based ‘‘core tool’’ industries and small-sized, flake-based ‘‘flake tool’’ industries. In a recent synthesis, Bellwood (1997) referred to these, respectively, as the

---

* Corresponding author. Tel.: +61 2 6773 5075; fax: +61 2 6773 3030.
E-mail addresses: mmoore5@une.edu.au (M.W. Moore), adam.brumm@anu.edu.au (A. Brumm).

0047-2484/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jhevol.2006.08.002

"chopper/chopping-tool industries" and the "pebble-and-flake technocomplex." As reviewed below, there is widespread acceptance that this pattern is chronologically meaningful and resulted from knapping by two hominin species, although debates revolve around the details.

Here, we argue that the "core tool"/"flake tool" dichotomy cannot be supported. We begin by reviewing the history of the concept and show how the dichotomy has been interpreted in cultural-historical terms. We then assess the dichotomy in the context of two Pleistocene lithic assemblages recently excavated on the island of Flores, Indonesia: Liang Bua Cave (Morwood et al., 2004, 2005; Moore, 2005) and Mata Menge (Morwood et al., 1997, 1998, 1999; Brumm et al., 2006) (Fig. 1). We argue that "core tool" and "flake tool" assemblages are aspects of one reduction sequence, a point obscured by the static nature of the typological approach commonly applied in the region. We conclude by discussing the implications of this for using stone artifacts to assess hominin phylogenetics (e.g., Foley and Lahr, 1997, 2003) in island Southeast Asia.

The "core tool"/"flake tool" dichotomy in Pleistocene research

"Core tool" assemblages in Pleistocene island Southeast Asia

In 1920s and 1930s Europe, Pleistocene chronologies were based on the identification of river-terrace marker horizons deposited during glacial or interglacial events (Breuil, 1926, 1939; Burkitt, 1922; Paterson, 1940, 1941; Dennell, 1990). The first researchers to begin systematic investigation of the Far Eastern Paleolithic record in the early 1930s sought to establish a terrace-based geochronological framework compatible with the terrace sequence in Europe (for Myanmar, see Morris, 1932, 1935; de Terra, 1938, 1939, 1943a; de Terra et al., 1938; for China, see Teilhard de Chardin, 1937a, 1941; Teilhard de Chardin and Young, 1935; Teilhard de Chardin et al., 1935; de Terra, 1941; for Indonesia, see Teilhard de Chardin 1937b; van Stein Callenfels, 1934: 255; de Terra, 1943b; see Anderson, 1997 and Pope, 1997 for discussion).

The German paleontologist von Koenigswald (1936) described the "Pacitanian" industry based on his work in the Baksoka River valley of southern Java. The Pacitanian is the best-known example of a putative Pleistocene stone-tool industry in island Southeast Asia dominated by large "core tools" made from pebbles (Fig. 2).[1] Another well-known large "core tool" assemblage from the region is the Hoabinhian industry (Gorman, 1971; White and Gorman, 2004). First reported in Vietnam, the Hoabinhian is a pebble-based industry generally thought to date to the terminal Pleistocene/early–middle Holocene (Fig. 3). The Hoabinhian is thought to be a manifestation of a Paleolithic tradition that persisted into the Holocene (Solheim, 1969: 128; Bellwood, 1997: 58, 171–172). Solheim (1969: 128) considered the Hoabinhian to have evolved from Movius's (1944) chopper/chopping-tool industry "in an apparently straight line with the only change being … a slow improvement of workmanship."

Archaeologists have long suggested that systematic flake production was absent in the Pacitanian (Mulvaney, 1970; Hutterer, 1977: 48; Ikawa-Smith, 1978: 3; Bartstra, 1984: 254; Hutterer, 1985: 11; Anderson, 1990; Veth et al., 1998a). Although von Koenigswald (1936) acknowledged the presence of flake tools, they suggested to him an Old World "Clactonian" influence. He placed little emphasis on the role of flakes in the industry, arguing instead that Pacitanian knappers were focused on "core tool" production. Later, Movius (1944, 1948) and van Heekeren (1955) drew attention to the significant proportion of flakes in the Pacitanian. However, as Mulvaney (1970: 185) noted, the terminology they employed obscured the role of flake production since the authors emphasized choppers, chopping tools, protohandaxes, and other types of "core tools" in their descriptions (see also Bartstra, 1976: 78; Anderson, 1990). Movius (1944: 93, 1948: 355), in particular, argued that the unretouched flakes in the industry were unwanted by-products of "core tool" manufacture. The role of flakes in the Hoabinhian industry was portrayed in the same terms (e.g., van Heekeren and Knuth, 1967: 23); flakes were downplayed or ignored altogether as the by-products of making "core tools": "interassemblage comparisons have been based largely on the mere presence or absence of … flaked cobbles" (White and Gorman, 2004: 413).

"Flake tool" assemblages in Pleistocene island Southeast Asia

Von Koenigswald (1936: 52) claimed to have recovered Paleolithic stone implements from high terrace gravels at the famous Ngandong hominin fossil site, central Java, in 1932 (see also van Stein Callenfels, 1934, 1940; de Terra, 1943b: 454; van Heekeren, 1972, Bartstra et al., 1988; Soejono, 2001: 147). Movius (1948: 354–355) later described the "Ngandong industry" as consisting of "rather crude and small (less than 7 centimeters long) … flakes and blades, although a few cores occur as well." Movius noted that most of the material was rather poorly provenienced and probably composed of a mixture of artifacts from different time periods (for contemporary critiques, see van Stein Callenfels, 1934, 1940; von Heine-Geldern, 1945: 154). He observed that identical lithic material was found throughout the Notopuro series, implying that the Ngandong industry was contemporaneous with makers of the Sangiran flake industry (see below). Bartstra et al. (1988: 332) later confirmed the presence of small cores and flakes (<50 mm in length) made from siliceous stones in the

---

[1] Key papers in the development and evolution of the "Pacitanian" concept and salient commentaries include von Koenigswald, 1936; van Stein Callenfels, 1940; McCarthy, 1940; Movius, 1944; von Heine-Geldern, 1945; Clark, 1946; Braidwood, 1947; Movius, 1948; van Heekeren, 1955, 1957; Soejono, 1961; de Sieveking, 1962; Oakley, 1963; Coon, 1966; Mulvaney, 1970; Ghosh, 1971; van Heekeren, 1972; Glover, 1973; Harrisson, 1975; Bartstra, 1976; Hutterer, 1977; Bartstra, 1978a,b; Marks, 1982; Hutterer, 1985; Bellwood, 1987; Jones, 1989; Allen, 1991; Bartstra, 1992; Reynolds, 1993; Pope and Keates, 1994; Bartstra, 1994; Bellwood, 1997; Keates and Bartstra, 2001; Simanjuntak, 2004.

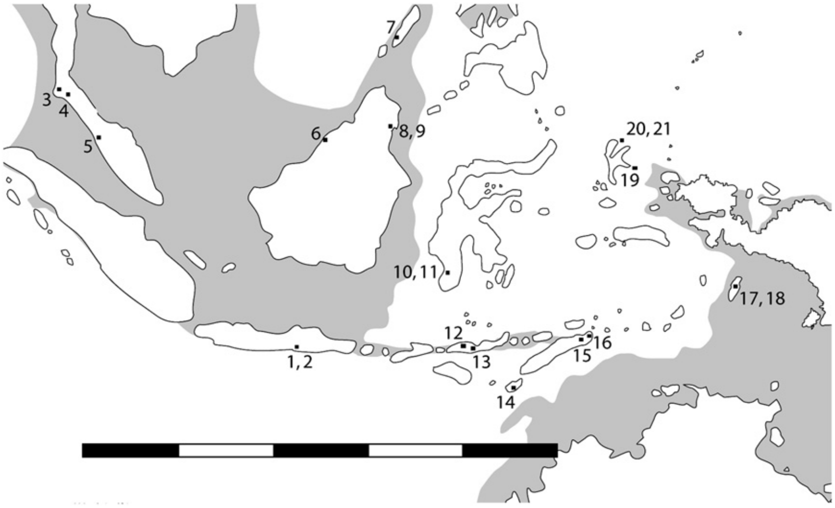

Fig. 1. Map of island Southeast Asia showing places mentioned in text. 1: Pacitan (Baksoka River valley); 2: Song Terus; 3: Lang Rongrien; 4: Moh Khiew; 5: Kota Tampan, Bukit Bunuh, Bukit Jawa, Lawin, Temelong; 6: Niah Cave; 7: Tabon Cave; 8: Hagop Bilo; 9: Madai; 10: Leang Sakapao 1; 11: Leang Burung 2; 12: Liang Bua; 13: Mata Menge; 14: Pia Hudale; 15: Uai Bobo 2; 16: Lene Hara; 17: Liang Nabulei Lisa; 18: Liang Lemdubu; 19: Golo Cave; 20: Daeo Cave 2; 21: Tanjung Pinang. Site 19 is on Gebe Island and sites 20 and 21 are on Morotai Island. Grey shaded area indicates the late Pleistocene coastline. Scale = 2500 km (base map courtesy of D. Hobbs).

''Solo High Terrace'' at Ngandong. No absolute dates were available, but based on geomorphological evidence, they argued that the artifact-bearing deposits are Pleistocene in age (ca. 135 ka). The authors also observed that, in addition to small artifacts, ''occasionally larger pebbles of volcanic material or fossil wood were transformed into heavier-duty chopping instruments'' at Ngandong (Bartstra et al., 1988: 332).

The Sangiran flake industry was first reported by von Koenigswald (1936), who recovered an assemblage of small-sized siliceous artifacts in stream-laid sediments capping the Ngebung hills at Sangiran, near the Solo River of Java, in 1934 (von Koenigswald, 1936: 52, 1937: 29, 1978). Von Koenigswald and Ghosh (1973) later described the Sangiran flake industry based on artifacts supposedly recovered from the hominin-bearing Kabuh Bed (Trinil) sediments at Ngebung between 1934 and 1941. The authors thought that *Homo erectus* manufactured the small-sized stone artifacts; however, in the same paper they revealed that the Sangiran flake industry was recovered from unstratified surface contexts: ''we had only limited chances to collect specimen [sic] in situ. Therefore the series of implements, described here, have entirely been collected from the surface, and it is for that reason that for so long we have hesitated to describe them'' (von Koenigswald and Ghosh, 1973: 2).

Recently, artifacts attributed to the Sangiran flake industry were excavated from the ''Grenzbank'' formation at Sangiran (Widianto et al., 2001), a calcareous channel-lag deposit intermediate between the Pucangan and Kabuh Series (see Sudijono, 1985). The Grenzbank is argued to be more than 800 kyr old (Bellwood, 1997: 65; Widianto et al., 2001 [Stone 2006 reported much earlier stone artifacts from below the Grenzbank]). These artifacts show that hominins at that time were selecting flakes of fine-grained material measuring between about 40 mm and 50 mm in their largest dimensions and reducing them as bifacial radial cores (Aziz et al., n.d.). The early age for the Sangiran flake industry is not without controversy (Keates, 1998: 184; Corvinus, 2004). Bartstra (1985) noted that small flake-based artifacts attributed to the Sangiran flake industry occurred primarily in the uppermost alluvial layers capping the Ngebung hills, and he estimated a minimum age of 135 ka for these artifacts (Bartstra, 1985; Bartstra and Basoeki, 1989). Sémah et al. (1992; Simanjuntak and Sémah, 1996; Simanjuntak, 2001; Sémah et al., 2003) have also reported the discovery of a middle Pleistocene

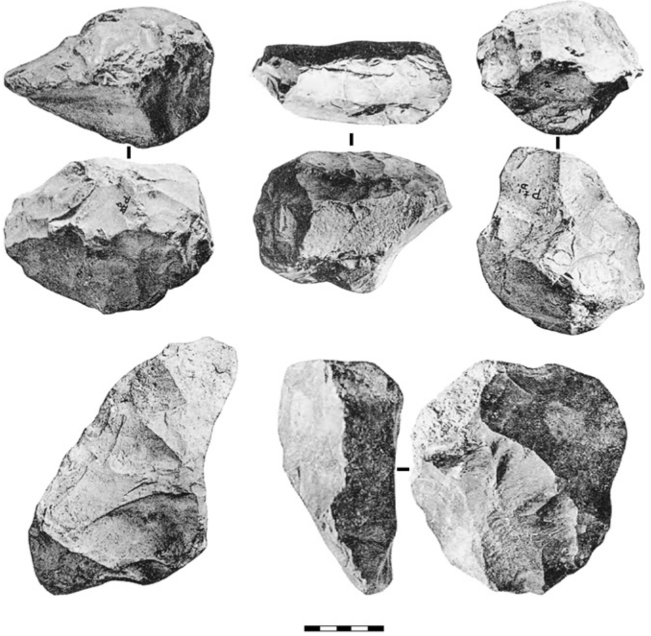

Fig. 2. Pacitanian ''core tools'' collected by von Koenigswald in Java (after Movius, 1944). Scale = 50 mm.

