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Hoabinhian variability in Mainland Southeast Asia revisited: The lithic assemblage of Moh Khiew Cave, Southwestern Thailand

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Abstract

The Hoabinhian has been a major topic in prehistoric research in Mainland Southeast Asia for nearly 90 years. However, its variability in terms of lithic assemblages is still poorly understood, as a limited number of sites have been analyzed from a technological perspective. This variability is to be expected, considering that the Hoabinhian covers a timespan of more than 30,000 years, a wide region extending from mountainous south-western China to insular Indonesia and diversified sub-tropical to tropical environments. In this research, we present the variability of Hoabinhian tools at the site of Moh Khiew Cave in Southern Thailand. Unlike other 'typical'-Hoabinhian sites discovered in this region, the Hoabinhian lithic assemblage (~11,000–9000 BP) at Moh Khiew is dominated by unifacially shaped *limaces* and unifaces, on large/medium and thick flakes, and thus involves a mixed operational sequence (*chaîne opératoire*) of *debitage* and shaping methods. No classic sumatralith tools were found in the site, which are usually made on river cobbles and considered to be the hallmark of the Hoabinhian. Another exceptional tool type is the biface, made on shale slabs or blocks, other cutting tool types include chopper-chopping-tools and flake tools, etc. In view of the production methods of unifaces and *limaces*, their distinct volumetric structures, and the co-existence of unifaces with other shaped tool types; the Moh Khiew lithic assemblage is different from other Hoabinhian sites, and may represent a local variant of the Hoabinhian in this region of south-western Thailand.

Introduction

Since its first definition by the French archaeologist Madeleine Colani in the early 1930s (Collectif 1932), the Hoabinhian has no doubt been one of the most debated topics of prehistoric research in Mainland Southeast Asia. A wide range of subjects pertaining to the Hoabinhian have been discussed, such as its tempo-spatial distribution (Bowdler 1994; Huong 1994; Matthews, 1964; Reynolds 1990; Saurin 1969; Solheim 1974), its definition (Matthews 1966; Moser 2001; Pautreau 1994; Reynolds 1990; Tan 1994), the technological, experimental and functional analysis of the lithic assemblages (Gorman 1969; J'ér'emie 1990; Pookajorn 1985; Reynolds 1989; Sorensen 1982; White and Gorman 2004), economic aspects of Hoabinhian hunter-gatherers (Glover 1977; Gorman 1969, 1970, 1971; Vu 1994; Yen 1977) and their environmental context (Shoocongdej 2000), the interpretation of the widespread sites in Southeastern Asia (Gorman 1970), the origin, development, and disappearance of the Hoabinhian in the region (Bellwood 1985; Bui 1994; Chu 1984; Ha 1995a, 1997; Nga 1994; Nguyen 1991, 1994a), Hoabinhian human remains (Nguyen 1986, 1987, 1994b) and burial patterns (Pookajorn 1994; Trinh 1993; Zeitoun et al. 2013, 2019a), etc. Over the first two decades of the twenty-first century, our knowledge of the Hoabinhian has been greatly enhanced by the application of new methods of research and newly excavated sites. On the one hand, the Hoabinhian has been redefined by a technological approach to the lithic industry, considered as a functional technocomplex containing several *chaînes opératoires* (Forestier et al. 2005; Forestier, 2010; Forestier et al. 2013, 2015, 2017; Forestier 2020; Zeitoun et al. 2008). On the other hand, the chronology of the Hoabinhian has been largely extended and is no longer viewed as a 'Mesolithic phenomenon', since the earliest known Hoabinhian site at Xiaodong Rock shelter in Southwest China dates to about 43, 000 BP (Ji et al. 2016). The site of Huai Hin in Northwest Thailand, dated to 3700 BP is considered to mark the end of the Hoabinhian (Forestier et al. 2013; Zeitoun et al. 2008). To date, more than one hundred Hoabinhian sites have been reported in Southeast Asia (Chung 2008; Forestier et al. 2017; Moser 2001; White 2011; Zeitoun et al. 2008). This introduces the question of the variability of Hoabinhian lithic assemblages since we cannot logically expect a cobble toolkit to be uniform and homogeneous for more than 30,000 years among different hunter-gatherer groups in a large region comprising diverse environmental, ecological and geographical contexts. White (2011) proposed that the emergence of cultural diversity in mainland Southeastern Asia started during the Hoabinhian period in the Late Upper Pleistocene. This was subsequently suggested from the viewpoint of burials by Imdirakphol et al. (2017). However, it was difficult to pursue this line of investigation up until now due to the lack of systematic scientific methods among previous researchers (Marwick 2007). Over the past two decades, the *chaîne opératoire* approach and the methodology of technological analysis (Inizan et al. 1999) have been applied to lithic studies and could provide a general framework for comparing synchronous and diachronic Hoabinhian technical behaviors. Preliminary technological studies on several Hoabinhian sites have proved the efficacy of this approach and contributed to a technological definition of the Hoabinhian (Celiberti et al. 2018; Forestier et al. 2005, 2013, 2015, 2017; Zeitoun et al. 2008). Nonetheless, Forestier et al. (2013) argue that more analysis is still needed to evaluate the whole corpus of Southeast Asian lithic industries. In an effort toward this aim, here we present the results of the technological analysis of the lithic industry of another Hoabinhian site—Moh Khiew Cave - in Southwestern Thailand. We focus on the *chaîne opératoire* of lithic production and the tools obtained to define the technological characteristics of the industry, and then discuss the nature of the lithic assemblage, whether or not it is a Hoabinhian techno-complex and how to recognize the Hoabinhian in the absence of sumatraliths. Finally, we propose rethinking the definition of the Hoabinhian. Firstly, we will introduce the general definition of Hoabinhian from two different perspectives: typological and technological.

What is the Hoabinhian?

Since its first definition as a ‘Mesolithic’ -culture by Madeleine Colani in the early 1930s (Collectif 1932), the Hoabinhian has been re-defined several times by scholars over the course of 90 years of research (Forestier 2020; Gorman 1969; Marwick 2007; Moser 2001