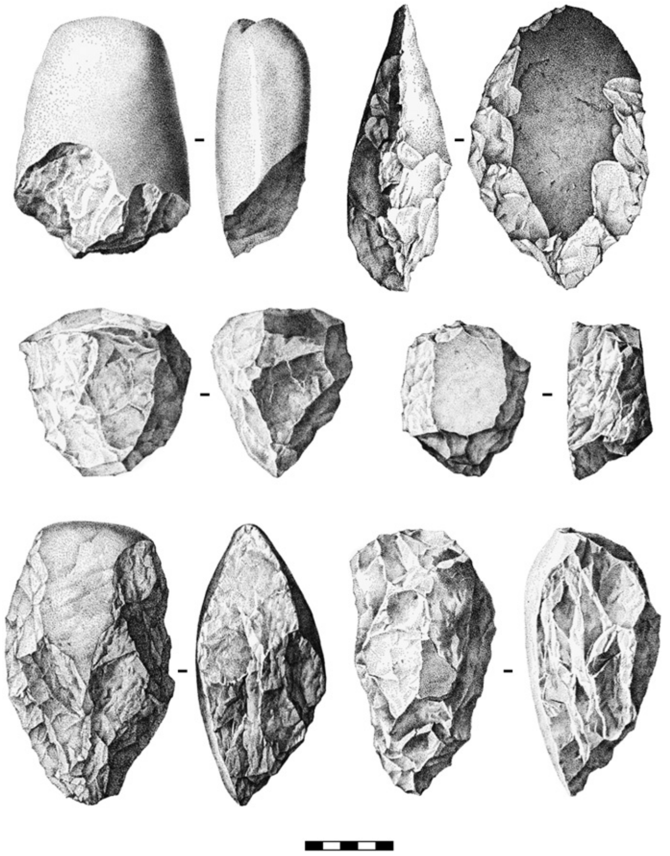

Fig. 3. Hoabinhian "core tools" from Kanchanaburi Province, Thailand (after van Heekeren and Knuth, 1967). Scale = ca. 50 mm.

"paleosurface" and other discrete archaeological "floors" containing at least 20 small flake-based artifacts from the lower part of the Kabuh layers at Ngebung. The largest flake recovered measured 36 mm in length. Significantly, large artifacts are also present, including big "bola" stones, choppers, spheroids, and cleavers manufactured mostly from local fine- and coarse-grained andesitic stones.

It was not until the 1950s and 1960s, with the development of radiocarbon dating, that the locus of Pleistocene archaeological excavations shifted from open-air river-terrace sites to stratified caves and rock-shelters (e.g. Harrisson 1957, 1959; Fox 1970, 1978; see Pope, 1997 for discussion). The results of these excavations emphasized the importance of small-sized flake-based assemblages in Pleistocene island Southeast Asia (Ikawa-Smith, 1978; Anderson, 1990).

The evidence for later Pleistocene "flake tool" industries—the assemblages Bellwood (1997) assigned to his "pebble-and-flake technocomplex"—derives mostly from island Southeast Asian caves and rock-shelters (Table 1). These assemblages are characterized by the presence of small-sized unmodified flakes, retouched flakes, and cores (Fig. 4). According to Bellwood, the earliest known manifestation of the pebble-and-flake technocomplex occurs at Lang Rongrien rock-shelter in Thailand, dating to about 43 ka (Anderson, 1988, 1990, 1997). Another early pebble-and-flake technocomplex assemblage is documented at Leang Burung 2 on Sulawesi, dating to between about 31 ka and 19 ka (Glover, 1981). O'Connor et al. (2002b) report a similar flake-based assemblage from the 30–35 ka Lene Hara cave site in East Timor. Small flakes dominate the 28.58 ka assemblage from Liang Lemdubu cave in the Aru Islands (Veth et al., 1998a,b; O'Connor et al., 2002a, 2005b; Hiscock, 2005). At both Niah Cave (Harrisson, 1957, 1959; Majid, 1982; Barker et al., 2002b: 129) and Tabon Cave (Fox, 1970)—both dated to ca. 40–50 ka—Pleistocene stone-tool technologies were based on the use of mostly small, amorphous flakes that were brought into the caves; large cores formed a statistically insignificant proportion of these assemblages (Anderson, 1990). The flaked-stone assemblage from the Hagop Bilo rock-shelter in eastern Sabah (Borneo), associated with an uncalibrated radiocarbon age of 17.9 ± 0.2 ka, is described in similar terms (Bellwood, 1988). So too are the stone assemblages from several late Pleistocene cave and rock-shelter sites in the northern Moluccas group, eastern Indonesia, which collectively span the period between around 33 ka and 10 ka (Bellwood et al., 1998). The lithic assemblage from the 16.2–12 ka (cal.) site of Liang Nabulei Lisa in the Aru Islands is also composed of small flakes and tools (O'Connor et al., 2005b).

Bellwood (1997) argued that Pleistocene and Holocene technological innovations in various parts of Indonesia—such as the backed and unifacially retouched points on Java's Bandung Plateau, the backed microliths and bifacial points of the Taolian industry on Sulawesi, widespread blade-making techniques, and Neolithic tools such as quadrifacial adzes—were grafted onto a pebble-and-flake-technocomplex-base technology (see also Presland, 1980). In some parts of Indonesia, no such technological elaboration occurred and the pebble-and-flake technocomplex persisted until relatively recently (Bellwood, 1997: 58, 172).

Attempts at extracting meaning from the patterns

There are several schools of thought about the meaning of these patterns. The traditional position is that the "core tool" industries are earlier than the "flake tool" industries, and, because they are said to date so early, the "core tools" are inferred to be the handiwork of *Homo erectus* or a taxonomically indeterminate early hominin. For instance, Simanjuntak (2004) argued that the lack of large "core tools" in the earliest deposits of Song Terus cave in south Java (van Heekeren, 1955; Simanjuntak, 1996; Sémah et al., 2003, 2004) implies that the Pacitanian industry and its makers must predate the oldest artifacts from the cave. On this basis, a succession of hominins is inferred to have occurred on Java prior to 180–60 ka. As Simanjuntak (2004: 15) concluded:

> The distribution of [Pacitanian artifacts] along river courses [in eastern Java] suggests that life in the past was perhaps nomadic, within [sic] groups of [early hominins] following the course of rivers and exploiting available natural resources. … cave life apparently did not have any great

Table 1
Sites in island Southeast Asia with Pleistocene stone-artifact assemblages

Site name	Site type	Location	Maximum age	Stone reduction technology	References
Bukit Jawa, Lawin, Temelong	Open-air fluvial contexts	West Malaysia	200 ka or 50–100 ka	These three open-air sites, probably in a lakeshore setting, consist of primary-stone reduction areas or ‘‘lithic workshops’’ containing profuse numbers of simple cores, flakes, amorphous chunks, debitage, anvils, and hammerstones from the in situ reduction of locally available fluvial pebbles. The technology at these sites is argued to be similar but antecedent to the technology from Kota Tampan.	Majid, 1997, 2003
Song Terus	Cave	Java	ca. 180 ka	Many of the stone artifacts from the earliest deposits are water-rolled and probably redeposited from outside the cave. However, available descriptions of the technology imply that large, amorphous flakes were brought into the cave from cores struck elsewhere—the assemblage contains no large flaked pebbles or cores.	Sémah et al., 2003, 2004; Simanjuntak, 2004
Kota Tampan	Open-air fluvial context	West Malaysia	74 ka	Kota Tampan reputedly consists of an open-air stone-reduction area or ‘‘lithic workshop’’ containing a large number of flaked quartzite pebbles, flakes, amorphous detached pieces, and hammerstones found in association with small boulders used as anvils. The fluvial deposits formed in low-energy lakeshore conditions. The stones used for knapping were probably introduced to the site.	Majid and Tjia, 1988; Majid, 1990, 2003
Tabon	Cave	Palawan	ca. 58–30 ka	The technology is not fully described; however, reports suggest that amorphous flakes were brought into the cave from cores struck elsewhere. Large cores or flaked pebbles are rare in the assemblage.	Fox, 1970, 1978; Détroit et al., 2004
Niah	Cave	Sarawak (Borneo)	44–43 ka	The technology is not well-documented. Available evidence suggests that small, amorphous flakes were brought into the cave and minimally reduced. Large cores or flaked pebbles formed statistically insignificant proportions of the assemblage.	Barker et al., 2000, 2001, 2002a, b
Lang Rongrien	Rock-shelter	Thailand	>43 ka	Although only 45 stone artifacts were recovered from the basal deposits, 47.9% of these consisted of small retouched flakes or flake tools. Flakes were presumably brought into the site because no matching cores and no decortication flakes were recovered.	Anderson, 1988, 1990, 1997
Bukit Bunuh	Open-air fluvial context	West Malaysia	39 ± 2.6 ka	Detailed descriptions of the technology are not yet available; however, strong affinities with the Kota Tampan technology are implied.	Majid, 2003; Roberts et al., 2005
Lene Hara	Cave	East Timor	35–30 ka	The over 400 artifacts from Lene Hara consist primarily of small unretouched flakes that were presumably introduced to the cave from cores struck elsewhere.	O’Connor et al., 2002b
Golo	Cave	Gebe Island, northern Moluccas	32 ka	Medium (ca. 21–50 mm in maximum dimensions) and large-sized flakes and flake fragments (>21 mm in maximum dimension) were brought into the cave from cores struck elsewhere. Smaller flakes (<20 mm in maximum dimension) were probably manufactured inside the cave itself, although some may also have been transported from reduction areas located outside the cave.	Bellwood et al. 1998; Szabó et al., submitted for publication
Leang Burung 2	Rock-shelter	Sulawesi	31 ka	Stone technology was focused on the reduction of small flakes and flake fragments which were brought into the shelter from cores struck elsewhere. The majority of lithic material consisted of unretouched and nonutilized flakes, most of which measured between 20–30 mm in length. Cores ($n = 26$) constituted 0.5% of the assemblage.	Glover, 1978; Presland, 1980; Glover, 1981
Leang Sakapao 1	Cave	Sulawesi	30–20 ka, 28–22 ka	Stone technology was based on the production of large-to-medium-sized flakes from unmodified or partially worked chert nodules that were brought into the cave. Some large flakes were also used as cores. The mean length of complete flakes was around 25 mm; however, flakes measuring up to and over 90 mm in length were recorded. A total of 24 cores were recovered, constituting 2.9% of the assemblage.	Bulbeck et al., 2004

(*continued on next page*)

Table 1 (*continued*)

Site name	Site type	Location	Maximum age	Stone reduction technology	References
Liang Lemdubu	Cave	Aru Islands	28.58 ka	Stone technology involved the minimal retouch of flakes that were struck elsewhere and brought into the cave. The artifact assemblage was dominated by flakes (98.5%), only a few of which were retouched. There was an almost complete absence of cores. Flakes brought into the cave were quite small. The complete flakes have a mean percussion length of 14.2 mm.	Hiscock, 2005; O'Connor et al., 2005b
Moh Khiew	Rock-shelter	West Malaysia	27.1 ± 0.615 ka	Published descriptions of the technology offer little detail. In terms of raw material and typology, however, the artifacts are described as being very similar to those recovered from nearby Lang Rongrien.	Pookajorn, 1994a, b, 1996
Hagop Bilo	Rock-shelter	Sabah (Borneo)	17 ka	Small, amorphous flakes were carried into the site from larger cores struck elsewhere.	Bellwood, 1988, 1997
Liang Nabulei Lisa	Cave	Aru Islands	16.2–12 cal ka	Available descriptions imply the expedient use of small, amorphous unretouched flakes, the majority of which appear to have been carried into the site from cores struck elsewhere.	O'Connor et al., 2005a
Daeo Cave 2	Cave	Morotai Island, northern Moluccas	15.5 ka	Available descriptions imply the expedient use of small, amorphous unretouched flakes, the majority of which appear to have been carried into the site from cores struck elsewhere. Some cores from local beach pebbles were also present, although these are not fully described (P. Bellwood, pers. comm.).	Bellwood et al., 1998
Uai Bobo 2	Cave	East Timor	14.8 ka	Stone technology was focused on the production of small flakes that were used as light-duty cutting and scraping tools, and the retouch of large flakes. Most large flakes were struck elsewhere and carried into the cave.	Glover, 1972, 1986
Pia Hudale	Rock-shelter	Roti Island	12–11.5 ka	Stone technology was based on the production of small, mostly unretouched, flakes from chert nodules and cores (maximum dimension ca. 60 mm) that are thought to have been brought into the cave. The average maximum dimension of cores in the assemblage was 28 mm.	Mahirta et al., 2004
Madai	Cave	Sabah (Borneo)	11 ka	The technology was apparently based on the reduction of chert nodules. Flakes were amorphous and there was no unambiguous evidence for retouch.	Bellwood, 1988, 1997
Tanjung Pinang	Rock-shelter	Morotai Island, northern Moluccas	10 ka	Available descriptions imply the expedient use of small, amorphous unretouched flakes, the majority of which appear to have been carried to the site from cores struck elsewhere. Some cores from local beach pebbles were also present, although these are not fully described (P. Bellwood, pers. comm.).	Bellwood et al., 1998

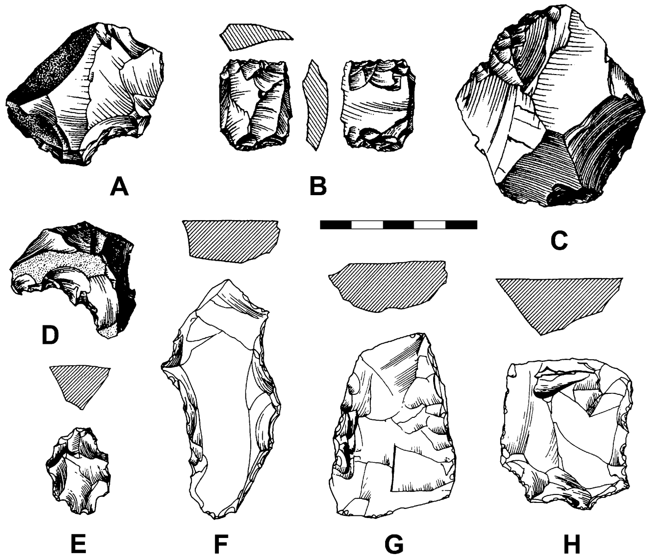

Fig. 4. "Pebble-and-flake technocomplex" artifacts from Leang Burung 2 (A–D) (after Glover, 1981) and Uai Bobo 2 (E–H) (after Glover, 1986). Scale = 50 mm.

> appeal, as there is no evidence of Pacitanian tools occurring in caves.

Other workers have suggested similar models of hominin succession, emphasizing the use of large "core tools" as typological markers of early hominin species in the region (e.g., Bellwood, 1992: 67; cf. Glover, 1973; White, 1977; Allen, 1991; Reynolds, 1993). Indeed, it seems that when assemblages of large-sized "core tools" are found at open sites in island Southeast Asia (and adjacent regions)—generally in channel and fluvial-related contexts (Fig. 5)—they are often related typologically to the Pacitanian and assigned a relative age and/or hominin manufacturer on that basis (Table 2). Harrisson's (1978: 41) comment that a large "chopping tool" found in southwest Sarawak (Borneo) has a "'feel' [that] is not very *Homo sapiens*" is a candid example of this method.

Fig. 5. Photograph from Movius (1944: Figure 36) showing a typical find-spot for Pacitanian assemblages. The original caption reads "Gravel-strewn surface in the bed of the Baksoka River, near Poenoeng, where Lower Palaeolithic implements are found."

Several approaches have been taken to accommodating the putatively early occurrences of "flake tool" industries into the "early core tool" scenario. One approach was to argue for two contemporary hominin species in the Pleistocene, one making "core tools" and one making "flake tools." This can be seen in the comments of van Stein Callenfels (1936: 210), who remarked that the differences between the "ponderous Patjitan type" and the Ngandong industry were proof of the presence of "two quite different types of primitive *Homo*" on Java (for similar observations, see Teilhard de Chardin, 1937b: 30; van Stein Callenfels, 1940: 98). More recently, early "flake tool" assemblages—particularly the Sangiran and Ngandong small-flake industries—have been dismissed on chronological grounds (e.g., van Heekeren, 1972: 49; Bartstra, 1974, 1978b; Bartstra and Basoeki, 1989; Keates, 1998). Another view held that many of the Sangiran objects are not artifacts (e.g., Bartstra, 1974: 9; Sartono, 1980; Corvinus, 2004: 143). Early "flake tool" industries have sometimes been absorbed into the "core tool" classification (e.g., Bellwood, 1997: 64–65), and, conversely, Holocene industries with "core tools" are included typologically with "flake tool" industries (e.g., Bellwood, 1997: 58). These interpretations preserve the notion that "flake tool" industries are the handiwork of *Homo sapiens* and that "core tool" industries are chronologically early and made by *Homo erectus* or a similar nonmodern hominin. An increasingly popular position argues that the "flake tool" industries date earlier than the "core tool" industries and must be the handiwork of *Homo erectus* (Reynolds, 1993). This view was championed by Bartstra (1984, 1985), who claimed that a Pleistocene stone-tool industry consisting mostly of small flakes could be separated chronologically from the supposedly later Pacitanian industry, which he considered to be a localized Hoabinhian. Each of these typologically distinct stone-tool industries, he argued, was the product of a different hominin species, with one replacing the other by around 50 ka:

> The Pacitanian core tools represent a distinct break with preceding lithic industries … In our view this break marks the succession of two hominid species that invaded Java during the Pleistocene: *H. erectus* and *H. sapiens* (Bartstra and Basoeki, 1989: 243).

According to this interpretation "it was *Homo sapiens* who brought the heavy core tools to Java …" (Bartstra et al., 1988: 335). To identify the elusive stone technology of *Homo erectus*, "the small and indistinct artifacts … show us what we have to look for" (Bartstra, 1985: 11).

These debates turn on dating, and it should be noted that there is still no agreement as to the precise age of the Pacitanian or other "core tool" industries (Simanjuntak, 2004: 16). The earliest—though controversial—evidence for hominins in island Southeast Asia comes from ^{40}Ar/^{39}Ar ages of 1.6–1.8

Table 2
Southeast Asian and Australasian sites containing "core tool" assemblages assigned to the Pleistocene period and/or specific hominins on the basis of their typological resemblance to the Pacitanian industry

Region	Site	References
West Java	Gombong, Parigi, Soekaboemi, Tjidjulang, Tasikmalaja, Djampang, Cipasang River, Cilacap River	Movius, 1948; Soejono, 1961; Jatmiko 2001
East Java	Linggis (Keser River basin), Bogoran (Tawing River basin), Kertosono (Panggul River basin)	Jatmiko, 2001
Central Java	Gremeng River basin, Gedongsari, Klaten	Jatmiko, 2001
Sumatra	Lho Seumawe, Tambangsawah, Tangjungkarang, Kikim, Kalianda, Nias Island, Lahat, Bungamas, Baturaja	Movius, 1948; Soejono, 1961; Jatmiko, 2001
Kalimantan	Awangbangkal	Soejono, 1961
Sarawak	Niah Cave	Harrisson, 1959
Sulawesi	Cabenge (Walanae valley), Paroto	van Heekeren, 1949; Bartstra, 1978b; Soejono, 1982b; Bartstra et al., 1991, 1994; Keates and Bartstra, 1994; Keates, 2004; Keates and Bartstra, 2001
Bali	Sembiran, Trunyan	Soejono, 1962; Jatmiko, 2001
Maluku	Central Seram	Jatmiko, 2001
Lombok	Plambik, Batukliang	Jatmiko, 2001
Sumbawa	Batutring	Soejono, 1982a
Flores	Mata Menge, Mengeruda, Boaleza, Lembahmenge, Olabula, Ruteng, Warloka, Maumere, Boawae, Lewolere, Riung	Glover and Glover, 1970; Maringer and Verhoeven, 1970; Glover, 1973; Soejono, 1982a; Jatmiko, 2001
Timor	Noelbaki, Manikin, Weaiwe, Atambua	Glover and Glover, 1970; Glover, 1973, Soejono, 1982b
West Malaysia	Kota Tampan	Collings, 1938; Tweedie, 1953
Philippines	Arubo 1	Pawlik and Ronquillo, 2003; Pawlik, 2004
Thailand	Ban-Kao	van Heekeren, 1948; Solheim, 1970
Australia	Koonalda Cave, Keilor, Portland-Mt. Gambier, Kangaroo Island	McCarthy, 1940; Noone, 1949; Gallus, 1964

million years for volcanic sediments associated with *Homo erectus* remains from Mojokerto and Sangiran in Java (Swisher et al., 1994; but see Huffman et al., 2006); but there are no in situ stone artifacts associated with these fossils. Jacob et al. (1978) reported the discovery of two in situ stone artifacts in 900–700-kyr-old sediments at Sambungmacan, central Java; these are the earliest claimed tools in island Southeast Asia. The claim is not without problems; Bartstra (1982, 1985) suggested that artifact-bearing deposits at Sambungmacan date from the later Pleistocene at the earliest. Hutterer twice reviewed the claims for Pleistocene stone-tool production in Southeast Asia (Hutterer, 1977, 1985) and drew the same conclusion both times: in all of island Southeast Asia, there was not a single stone artifact that could be chronologically attributed to nonmodern hominins (Hutterer, 1985: 10; see also Harrisson, 1975). A recent review by Corvinus (2004; see also Bowdler, 1992: 11–13; Reynolds, 1993; Schepartz et al., 2000) indicates little if any change in this area. At this stage, the notable exception comes from the 880–800-kyr-old site of Mata Menge and other securely dated early–middle Pleistocene sites in the Soa Basin of west central Flores (Maringer and Verhoeven, 1970; Sondaar et al., 1994; van den Bergh et al., 1996; van den Bergh, 1997; Morwood et al., 1997, 1998, 1999; O'Sullivan et al., 2001; Brumm et al., 2006).

Some characteristics of island Southeast Asian assemblages

A number of recurring patterns in stone-tool assemblages can be identified in the preceding review and Table 1. First, small-to-medium-sized flakes, often themselves flaked as small cores, constitute the majority of stone artifacts found in stratified deposits inside caves and rock-shelters. Second, large cores are rarely found within stratified deposits inside caves and rock-shelters. Third, large cores are usually found in unstratified open-air sites in and around channel- and fluvial-related contexts in which raw materials (flakable river pebbles) are common. Finally, assemblages with small-sized tools and assemblages with large-sized tools are contemporary with one another throughout the Pleistocene and into the Holocene in island Southeast Asia.

We infer from these patterns that assemblages of large-sized tools and assemblages of small-sized tools are parts of a single approach to reducing stone. The absence of large flaked cores inside caves and rock-shelters, coupled with the presence of high frequencies of these artifacts in open-air fluvial settings, points to the likelihood that flake blanks were struck from large, heavy cores that were, in turn, abandoned at the raw materials' sources (i.e., streams, rivers, gravel-beds). In other words, it is possible that most of the large "core tools" found in channel- and fluvial-related contexts in island Southeast Asia are, in fact, the sources for small transported flake blanks found in caves and rock-shelters. We will discuss supporting evidence for this from two Pleistocene sites on Flores, Indonesia.

Sources of blanks at Pleistocene sites on Flores, Indonesia

Here we present some initial results of analyses of lithic assemblages from Liang Bua Cave (Morwood et al., 2004, 2005; Moore 2005) and Mata Menge (Morwood et al., 1997, 1998, 1999; Brumm et al., 2006) on Flores, Indonesia. Analyses of Pleistocene assemblages in Indonesia have traditionally focused on formal artifact variation in cultural-historical reconstructions (Tanudirjo, 1995), but to avoid the static view of technology often implied in typological studies, we elected to apply a "reduction sequence" method to the Flores analyses. A reduction sequence is the "patterned way that people reduced pieces of stone to useful tools" (Shott, 2003: 96). Reduction-sequence analysis involves closely examining all of the stone-working products in an assemblage and preparing a model of the reduction processes that produced them (Moore, 2000a,b, 2003a,b, 2005; cf. Forestier 2000a,b).

Flake production at Liang Bua Cave, ca. 74 ka

Liang Bua is a limestone cave located in the Wae Racang Valley in western Flores. Recent excavations have revealed up to 12 m of stratified deposits (Morwood et al., 2004, 2005; Moore 2005). Analysis of stone artifacts has so far focused on Sectors III and IV, 3-m^2 excavations located near the front of the cave (Moore, 2005: 116–185). The data presented here are from Layer 9 in Sector IV, between spits 45 and 55 (4.5 to 5.5 m below the surface). The artifact concentration associated with this deposit is referred to as "Pulse C" (Moore, 2005: 120–121). A coupled ESR/uranium series sample from Layer 9 returned a date of 74 +14/−12 ka (Morwood et al., 2004: 1089). A *Homo floresiensis* premolar and radius were recovered from Sector IV, Pulse C (Morwood et al., 2004, 2005), in direct association with these stone artifacts.

The Pulse C reduction sequence in Liang Bua Cave involved the reduction of larger flakes into smaller flakes (Moore, 2005: 116–185; Moore, in press). Larger flakes were reduced by freehand hard-hammer percussion (Fig. 6). Reduction was both invasive (with scars extending at least halfway to the center of core faces) and noninvasive (with scars limited to the blank's edges) (after Odell, 2004: 74). Invasive flaking produced small "early-reduction flakes" (after Moore, 2000a: 59), probably to use as tools. Flakes struck

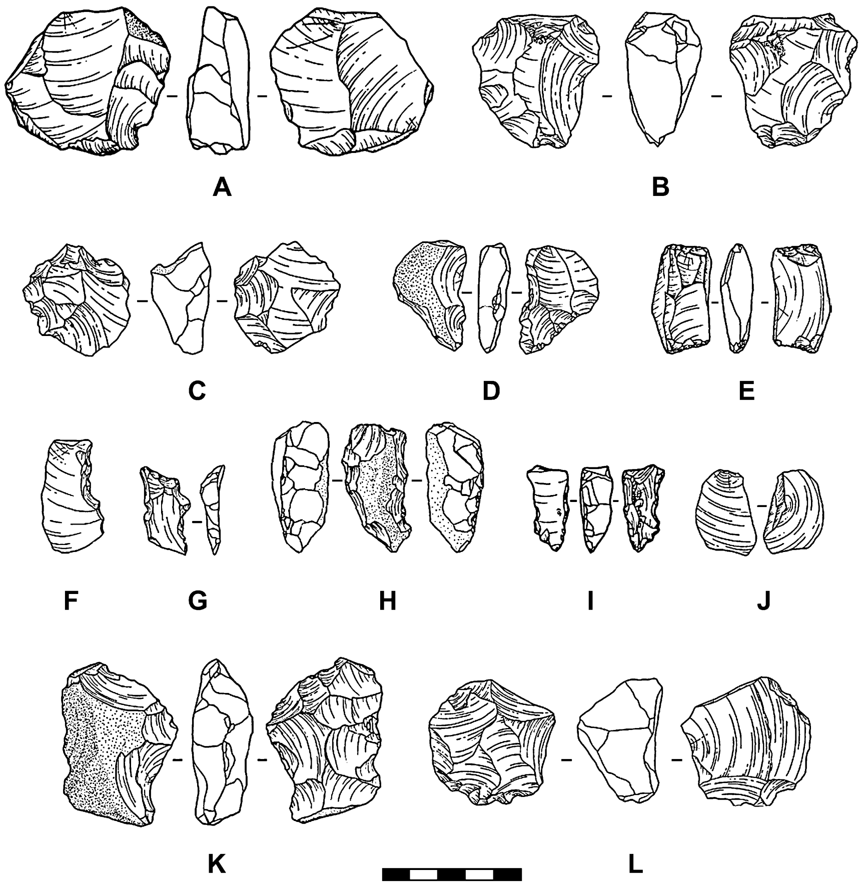

Fig. 6. Stone artifacts from Liang Bua Cave. (A–I) Artifacts made on flake blanks; (J) contact removal flake; (K, L) artifacts made on unidentified blanks. Scale = 50 mm.

from the ventral surfaces of larger flakes possessed remnant ventral surfaces as dorsal “detachment scars” (after Flenniken and Stanfill, 1980: 27). “Contact removal flakes” (after Moore 2003b: 30)—a form of “Kombewa flake” (Owen, 1938)—were produced by blows that removed the bulb of percussion and point of force initiation of the parent flakes. Noninvasive flaking produced small “uniface retouching flakes” (after Frison, 1968; Shott, 1994) and small early-reduction flakes, and was apparently done to modify an edge for use. In some cases, the flakes produced in the cave by invasive flaking were themselves subjected to noninvasive retouch or bipolar flaking. Of interest here is the technological source of the initial large flake blanks: were they struck from cores that were reduced inside the cave or did they derive from some other source?

This question was addressed by measuring the maximum sizes of scars on cores discarded in the cave and comparing these data to the maximum sizes of unmodified and modified early-reduction flakes. The sizes of unmodified flakes and scars are distributed similarly (Fig. 7), suggesting that the unmodified flakes were struck from the cores discarded in the cave.[2] Modified flakes proved too large to be accounted for by the core-scar sizes, despite the fact that their maximum dimensions were reduced by flaking (Fig. 8). A comparison of the thicknesses of unmodified flakes with modified flakes shows that the modified flakes are disproportionately thick, which suggests that the two types of flakes derived from different cores (Fig. 9). Size distributions suggest that most blanks selected for modification measured greater than 40 mm in maximum dimension.

The most parsimonious explanation for the Pulse C data is that large flake blanks were mostly produced off-site and that suitable large flakes were transported to Liang Bua Cave for further reduction. The large cores resulting from flake-blank production must be located on the landscape outside the cave.

The nature of cores reduced outside Liang Bua was explored by examining the platform types on flakes that were probably struck from them. Where identifiable, these flake blanks are dominated by single-facet platforms (Table 3). The facets are negative flake scars. This indicates that the cores were rotated at least once during the knapping process and that the production of “keeper” flakes usually occurred after this initial rotation. Thus, cores discarded at the stone source were probably bifacial or multiplatform cores or single-platform cores with the platform surface formed by the removal of one or more large flakes. Core faces must have scars measuring at least 40 mm in maximum dimension.

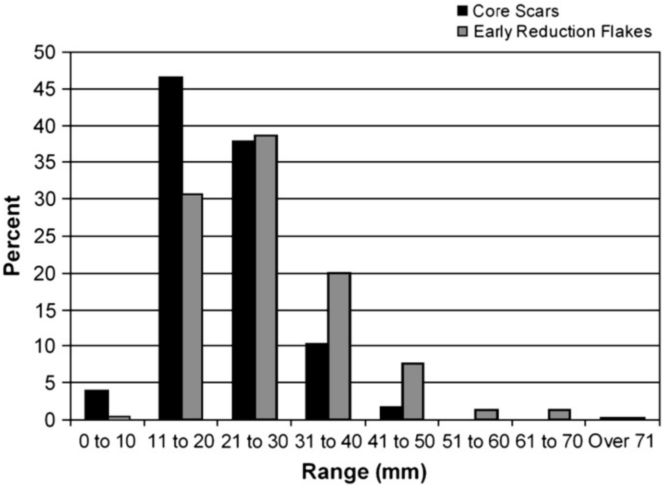

Fig. 7. Comparison of maximum core-scar sizes ($n = 776$) and early-reduction-flake sizes ($n = 765$, complete flakes only), Liang Bua Cave, Sector IV, Pulse C.

Pulse C is dominated by volcanic and metavolcanic artifacts (82%, $n = 2982$), with small numbers made from marine chert (18%, $n = 634$). The cortex on the volcanic and metavolcanic stones indicates that these materials derived exclusively from a fluvial source. In the Wae Racang Valley, this includes riverbed gravels, terrace surfaces, and conglomerate outcrops—all of which can be found within 200 m of the cave—and hence we might expect these landscape features to possess the large bifacial, single platform, or multiplatform “quarry cores” implied by the Liang Bua assemblage. Soejono (1982a)

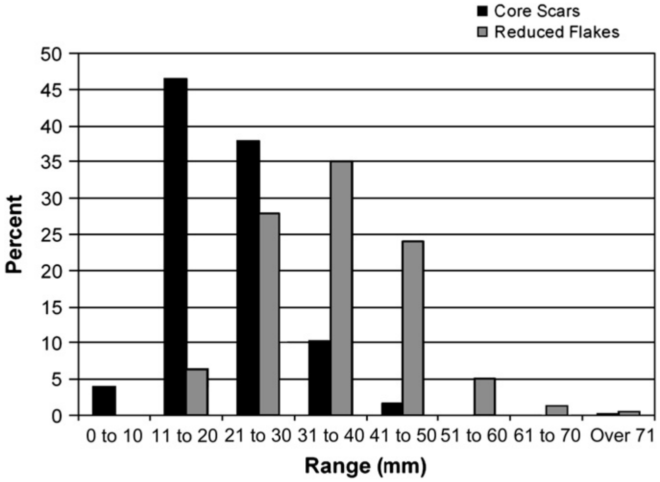

Fig. 8. Comparison of maximum core-scar sizes ($n = 776$) and reduced-flake sizes ($n = 237$), Liang Bua Cave, Sector IV, Pulse C.

---

[2] It is possible that the blanks for the reduced flakes were produced in the cave in an early stage of a reduction process that resulted in considerable attrition in core and therefore flake sizes. In this case, large scars on cores become progressively eliminated during reduction by what Braun et al. (2005) call “flake-scar erasure.” However, the lack of substantial overlap in the sizes of early-reduction flakes and reduced flakes argues against this. For instance, knapping experiments show that a proportion of flakes tend to break during detachment, and, if large flakes were frequently produced in the cave, there should be a continuous distribution in flake thicknesses (cf. Holdaway and Stern, 2004: 17−18). Figure 9 shows that relatively few thick, broken, unmodified flakes are present in Pulse C. In addition, knapping experiments suggest that the "flake-scar erasure" phenomenon begins after the removal of around 15 flakes (Braun et al., 2005) and the average number of blows on knapped objects in Pulse C is 8. Hence, there is no compelling reason to believe that large scars on cores were systematically erased by later reduction on Pulse C cores, a point borne out by the preservation of detachment scars and other ventral attributes on a large proportion of cores right to the end of their reduction life.

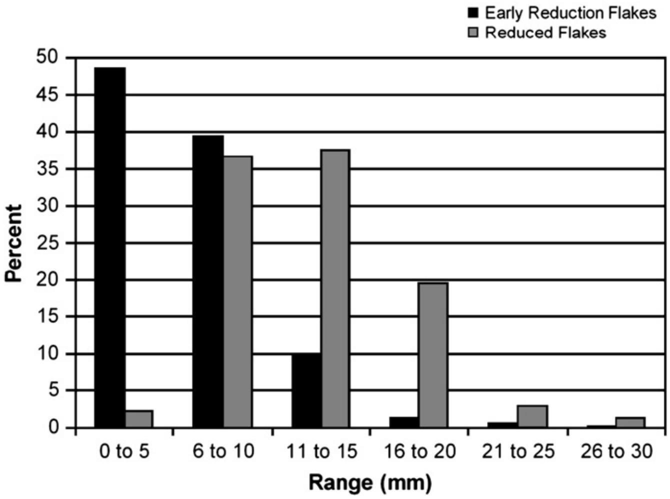

Fig. 9. Comparison of maximum thicknesses, unmodified early-reduction flakes ($n = 1002$) and reduced flakes ($n = 232$), Liang Bua Cave, Sector IV, Pulse C.

documented precisely these sorts of artifacts—including ‘‘chopper/chopping tools,’’ ‘‘cores,’’ and ‘‘pseudohandaxes’’—in undated channel deposits and elevated terrace surfaces throughout the Wae Racang Valley. Significantly for our argument, these artifacts were described as ‘‘massive’’ and ‘‘similar in form to the Pacitanian type’’ (Soejono 1982a: 585). In addition, a large core was recently discovered cemented in conglomerate deposits at the back of Liang Bua Cave. This artifact, associated with a minimum TIMS uranium-series date of 102 ka (Morwood et al., 2004: 1089), was carried into Liang Bua amid massive gravel deposits when the cave was suddenly exposed by the Wae Racang River (Westaway et al., in press); it attests to the presence of large artifacts in the Wae Racang gravels from an early age. A bifacially flaked metavolcanic river cobble measuring 300 mm in maximum dimension was recorded by one of us (AB) on the modern Wae Racang bank, about 300 m from the cave. Several scars on the core measure 100 mm in maximum length.

This two-part reduction sequence—off-site reduction producing large flake blanks and on-site reduction of these blanks—is known from Pleistocene sites across Southeast Asia. For instance, at Long Rongrien, the large-sized flakes in the assemblage lack corresponding cores, and Anderson (1990: 58) suggested that they were struck off-site and imported to the cave. At Leang Burung 2, mean maximum flake length is about 24 mm and mean maximum core-scar length is about 19 mm (Glover, 1981: 25, Table 5). Most of the flakes selected for retouching are considerably larger than this, which led Glover to conclude that ‘‘primary flake production was never a major activity at Leang Burung 2, and such knapping as took place there was rather a reworking of flakes brought in’’ (1981: 26). Glover (1986) suggested that, on Timor, stone was reduced in several cave sites to produce ‘‘small flakes used for light cutting and scraping jobs’’ (p. 171). Large flakes were struck elsewhere, imported to the sites, and retouched. For Palawan Island in the Philippines, Fox (1978) noted that ‘‘river-worn nodules of chert or large chunks of chert are extremely rare in Tabon Cave which would suggest that preliminary knapping was accomplished at the sources of the chert, possibly … at the nearby rivers, in order to obtain smaller cores which were brought back to the cave for flaking’’ (p. 64). The same pattern occurs at other cave and rock-shelter sites in the region (Table 1).

Table 3
Platform types* on invasively retouched flakes, Liang Bua, Sector IV, Pulse C

Platform type	Number	Percent	Maximum flake-blank dimension (mm)	
			Range	Average
Cortical	1	7.1	46	NA
Single Facet	12	85.7	34–61	45.3
Dihedral	1	7.1	43	NA

* Platform types were determined in reference to the location of the point of force application (PFA). If the PFA was located on cortex, the platform was classified as ‘‘cortical’’; if a single scar, ‘‘single facet’’; and on the junction between two scars, ‘‘dihedral.’’

Flake production at Mata Menge, ca. 880–800 ka

Mata Menge is an 880–800-kyr-old archaeological site located in the Soa Basin of west central Flores (Morwood et al., 1997, 1998, 1999; Brumm et al., 2006). Some 507 artifacts were excavated at this open-air site in 1994 and 2004–2005 (Brumm et al., 2006) (Fig. 10). Previous references to this material have invariably described it as Pacitanian-like: ‘‘These artefacts have many of the characteristics of the Patjitanian as described by Movius’’ (Glover and Glover, 1970: 189; see also Mulvaney, 1970; Glover, 1973; Lahr and Foley, 2004: 1044).

Fig. 10. Photograph of Mata Menge at the end of the 2005 excavations. The bar scale is 1.5 m long. Layer 1 is a mudstone horizon below the artifact-bearing strata. A zircon fission-track sample taken from Layer 1 returned a date of 880 ka (Morwood et al., 1998). Layer 2 consists of pebbly grey tuffaceous sandstone. Stone artifacts and fossilized faunal remains are found throughout the sandstone deposits. Layer 3 consists of lenses of well-sorted white/grey tuffaceous siltstones with abundant artifacts and fossils. A fission-track sample taken from the top of the Layer 3 returned a date of 800 ka (Morwood et al., 1998). Layer 4 is undated topsoil (after Brumm et al. 2006).

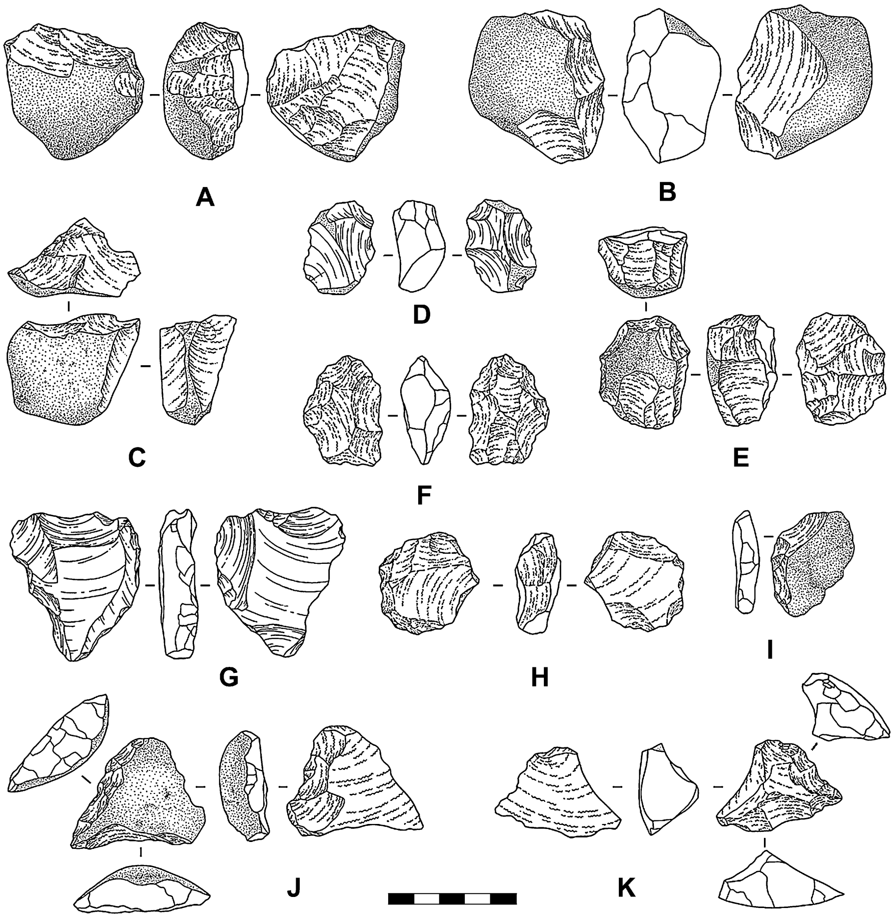

Fig. 11. Stone artifacts from Mata Menge. (A–E) Artifacts made on small pebble blanks; (F) artifact made on an unidentified blank; (G–K) artifacts made on flake blanks; artifacts (D) and (G) are chert. Scale = 50 mm.

The Mata Menge artifacts occur in low-energy fluviolacustrine sediments that also contain naturally occurring, unmodified volcanic/metavolcanic pebbles measuring 16–87 mm in maximum dimension (Brumm et al., 2006). Locally available stones provided the raw material for 91% of the artifacts. Stones were reduced mostly bifacially, resulting in radial cores, but unifacially retouched pebbles and multiplatform cores are also present (Fig. 11). The scars on these cores are compared to maximum flake sizes in Figure 12; using the same reasoning as for the Liang Bua evidence described above, the majority of the flakes at Mata Menge were struck from the pebble-based cores found in the assemblage. However, most of the modified flakes are considerably larger than the scars on cores (Fig. 13); as with Liang Bua, we infer that the blanks for the modified flakes were struck from cobbles abandoned elsewhere on the landscape. It is possible that the absence of large cores is due to fluvial sorting of gravels—although 58% of the Mata Menge artifacts are "fresh," 12% are "heavily abraded" (after Shea, 1999); however, 40 chert and chalcedony artifacts are present at the site, despite the complete absence of this material in the local environment. Significantly, modified chert/chalcedony flakes are relatively large compared to the scars on modified chert/chalcedony artifacts discarded at Mata Menge (Fig. 14). It appears from these patterns that large chert/chalcedony flakes and, probably, large volcanic/metavolcanic flakes, were struck from large cores that were abandoned elsewhere on the Soa

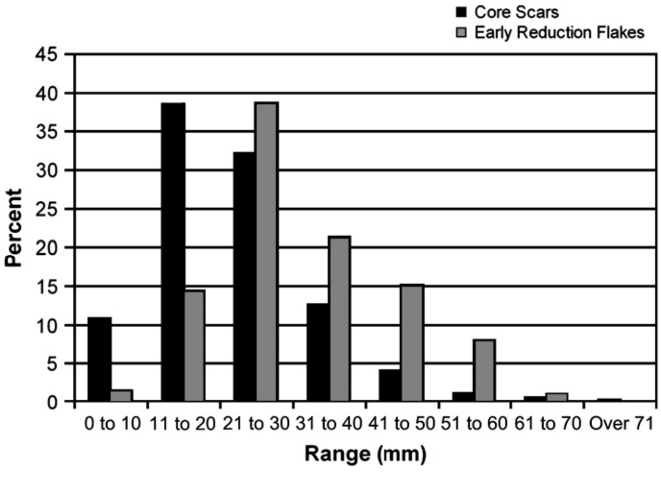

Fig. 12. Comparison of maximum core-scar sizes ($n = 470$) and early-reduction-flake sizes ($n = 277$, complete flakes only), Mata Menge.

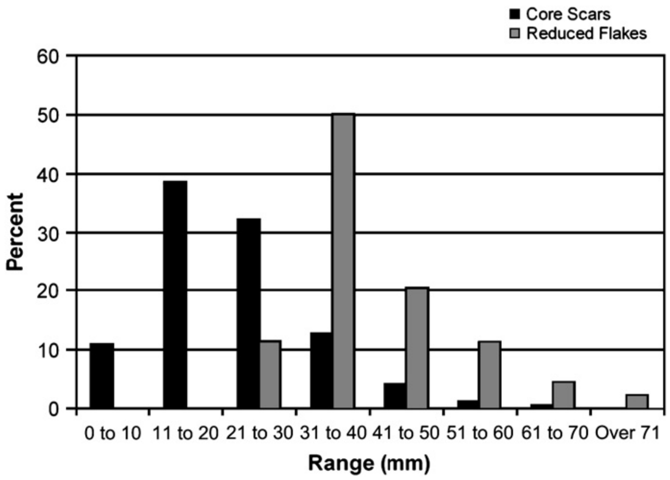

Fig. 13. Comparison of maximum core-scar sizes ($n = 470$) and reduced-flake sizes ($n = 44$), Mata Menge.

Basin landscape. The Mata Menge reduction sequence differs from Liang Bua in one important respect: the Mata Menge hominins often carried both small pebble cores and large flake blanks with them across the landscape, whereas small pebble cores were not often carried into Liang Bua Cave by Pulse C knappers. Nevertheless, we infer that both reduction sequences involved reducing large blocks of stone into more manageable pieces (large flake blanks) for transport elsewhere,[3] a pattern that persisted on Flores for over 700 kyr.

Economic decisions and spatial differentiation within reduction sequences

The observation that assemblages at Liang Bua Cave and Mata Menge reflect only part of a reduction sequence should not be surprising. The transport of stone between reduction events is a fundamental source of variation in stone-artifact assemblages (Pecora, 2001), a fact recognized from the earliest days of systematic lithic analysis (Holmes, 1894a,b) and one that underpins economic approaches to interpreting stone artifacts (e.g., Binford, 1979; Bleed, 1986; Torrence, 1989; Nelson, 1991; Carr, 1994; Odell, 1996). Evidence for the breaking-up of large rocks prior to transport is found in the earliest stone-artifact assemblages in Africa (e.g., Delagnes and Roche, 2005: 462–465) and the spatial differentiation of stone flaking across a landscape may have been an important step in early hominin evolution (Potts, 1991; Davidson and McGrew, 2005).

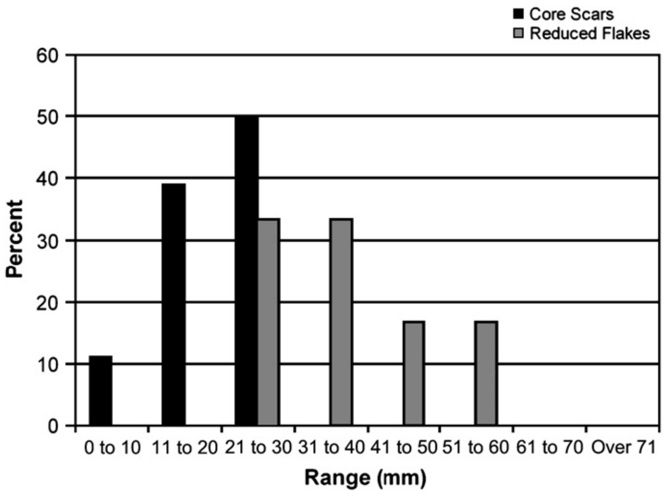

Fig. 14. Comparison of maximum core-scar sizes ($n = 18$) and reduced-flake sizes ($n = 6$), chert artifacts only, Mata Menge.

The decision not to transport large "quarry cores" at Liang Bua and Mata Menge was probably an economic one: the benefits of having large cores in a hominin's possession must have been outweighed by the costs involved in transporting them (cf. Torrence, 1989; Elston, 1990, 1992; Bousman, 1993). The reverse may have applied in other circumstances. For instance, large cores are present in the cave assemblage of Leang Sakapao 1 on Sulawesi because the site is located close to a source of large chert nodules (Bulbeck et al., 2004: 124); transport costs were probably negligible. In contrast, the nearest raw-material source to Leang Burung 2, situated in the same region as Leang Sakapao 1, is located approximately 15 km away from the site (Glover, 1981), and hence its occupants chose not to transport large cores. Later Holocene deposits at Liang Bua Cave contain large cores that apparently functioned as chopping tools (T. Sutikna, pers. comm.). The economic equation at Liang Bua apparently shifted in the Holocene to favor the transport of large cores as tools. The transport of large cores by Hoabinhian knappers (Bellwood, 1997) may represent a similar phenomenon.

Conclusions

Many archaeologists continue to view the Pacitanian and related pebble-based "core tool" assemblages in island Southeast Asia as spatiotemporally discrete industries associated with particular hominin species. In most cases, this association is based on the presence or absence of large-sized "core tools" and small-sized flake-based artifacts in stone assemblages (for discussion of a similar typological dichotomy in interpretations of the early Chinese Paleolithic, see Jia and Huang, 1991; Clark, 1998: 444). The evidence presented here complicates this interpretation. Our research indicates that Pleistocene knappers on Flores processed large cobbles into large flake blanks, abandoned the large cobble cores, and transported the blanks across the landscape. This produced two spatially segregated assemblage variants: (1) those containing large cores, and (2) those in which the blanks struck from large

---

[3] The reduction of stone prior to transport by early hominins was recently described by Delagnes and Roche (2005: 462–465) at the 2.34-million-year-old site of Lokalalei 2C. Lokalalei 2C hominins often reduced stones measuring greater than 80 mm in maximum dimension prior to transport, and they always reduced ones measuring larger than 150 mm. There, too, the initial stages of reduction occurred off-site. On-site reduction at Lokalalei 2C involved knapping the cobble sections carried to the site or pebbles measuring less than 80 mm. This strategy is essentially the same as that employed by the Mata Menge hominins.

cores were reduced. Large-sized artifacts (typologically "core tools") and small-sized artifacts were both produced from one reduction sequence. If this spatial segregation was typical across island Southeast Asia—and the literature suggests that it was—we can offer parsimonious explanations of the patterns discussed earlier, including why large-sized assemblages in island Southeast Asia tend to be found mostly on terraces and river gravels (these were the stone sources and the large-sized artifacts were discarded "quarry cores"), why small-sized artifacts are often found in caves and rock-shelters (these are postprocurement reduction areas), and why assemblages with small-sized and large-sized tools were contemporary with one another throughout the Pleistocene and Holocene (the dichotomy reflects two parts of a single reduction sequence). Seen in this light, the distinction between "core tool" and "flake tool" industries—a distinction that has formed the backbone of Pleistocene research in island Southeast Asia since the mid-1930s—is not meaningful.

Consequently, assemblage ages cannot be reliably assessed based on the "core tool"/"flake tool" dichotomy. The existing typological divisions developed for the island Southeast Asian Pleistocene are inadequate for this task and, instead, assemblage age must be determined from secure contextual evidence (Roberts et al., 2005). Tracking hominin groups on the basis of the traditional dichotomy is also misguided. Both aspects of the dichotomy were present from the early Pleistocene, in association with early hominin species, right through to the Holocene Neolithic, a period indisputably associated with *Homo sapiens*. We infer that early hominins (on present evidence, *Homo erectus* and/or *Homo floresiensis*) and *Homo sapiens* practiced a broadly similar approach to stone flaking.

With regard to knapped stone, it now seems evident that there is no reliable technological signature of modern humans in Pleistocene island Southeast Asia (see also Szabó et al., submitted for publication). Bellwood (1997) noted that "pebble-and-flake technocomplex" sites date from the Pleistocene right through to the Holocene, and we argue here that the "technocomplex" is a technological manifestation of a reduction sequence that extends back at least 840,000 years in Indonesia. Modern humans were certainly responsible for "technocomplex" assemblages in the later Holocene, and Bellwood (1997: 172) noted that more complex Holocene stone technologies were usually grafted onto a basic "technocomplex" way of making tools. A similar grafting approach characterizes the *Homo sapiens* stone-artifact sequence in Holocene Australia (Jones, 1977: 358), and it appears that technological grafting onto a simple base technology is characteristic of the modern human lithic adaptation to the Southeast Asian region. On present evidence, the earliest stone-technology evidence for the arrival of *Homo sapiens* in the region is marked by the graft of edge-ground and/or waisted stone axes onto a "technocomplex" technology (Veth et al., 1998a: 164–166) in Sahul by at least 32 ka (Groube et al., 1986; Morwood and Trezise, 1989; cf. Brumm and Moore, 2005). The evidence from island Southeast Asia demonstrates that there was nothing inevitable about the technological sequence seen in Africa and Eurasia.

Acknowledgements

Funding for the Liang Bua and Mata Menge excavations was provided by an Australian Research Council (ARC) grant to M.J. Morwood. The 2003–2004 excavations at Liang Bua Cave were conducted by the Indonesian National Centre for Archaeology (ARKENAS), with R.P. Soejono (counterpart), M.J. Morwood (counterpart), T. Sutikna, E. Wahyu Saptomo, Jatmiko, S. Wasisto, Rokus Awe Due, and D. Hobbs. The Liang Bua work was authorized by Dr. T. Djubiantono, (ARKENAS Director). The 2004–2005 excavations at Mata Menge were conducted by the Geological Research and Development Centre (GRDC), with F. Aziz (director), G.D. van den Bergh, M.J. Morwood (counterpart), I. Kurniawan, S. Sudjarwardi, Dadang, Ngaliman, I. Botha, J. Tode, D. Hobbs, and 20 Ngadha people led by K. Podhi. The Mata Menge work was authorized by Dr. Djadjang (GRDC Director). MWM was funded by an ARC Australian Postgraduate Award and an ARC Australian Postdoctoral Fellowship. AB was supported by an ANU Ph.D. cofunded stipend scholarship. G. Hope assisted in document translation. The manuscript was improved by comments by I. Davidson, M.J. Morwood, and three anonymous reviewers. S. O'Connor, K. Westaway, and D. Hobbs are also acknowledged for their assistance.

References

Allen, H., 1991. Stegodonts and the dating of stone tool assemblages in island Southeast Asia. Asian Perspect. 30, 243–265.

Anderson, D.D., 1988. Excavations of a Pleistocene rockshelter in Krabi and the prehistory of southern Thailand. In: Charoenwongsa, P., Bronson, B. (Eds.), Prehistoric Studies: The Stone and Metal Ages in Thailand. Thai Antiquity Working Group, Bangkok, pp. 43–59.

Anderson, D.D., 1990. Lang Rongrien Rockshelter: A Pleistocene–Early Holocene Archaeological Site from Krabi, Southwestern Thailand. University Museum Monograph 71. The University Museum, University of Pennsylvania, Philadelphia.

Anderson, D.D., 1997. Cave archaeology in Southeast Asia. Geoarchaeology 12, 607–638.

Aziz, F., van den Bergh, G.D., Sidarto, Maryanto, S., Ngaliman, M., Kurniawan, I., Dadang, Pritriani, E., Baskoro, S., Christiana, I., Yulianty, R., Morwood, M.J., n.d. A study of the Solo River Terraces: Kendeng Hills, East and Central Java 2004–5.

Barker, G., Badang, D., Barton, H., Beavitt, P., Bird, M., Daly, P., Doherty, C., Gilbertson, D., Glover, I., Hunt, C., Manser, J., McLaren, S., Paz, V., Pyatt, B., Reynolds, T., Rose, J., Rushworth, G., Stephens, M., 2001. The Niah Cave Project: the second (2001) season of fieldwork. Sarawak Mus. J. New Series 56, 38–119.

Barker, G., Barton, H., Beavitt, P., Bird, M., Daly, P., Doherty, C., Gilbertson, D., Hunt, C., Krigbaum, J., Lewis, H., Manser, J., McClaren, S., Paz, V., Piper, P., Pyatt, B., Rabett, R., Reynolds, T., Rose, J., Rushworth, G., Stephens, M., 2002a. Prehistoric foragers and farmers in south-east Asia: renewed investigations at Niah Cave, Sarawak. Proc. Prehist. Soc. 68, 147–164.

Barker, G., Barton, H., Beavitt, P., Chapman, S., Derrick, M., Doherty, C., Farr, L., Gilbertson, D., Hunt, C., Jarvis, W., Krigbaum, J., Maloney, D., McLaren, S., Pettitt, P., Pyatt, B., Reynolds, T., Rushworth, G., Stephens, M., 2000. The Niah Caves Project: preliminary report on the first (2000) season. Sarawak Mus. J. New Series 55, 111–149.

Barker, G., Barton, H., Bird, M., Cole, F., Daly, P., Gilbertson, D., Hunt, C., Krigbaum, J., Lampert, C., Lewis, H., Lloyd-Smith, L., Manser, J., McLaren, S., Menotti, F., Paz, V., Piper, P., Pyatt, B., Rabett, R., Reynolds, T., Stephens, M., Thompson, J., Trickett, M., Whittaker, P., 2002b. The Niah Cave Project: the third (2002) season of fieldwork. Sarawak Mus. J. New Series 57, 88–177.

Bartstra, G.-J., 1974. Notes about Sangiran (Java, Indonesia). Quartär 25, 1–11.

Bartstra, G.-J., 1976. Contributions to the Study of the Palaeolithic Patjitanian Culture Java, Indonesia. E.J. Brill, Leiden.

Bartstra, G.-J., 1978a. Recent Palaeolithic research in Java (Kali Glagah, Pacitan, Gombong, Sangiran): the first six months of a new project. Mod. Quat. Res. SE Asia 4, 63–70.

Bartstra, G.-J., 1978b. Note on new data concerning the fossil vertebrates and stone tools in the Walanae Valley in south Sulawesi (Celebes). Mod. Quat. Res. SE Asia 4, 71–72.

Bartstra, G.-J., 1982. *Homo erectus erectus*: the search for his artefacts. Curr. Anthropol. 23, 318–320.

Bartstra, G.-J., 1984. Dating the Pacitanian: some thoughts. Cour. Forsch.-Inst. Senckenberg 69, 253–258.

Bartstra, G.-J., 1985. Sangiran, the stone implements of Ngebung, and the Paleolithic of Java. Mod. Quat. Res. SE Asia 9, 99–113.

Bartstra, G.-J., 1992. Pacitan and Sangiran, and Java Man's tools. In: Bellwood, P. (Ed.), Man and His Culture: A Resurgence. Books and Books, New Delhi, pp. 93–103.

Bartstra, G.-J., 1994. Indonesia in the period of *Homo habilis* and *Homo erectus*. In: De Laet, S.J. (Ed.), History of Humanity: volume 1, Prehistory and the Beginnings of Civilization. UNESCO, Paris, pp. 89–95.

Bartstra, G.-J., Basoeki, 1989. Recent work on the Pleistocene and the Palaeolithic of Java. Curr. Anthropol. 30, 241–244.

Bartstra, G.-J., Hooijer, D.A., Kallupa, B., Akib, M.A., 1994. Notes on fossil vertebrates and stone tools from Sulawesi, Indonesia, and the stratigraphy of the Northern Walanae Depression. Palaeohistoria 33/34, 1–18.

Bartstra, G.-J., Keates, S.G., Basoeki, Kallupa, B., 1991. On the dispersion of *Homo sapiens* in eastern Indonesia: the Palaeolithic of south Sulawesi. Curr. Anthropol. 32, 317–321.

Bartstra, G.-J., Soegondho, A., van der Wijk, A., 1988. Ngandong Man: age and artifacts. J. Hum. Evol. 17, 325–337.

Bellwood, P., 1987. The prehistory of island Southeast Asia: a multidisciplinary review of recent research. J. World Prehist. 1, 171–224.

Bellwood, P., 1988. Archaeological Research in South-Eastern Sabah. Sabah Museum Monograph No. 2. Sabah Museum and State Archives, Sabah.

Bellwood, P., 1992. The antiquity of equatorial rainforest occupation in Southeast Asia. In: Bellwood, P. (Ed.), Man and His Culture: A Resurgence. Books and Books, New Delhi, pp. 67–78.

Bellwood, P., 1997. Prehistory of the Indo-Malaysian Archipelago, revised ed. University of Hawai'i Press, Honolulu.

Bellwood, P., Nitihaminoto, G., Irwin, G., GunadiWaluyo, A., Tanudirjo, D., 1998. 35,000 years of prehistory in the northern Moluccas. Mod. Quat. Res. SE Asia 15, 233–275.

van den Bergh, G.D., 1997. 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. Scr. Geol. 117, 1–419.

van den Bergh, G.D., de Vos, J., Sondaar, P.Y., Aziz, F., 1996. Pleistocene zoogeographic evolution of Java (Indonesia) and glacio-eustatic sea level fluctuations: a background for the presence of *Homo*. Indo-Pac. Prehist. Assoc. Bull. 14, 7–21.

Binford, L.R., 1979. Organization and formation processes: looking at curated technologies. J. Anthropol. Res. 35, 255–272.

Bleed, P., 1986. The optimal design of hunting weapons: maintainability or reliability. Am. Antiq. 51, 737–747.

Boriskovsky, P.I., 1966. Vietnam in primeval times. Sov. Anthropol. Archeol. 7 (2), 14–32, 7 (3), 3–19, 10 (1), 70–88.

Bousman, C.B., 1993. Hunter-gatherer adaptations, economic risk and tool design. Lithic Technol. 18, 59–86.

Bowdler, S., 1992. The earliest Australian stone tools and implications for Southeast Asia. Bull. Indo-Pac. Prehist. Assoc. 12, 10–22.

Braidwood, R.J., 1947. Asiatic prehistory and the origin of man. J. Near East. Stud. 6, 30–42.

Braun, D.R., Tactikos, J.C., Ferraro, J.V., Harris, J.W.K., 2005. Flake recovery rates and inferences of Oldowan hominin behavior: a response to Kimura 1999, 2002. J. Hum. Evol. 48, 525–531.

Breuil, H., 1926. Palaeolithic industries from the beginning of the Rissian to the beginning of the Würmian glaciation. Man 26, 176–179.

Breuil, H., 1939. The Pleistocene succession in the Somme Valley. Proc. Prehist. Soc. 5, 33–38.

Brumm, A., Aziz, F., van den Bergh, G.D., Morwood, M.J., Moore, M.W., Kurniawan, I., Hobbs, D.R., Fullagar, R., 2006. Early stone technology on Flores and its implications for *Homo floresiensis.* Nature 441, 624–628.

Brumm, A., Moore, M.W., 2005. Symbolic revolutions and the Australian archaeological record. Camb. Archaeol. J. 15, 157–175.

Bulbeck, D., Sumantri, I., Hiscock, P., 2004. Leang Sakapao 1, a second dated Pleistocene site from South Sulawesi, Indonesia. Mod. Quat. Res. SE Asia 18, 111–128.

Burkitt, M.C., 1922. Notes on the chronology of the Ice Age. Man 22, 179–182.

Carr, P.J. (Ed.), 1994. The Organization of North American Prehistoric Chipped Stone Tool Technologies. International Monographs in Prehistory, Archaeological Series 7.

Clark, J.D., 1998. The Early Palaeolithic of the eastern region of the Old World in comparison to the West. In: Petraglia, M.D., Korisettar, R. (Eds.), Early Human Behaviour in Global Context: The Rise and Diversity of the Lower Palaeolithic Record. Routledge, London, pp. 437–450.

Clark, W.E. Le Gros, 1946. Pleistocene chronology in the Far East. Antiquity 20, 9–12.

Collings, H.D., 1938. Pleistocene site in the Malay Peninsula. Nature 142, 575–576.

Corvinus, G., 2004. *Homo erectus* in east and Southeast Asia, and the questions of the age of the species and its association with stone artifacts, with special attention to handaxe-like tools. Quat. Int. 117, 141–151.

Coon, C.S., 1966. The Living Races of Man. Jonathon Cape, London.

Davidson, I., McGrew, W., 2005. Stone tools and the uniqueness of human culture. J. R. Anthropol. Inst. 11, 793–817.

Delagnes, A., Roche, H., 2005. Late Pliocene hominid knapping skills: the case of Lokalalei 2C, West Turkana, Kenya. J. Hum. Evol. 48, 435–472.

Dennell, R., 1990. Progressive gradualism, imperialism, and academic fashion: Lower Palaeolithic archaeology in the 20th century. Antiquity 64, 549–558.

de Sieveking, A.G., 1962. The Palaeolithic industry of Kota Tampan, Perak, Malaya: Part II, Archaeology. Proc. Prehist. Soc. 6, 103–139.

de Terra, H., 1938. Preliminary report on recent geological and archaeological discoveries relating to early man in Southeast Asia. Proc. Natl. Acad. Sci. U.S.A. 24, 407–413.

de Terra, H., 1939. The Quaternary terrace system of southern Asia and the age of man. Geogr. Rev. 29, 101–118.

de Terra, H., 1941. Pleistocene formations and Stone Age man in China. Institut de Géo-Biologie Pékin 6, 1–54.

de Terra, H., 1943a. The Pleistocene of Burma. Trans. Am. Phil. Soc. 32, 267–339.

de Terra, H., 1943b. Pleistocene geology and early man in Java. Trans. Am. Phil. Soc. 32, 437–464.

de Terra, H., Teilhard de Chardin, P., Movius Jr., H.L., 1938. Geological and archaeological aspects of South-Eastern Asia. Nature 142, 275.

Détroit, F., Dizon, E., Falguères, C., Hameau, S., Ronquillo, W., Sémah, F., 2004. Upper Pleistocene *Homo sapiens* from the Tabon cave (Palawan, the Philippines): description and dating of new discoveries. C. R. Palevol. 3, 705–712.

Elston, R.G., 1990. Lithic raw materials: sources and utility. In: Elson, R.G., Budy, E.E. (Eds.), The Archaeology of James Creek Shelter. Anthropological Papers No. 115. University of Utah, Salt Lake City, pp. 165–174.

Elston, R.G., 1992. Modeling the economics and organization of lithic procurement. In: Elston, R.G., Raven, C. (Eds.), Archaeological Investigations at Tosawihi, a Great Basin Quarry, Part 1: The Periphery. Intermountain Research, Silver City, pp. 31–70.

Flenniken, J.J., Stanfill, A.L., 1980. A preliminary technological examination of 20 archaeological sites located during the cultural resource survey of the Whitehorse Ranch Public Land Exchange. Contract Abstracts 1, 23–30.

Foley, R., Lahr, M.M., 1997. Mode 3 technologies and the evolution of modern humans. Camb. Archaeol. J. 7, 3–36.

Foley, R., Lahr, M.M., 2003. On stony ground: lithic technology, human evolution, and the emergence of culture. Evol. Anthropol. 12, 109–122.

Forestier, H., 2000a. De quelques chaînes opératoires lithiques en Asie du Sud-Est au Pléistocène supérieur final et au début de l'Holocène. L'Anthropologie 104, 531–548.

Forestier, H., 2000b. Les industries lithiques du Paléolithique tardif et du début de l'Holocène en Insulinde. Aséanic 6, 13–56.

Fox, R.B., 1970. The Tabon Caves: Archaeological Explorations and Excavations on Palawan Island, Philippines. Monograph of the National Museum 1. National Museum, Manila.

Fox, R.B., 1978. The Philippine Paleolithic. In: Ikawa-Smith, F. (Ed.), Early Paleolithic in South and East Asia. Mouton, The Hague, pp. 60–85.

Frison, G.C., 1968. A functional analysis of certain chipped stone tools. Am. Antiq. 33, 149–155.

Gallus, A., 1964. Two Australian stratigraphic sequences. Curr. Anthropol. 5, 127.

Ghosh, A.K., 1971. Ordering of the Lower Palaeolithic traditions in South and South-East Asia. Archaeol. Phys. Anthropol. Oceania 6, 87–101.

Glover, I.C., 1972. Excavations in Timor: A study of economic change and cultural continuity in prehistory. Ph.D. Dissertation, Australian National University.

Glover, I.C., 1973. Island Southeast Asia and the settlement of Australia. In: Strong, D., Evans, J.D. (Eds.), Archaeological Theory and Practice. Seminar Press, London, pp. 105–129.

Glover, I.C., 1978. Survey and excavation in the Maros District, south Sulwesi, Indonesia: the 1975 field season. Bull. Indo-Pac. Prehist. Assoc. 1, 60–103.

Glover, I.C., 1981. Leang Burung 2: an Upper Palaeolithic rock shelter in south Sulawesi, Indonesia. Mod. Quat. Res. SE Asia 6, 1–38.

Glover, I.C., 1986. Archaeology in Eastern Timor, 1966–67. Terra Australis 11. Australian National University, Canberra.

Glover, I.C., Glover, E.A., 1970. Pleistocene flaked stone tools from Timor and Flores. Mankind 7, 188–190.

Gorman, C., 1971. The Hoabinhian and after: subsistence patterns in Southeast Asia during the late Pleistocene and early Recent periods. World Archaeol. 2, 300–320.

Groube, L., Chappell, H., Muke, J., Price, D., 1986. A 40,000 year-old human occupation site at Huon Peninsula, Papua New Guinea. Nature 324, 453–455.

Harrisson, T., 1957. The Great Cave of Niah: a preliminary report on Bornean prehistory. Man 57, 161–166.

Harrisson, T., 1959. New archaeological and ethnological results from Niah Caves, Sarawak. Man 59, 1–8.

Harrisson, T., 1975. Tampan: Malaysia's Palaeolithic reconsidered. Mod. Quat. Res. SE Asia 1, 53–69.

Harrisson, T., 1978. Present status and problems for Paleolithic studies in Borneo and adjacent islands. In: Ikawa-Smith, F. (Ed.), Early Paleolithic in South and East Asia. Mouton, The Hague, pp. 37–57.

Hiscock, P., 2005. Artefacts on Aru: evaluating the technological sequences. In: O'Connor, S., Spriggs, M., Veth, P. (Eds.), The Archaeology of the Aru Islands, Eastern Indonesia. Terra Australis 22. Australian National University, Canberra, pp. 205–234.

Holdaway, S., Stern, N., 2004. A Record in Stone: The Study of Australia's Flaked Stone Artefacts. Museum Victoria and Aboriginal Studies Press, Canberra.

Holmes, W.H., 1894a. Natural history of flaked stone implements. In: Wake, C.S. (Ed.), Memoirs of the International Congress of Anthropologists. Schulte, Chicago, pp. 120–139.

Holmes, W.H., 1894b. An Ancient Quarry in Indian Territory. Bulletin 21. Smithsonian Institution Bureau of Ethnology, Washington D.C.

Hou, Y., Potts, R., Baoyin, Y., Zhengtang, G., Deino, A., Wang, W., Clark, J., Guangmao, X., Weiwen, H., 2000. Mid-Pleistocene Acheulean-like stone technology of the Bose Basin, south China. Science 287, 1622–1626.

Huang, W., 1987. Bifaces in China. Acta Anthropol. Sinica 6, 60–68.

Huffman, O.F., Zaim, Y., Kappelman, J., Ruez Jr., D.R., de Vos, J., Rizal, Y., Aziz, F., Hertler, C., 2006. Relocation of the 1936 Mojokerto skull discovery site near Perning, East Java. J. Hum. Evol. 50, 431–451.

Hutterer, K.L., 1977. Reinterpreting the Southeast Asian Palaeolithic. In: Allen, J., Golson, J., Jones, R. (Eds.), Sunda and Sahul: Prehistoric studies in Southeast Asia, Melanesia and Australia. Academic Press, London, pp. 31–71.

Hutterer, K.L., 1985. The Pleistocene archaeology of Southeast Asia in regional context. Mod. Quat. Res. SE Asia 9, 1–22.

Ikawa-Smith, F., 1978. Introduction: the Early Paleolithic tradition of East Asia. In: Ikawa-Smith, F. (Ed.), Early Paleolithic in South and East Asia. Mouton, The Hague, pp. 1–10.

Jacob, T., Soejono, R.P., Freeman, L.G., Brown, F.H., 1978. Stone tools from Mid-Pleistocene sediments in Java. Science 202, 885–887.

Jatmiko, 2001. New discoveries of Paleolithic tools in some Paleolithic sites in Indonesia. In: Simanjuntak, T., Prasetyo, B., Handini, R. (Eds.), Sangiran: Man, Culture and Environment in Pleistocene Times. The National Research Centre of Archaeology, Yayasan Obor, pp. 171–184.

Jia, L., Huang, W., 1991. The Paleolithic of China. In: Liu, T. (Ed.), Quaternary Geology and Environment in China. Science Press, Beijing, pp. 136–140.

Jones, R., 1977. Australia felix—the discovery of a Pleistocene prehistory. J. Hum. Evol. 6, 353–361.

Jones, R., 1989. East of Wallace's Line: issues and problems in the colonisation of the Australian continent. In: Mellars, P., Stringer, C. (Eds.), The Human Revolution: Behavioural and Biological Perspectives on the Origins of Modern Humans. Edinburgh University Press, Edinburgh, pp. 743–782.

Keates, S.G., 1998. A discussion of the evidence for early hominids on Java and Flores. Mod. Quat. Res. SE Asia 15, 179–191.

Keates, S.G., 2002. The Movius Line: fact or fiction? Bull. Indo-Pac. Prehist. Assoc. 22, 17–24.

Keates, S.G., 2004. Notes on the Palaeolithic finds from the Walanae valley, southwest Sulawesi, in the context of the late Pleistocene of island Southeast Asia. Mod. Quat. Res. SE Asia 18, 95–110.

Keates, S.G., Bartstra, G.-J., 1994. Island migration of early modern *Homo sapiens* in Southeast Asia: the artifacts from the Walanae Depression, Sulawesi, Indonesia. Palaeohistoria 33/34, 19–30.

Keates, S.G., Bartstra, G.-J., 2001. Observations on Cabengian and Pacitanian artefacts from island Southeast Asia. Quärtar 51/52, 9–32.

Lahr, M.M., Foley, R., 2004. Human evolution writ small. Nature 431, 1043–1044.

Mahirta, K.P., Aplin, K., Bulbeck, D., Boles, W.E., Bellwood, P., 2004. Pia Hudale rockshelter: a Terminal Pleistocene occupation site on Roti Island, Nusa Tenggara Timur, Indonesia. Mod. Quat. Res. SE Asia 18, 361–394.

Majid, Z., 1982. The West Mouth, Niah, in the prehistory of Southeast Asia. Sarawak Mus. J. 52, 1–200.

Majid, Z., 1990. The Tampanian problem resolved: archaeological evidence of a late Pleistocene lithic workshop. Mod. Quat. Res. SE Asia 11, 71–96.

Majid, Z., 1997. The discovery of Bukit Jawa, Gelok, a Middle-Late Palaeolithic site in Perak, Malaysia. J. Malays. Branch R. Asiat. Soc. 70, 49–52.

Majid, Z., 2003. Archaeology in Malaysia. Centre for Archaeological Research. Universiti Sains Malaysia, Penang.

Majid, Z., Tjia, H.D., 1988. Kota Tampan, Perak: the geological and archaeological evidence for a late Pleistocene site. J. Malayan Branch R. Asiat. Soc. 61, 123–134.

Maringer, J., Verhoeven, T., 1970. Die steinartefakte aus der Stegodon-fossilschicht von Mengeruda auf Flores, Indonesien. Anthropos 65, 229–245.

Marks, P., 1982. On the manipulation of Palaeolithic hand-axes. Mod. Quat. Res. SE Asia 7, 195–199.

McCarthy, F.D., 1940. Comparison of the prehistory of Australia with that of Indo-China, the Malay Peninsula, and the Netherlands East Indies. In: Chasen, F.N., Tweedie, M.W.F. (Eds.), Proceedings of the Third Congress of Prehistorians of the Far East. Government Printing Office, Singapore, pp. 30–50.

Moore, M.W., 2000a. Lithic technology in Tasmania. Archaeol. Oceania 35, 57–73.

Moore, M.W., 2000b. Technology of Hunter Valley microlith assemblages, New South Wales. Aust. Archaeol. 51, 28–39.

Moore, M.W., 2003a. Australian Aboriginal biface reduction techniques on the Georgina River, Camooweal, Queensland. Aust. Archaeol. 56, 22–34.

Moore, M.W., 2003b. Flexibility of stone tool manufacturing methods on the Georgina River, Camooweal, Queensland. Archaeol. Oceania 38, 23–36.

Moore, M.W., 2005. The design space of lithic technology. Ph.D. Dissertation, University of New England.

Moore, M.W. Lithic design space modelling and cognition in *Homo floresiensis*. In: Shalley, A., Khlentzos, D. (Eds.), Mental States: Nature, Function and Evolution. John Benjamins, Amsterdam, in press.

Morris, T.O., 1932. A Palaeolith from Upper Burma. J. Burma Res. Soc. 22, 19–20.

Morris, T.O., 1935. The prehistoric stone implements of Burma. J. Burma Res. Soc. 25, 1–39.

Morwood, M.J., Aziz, F., O'Sullivan, P., Nasruddin, Hobbs, D.R., Raza, A., 1999. Archaeological and paleontological research in central Flores, east Indonesia: results of fieldwork 1997–98. Antiquity 73, 273–286.

Morwood, M.J., Aziz, F., van den Bergh, G.D., Sondaar, P.Y., de Vos, J., 1997. Stone artefacts from the 1994 excavation at Mata Menge, west central Flores, Indonesia. Aust. Archaeol. 44, 26–34.

Morwood, M.J., Brown, P., Jatmiko, Sutikna, T., Wahyu Saptomo, E., Westaway, K.E., Due, R.A., Roberts, R.G., Maeda, T., Wasisto, S., Djubiantono, T., 2005. Further evidence for small-bodied hominins from the late Pleistocene of Flores, Indonesia. Nature 437, 1012–1017.

Morwood, M.J., O'Sullivan, P.B., Aziz, F., Raza, A., 1998. Fission-track ages of stone tools and fossils on the east Indonesian island of Flores. Nature 392, 173–179.

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

Morwood, M.J., Trezise, P.J., 1989. Edge-ground axes in Pleistocene greater Australia: new evidence from S.E. Cape York Peninsula. QLD Archaeol. Res. 6, 77–90.

Movius Jr., H.L., 1943. The Stone Age of Burma. Trans. Am. Phil. Soc. 32, 341–393.

Movius, Jr., H.L., 1944. Early man and Pleistocene stratigraphy in southern and eastern Asia. Papers of the Peabody Museum of American Archaeology and Ethnology 19.

Movius Jr., H.L., 1948. The Lower Palaeolithic cultures of southern and eastern Asia. Trans. Am. Phil. Soc. 38, 329–420.

Mulvaney, D.J., 1970. The Patjitanian industry: some observations. Mankind 7, 184–187.

Nelson, M.C., 1991. The study of technological organization. J. Archaeol. Method Theory 3, 57–100.

Noone, H.V.V., 1949. Some implements of the Australian Aborigines with European parallels. Man 49, 111–114.

Oakley, K.P., 1963. Man the Tool-Maker. British Museum, London.

O'Connor, S., Aplin, K.P., Pasveer, J., Hope, G., 2005a. Liang Nabulei Lisa: a late Pleistocene and Holocene sequence from the Aru Islands. In: O'Connor, S., Spriggs, M., Veth, P. (Eds.), The Archaeology of the Aru Islands, Eastern Indonesia. Terra Australis 22. Australian National University, Canberra, pp. 125–161.

O'Connor, S., Aplin, K.P., Spriggs, M., Veth, P., Ayliffe, L.K., 2002a. From savannah to rainforest: changing environments and human occupation at Liang Lemdubu, Aru Islands, Maluku (Indonesia). In: Kershaw, P., David, B., Tapper, N., Penny, D., Brown, J. (Eds.), Bridging Wallace's Line: The Environmental and Cultural History and Dynamics of the SE Asian–Australian Region. Catena Verlag, Reiskirchen, pp. 279–306.

O'Connor, S., Aplin, K.P., Szabó, K., Pasveer, J., Veth, P., Spriggs, M., 2005b. Liang Lemdubu: A Pleistocene cave site in the Aru Islands. In: O'Connor, S., Spriggs, M., Veth, P. (Eds.), The Archaeology of the Aru Islands, Eastern Indonesia. Terra Australis 22. Australian National University, Canberra, pp. 171–204.

O'Connor, S., Spriggs, M., Veth, P., 2002b. Excavation at Lene Hara Cave establishes occupation in East Timor at least 30,000–35,000 years ago. Antiquity 76, 45–50.

Owen, W.E., 1938. The Kombewa Culture, Kenya Colony. Man 38, 203–205.

Odell, G.H. (Ed.), 1996. Stone Tools: Theoretical Insights into Human Prehistory. Plenum Press, New York.

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

Odell, G.H., 2004. Lithic Analysis. Manuals in Archaeological Method, Theory, and Technique. Kluwer Academic, New York.

Paterson, T.T., 1940. Geology and early man (Parts 1 and 2). Nature 146, 12–15, 49–52.

Paterson, T.T., 1941. On a world correlation of the Pleistocene. Trans. R. Soc. Edinburgh 60, 373–425.

Pawlik, A.F., 2004. The Palaeolithic site of Arubo 1 in central Luzon, Philippines. Indo-Pac. Prehist. Assoc. Bull. 24, 3–12.

Pawlik, A.F., Ronquillo, W.P., 2003. The Palaeolithic in the Philippines. Lithic Technol. 28, 79–93.

Pecora, A.M., 2001. Chipped stone tool production strategies and lithic debitage patterns. In: Andrefsky Jr. W. (Ed.), Lithic Debitage: Context, Form, Meaning. University of Utah Press, Salt Lake City, pp. 173–190.

Pookajorn, S., 1994a. The geographic setting of Krabi and excavation report of Moh Khiew Cave. In: Pookajorn, S., Waiyasadamrong, A., Sinsakul, S., Wattanasak, M., Chaimanee, Y. (Eds.), Final Report of Excavations at Moh Khiew Cave, Krabi Province: The Hoabinhian Research Project in Thailand, vol. 2. Silkaporn University, Bangkok, pp. 306–347.

Pookajorn, S., 1994b. Interpretation and conclusion of archaeological context from Moh Khiew and Sakai Caves. In: Pookajorn, S., Waiyasadamrong, A., Sinsakul, S., Wattanasak, M., Chaimanee, Y. (Eds.), Final Report of Excavations at Moh Khiew Cave, Krabi Province: The Hoabinhian Research Project in Thailand, vol. 2. Silkaporn University, Bangkok, pp. 419–442.

Pookajorn, S., 1996. Human activities and environmental changes during the late Pleistocene to middle Holocene in southern Thailand and Southeast Asia. In: Straus, L.G., Eriksen, B.V., Erlandson, J.M., Yesner, D.R. (Eds.), Humans at the End of the Ice Age: The Archaeology of the Pleistocene–Holocene Transition. Plenum Press, New York, pp. 201–213.

Pope, G.G., 1997. Paleoanthropological research traditions in the Far East. In: Clark, G.A., Willermet, C.M. (Eds.), Conceptual Issues in Modern Human Origins Research. Aldine de Gruyter, New York, pp. 269–282.

Pope, G.G., Keates, S.G., 1994. The evolution of human cognition and cultural capacity: a view from the Far East. In: Corruccini, R.S., Ciochon, R.L. (Eds.), Integrative Paths to the Past: Palaeoanthropological Advances in Honor of F. Clark Howell. Prentice Hall, Englewood Cliffs, pp. 531–568.

Potts, R., 1991. Why the Oldowan? Plio-Pleistocene toolmaking and the transport of resources. J. Anthropol. Res. 47, 153–176.

Presland, G., 1980. Continuity in Indonesian lithic traditions. The Artefact 5, 19–46.

Ranov, N., 1995. The "loessic Palaeolithic" in south Tadjikistan, central Asia: its industries, chronology and correlation. Quat. Sci. Rev. 14, 731–745.

Reynolds, T.E.G., 1993. Problems in the Stone Age of South-east Asia. Proc. Prehist. Soc. 59, 1–15.

Roberts, R.G., Morwood, M.J., Westaway, K.E., 2005. Illuminating Southeast Asian prehistory: new archaeological and paleoanthropological frontiers for luminescence dating. Asian Perspect. 44, 293–319.

Sartono, S., 1980. *Homo erectus ngandongensis*: the possible maker of the "Sangiran flakes". Anthropologie 18, 121–131.

Schepartz, L.A., Miller-Antonio, S., Bakken, D.A., 2000. Upland resources and the Early Palaeolithic occupation of southern China, Vietnam, Laos, Thailand and Burma. World Archaeol. 32, 1–13.

Schick, K.D., 1994. The Movius Line reconsidered: Perspectives on the earlier Paleolithic of eastern Asia. In: Corruccini, R.S., Ciochon, R.L. (Eds.), Integrative Paths to the Past: Palaeoanthropological Advances in Honor of F. Clark Howell. Prentice Hall, Englewood Cliffs, pp. 569–596.

Sémah, F., Sémah, A.-M., Djubiantono, T., Simanjuntak, H.T., 1992. Did they also make stone tools? J. Hum. Evol. 23, 439–446.

Sémah, F., Sémah, A.-M., Falguéres, C., Détroit, F., Gallet, X., Hameau, S., Moigne, A.-M., Simanjuntak, H.T., 2004. The significance of the Punung karstic area (eastern Java) for the chronology of the Javanese Palaeolithic, with special reference to the Song Terus cave. Mod. Quat. Res. SE Asia 18, 45–62.

Sémah, F., Sémah, A.-M., Simanjuntak, T., 2003. More than a million years of human occupation in insular Southeast Asia: the early archaeology of eastern and central Java. In: Mercader, J. (Ed.), Under the Canopy: The Archaeology of Tropical Rain Forests. Rutgers University Press, New Brunswick, pp. 161–190.

Shea, J.J., 1999. Artifact abrasion, fluvial processes, and "living floors" from the Early Paleolithic site of 'Ubeidiya (Jordan Valley, Israel). Geoarchaeology 14, 191–207.

Shott, M.J., 1994. Size and form in the analysis of flake debris: review and recent approaches. J. Archaeol. Method Theory 1, 69–110.

Shott, M.J., 2003. Chaîne opératoire and reduction sequence. Lithic Technol. 28, 95–105.

Simanjuntak, T., 1996. Cave habitation during the Holocene period in Gunung Sewu. Aspects Indones. Archaeol. 18, 1–28.

Simanjuntak, T., 2001. New insights on the tools of pithecanthropus. In: Simanjuntak, T., Prasetyo, B., Handini, R. (Eds.), Sangiran: Man, Culture and Environment in Pleistocene Times. The National Research Centre of Archaeology, Yayasan Obor, pp. 154–170.

Simanjuntak, T., 2004. New insight on the prehistoric chronology of Gunung Sewu, Java, Indonesia. Mod. Quat. Res. SE Asia 18, 9–30.

Simanjuntak, T., Sémah, F., 1996. A new insight into the Sangiran flake industry. Indo-Pac. Prehist. Assoc. Bull. 14, 22–26.

Soejono, R.P., 1961. Preliminary notes on new finds of Lower-Palaeolithic implements from Indonesia. Asian Perspect. 5, 217–232.

Soejono, R.P., 1962. Indonesia. Asian Perspect. 6, 34–43.

Soejono, R.P., 1982a. New data on the Palaeolithic industry in Indonesia. In: Pivetean, J., de Lumley, H., de Lumley, M.-A. (Eds.), L'*Homo erectus* et la Place de L'Homme de Tautavel Parmi les Hominidés Fossils. Congrès International de Paléontologie Humaine Ier Congrès, Tome 2. Palais des Expositions, Nice, pp. 578–592.

Soejono, R.P., 1982b. Trends in prehistoric research in Indonesia. Mod. Quat. Res. SE Asia 7, 25–31.

Soejono, R.P., 2001. Remarks on the development and problems of the Paleolithic in Indonesia. In: Simanjuntak, T., Prasetyo, B., Handini, R. (Eds.), Sangiran: Man, Culture and Environment in Pleistocene Times. The National Research Centre of Archaeology, Yayasan Obor, pp. 143–153.

Solheim II, W.G., 1969. Reworking Southeast Asian prehistory. Paideuma 15, 125–139.

Solheim II, W.G., 1970. Northern Thailand, Southeast Asia, and world prehistory. Asian Perspect. 13, 145–162.

Sondaar, P.Y., van den Bergh, G.D., Mubroto, B., Aziz, F., de Vos, J., Batu, U.L., 1994. Middle Pleistocene faunal turn-over and colonisation of Flores (Indonesia) by *Homo erectus*. C. R. Acad. Sci. 319, 1255–1262.

van Stein Callenfels, P.V., 1934. Implements used by Solo Man at least 40,000 years ago? Tools associated with the mid-Pleistocene Javanese. The Illustrated London News August 18, 254–255.

van Stein Callenfels, P.V., 1936. Recent discoveries of skulls and Pleistocene stone implements in Java. Man 36, 209–210.

van Stein Callenfels, P.V., 1940. Miscellaneous notes on the prehistory of Southeast Asia. In: Chasen, F.N., Tweedie, M.W.F. (Eds.), Proceedings of the Third Congress of Prehistorians of the Far East. Government Printing Office, Singapore, pp. 96–99.

Stone, R., 2006. Java Man's first tools. Science 312, 361.

Sudijono, 1985. The Grenzbank, a key marker bed. In: Watanabe, N., Kadar, D. (Eds.), Quaternary Geology of the Hominid Fossil Bearing Formations in Java. Geological Research and Development Centre, Bandung, pp. 135–152.

Swartz, B.K., 1980. Continental line-making: a reexamination of basic Palaeolithic classification. In: Leakey, R.E., Ogot, B.A. (Eds.), Proceedings of the Eighth Congress of Prehistory and Quaternary Studies, Nairobi, 5 to 10 September 1977. International Louis Leakey Memorial Institute for African Prehistory, Nairobi, pp. 33–35.

Swisher III, C.C., Curtis, G.H., Jacob, T., Getty, A.G., 1994. Age of the earliest known hominids in Java, Indonesia. Science 263, 1118–1121.

Szabó, K., Brumm, A., Bellwood, P. Shell artefact production at 32,000 BP in island Southeast Asia: thinking across media?, Curr. Anthropol., submitted for publication.

Tanudirjo, D.A., 1995. Theoretical trends in Indonesian archaeology. In: Ucko, P.J. (Ed.), Theory in Archaeology: A World Perspective. Routledge, London, pp. 61–75.

Teilhard de Chardin, P., 1937a. The Pleistocene of China: stratigraphy and correlations. In: MacCurdy, G.G. (Ed.), Early Man. J.B. Lippincott, London, pp. 211–220.

Teilhard de Chardin, P., 1937b. Notes sur la paléontologie humaine en Asie méridionale. L'Anthropologie 47, 23–33.

Teilhard de Chardin, P., 1941. Early Man in China. Institut de Géo-Biologie, Peking.

Teilhard de Chardin, P., Young, C.C., 1935. The Cenozoic sequence in the Yangtze Valley. Bull. Geol. Soc. China 14, 161–178.

Teilhard de Chardin, P., Young, C.C., Pei, W.C., 1935. On the Cenozoic formations of Kwangsi and Kwangtung. Bull. Geol. Soc. China 14, 179–211.

Torrence, R. (Ed.), 1989. Time, Energy and Stone Tools. Cambridge University Press, Cambridge.

Tweedie, M.W.F., 1953. The Stone Age of Malaya. J. Malayan Branch R. Asiat. Soc. 26, 1–90.

van Heekeren, H.R., 1948. Prehistoric discoveries in Siam, 1943-44. Proc. Prehist. Soc. 14, 24–32.

van Heekeren, H.R., 1949. Early man and fossil vertebrates on the island of Celebes. Nature 163, 492.

van Heekeren, H.R., 1955. New investigations on the Lower Palaeolithic Patjitanian culture in Java. Bull. Archaeol. Serv. Repub. Indonesia 1, 1–12.

van Heekeren, H.R., 1957. The Stone Age of Indonesia. Martinus Nijhoff, 'S-Gravenhage.

van Heekeren, H.R., 1972. The Stone Age of Indonesia, second ed. Martinus Nijhoff, The Hague.

van Heekeren, H.R., Knuth, E., 1967. Archaeological Excavations in Thailand 1. Sai-Yok: Stone-age Settlements in the Kanchanaburi Province. Munksgaard, Copenhagen.

von Heine-Geldern, R., 1945. Prehistoric research in the Netherlands Indies. In: Honig, P., Verdoorn, F. (Eds.), Science and Scientists in the Netherlands Indies. Board for the Netherlands Indies. Surinam and Curaçao, New York, pp. 129–167.

von Koenigswald, G.H.R., 1936. Early Palaeolithic stone implements from Java. Bull. Raffles Mus. Singap. 1, 52–60.

von Koenigswald, G.H.R., 1937. A review of the stratigraphy of Java and its relations to early man. In: MacCurdy, G.G. (Ed.), Early Man. J.B. Lippincott, London, pp. 23–32.

von Koenigswald, G.H.R., 1978. Lithic industries of *Pithecanthropus erectus* of Java. In: Ikawa-Smith, F. (Ed.), Early Paleolithic in South and East Asia. Mouton, The Hague, pp. 23–27.

von Koenigswald, G.H.R., Ghosh, A.K., 1973. Stone implements from the Trinil Beds of Sangiran, central Java. Proc. K. Ned. Akad. Wet. (Ser. B) 76, 1–34.

Veth, P., Spriggs, M., Jatmiko, A., O'Connor, S., 1998a. Bridging Sunda and Sahul: the archaeological significance of the Aru Islands, southern Moluccas. Mod. Quat. Res. SE Asia 15, 157–177.

Veth, P., O'Connor, S., Spriggs, M., 1998b. After Wallace: preliminary results of the first season's excavation of Liang Lemdubu, Aru Islands, Maluku. In: Klokke, M.J., de Bruijn, T. (Eds.), Southeast Asian Archaeology 1996. Centre for South-East Asian Studies. University of Hull, Hull, pp. 75–81.

Westaway, K.E., Morwood, M.J., Roberts, R.G., Zhao, J-x., Sutikna, T., Saptomo, E.W., Rink, W.J. Establishing the time of initial human occupation of Liang Bua, western Flores, Indonesia. Quat. Geochronol., in press.

White, J.C., Gorman, C.F., 2004. Patterns in "amorphous" industries: the Hoabinhian viewed through a lithic reduction sequence. In: Paz, V. (Ed.), Southeast Asian Archaeology: Wilholm G. Solheim II Festschrift. University of the Philippines, Manila, pp. 411–441.

White, J.P., 1977. Crude, colourless and unenterprising? Prehistorians and their views on the Stone Age of Sunda and Sahul. In: Allen, J., Golson, J., Jones, R. (Eds.), Sunda and Sahul: Prehistoric studies in Southeast Asia, Melanesia and Australia. Academic Press, London, pp. 13–30.

Widianto, H., Toha, B., Simanjuntak, T., 2001. The discovery of stone implements in the Grenzbank: new insights into the chronology of the Sangiran Flake Industry. Indo-Pac. Prehist. Assoc. Bull. 21, 157–161.

Yi, S., Clark, G.A., 1983. Observations on the Lower Palaeolithic of Northeast Asia. Curr. Anthropol. 24, 181–202.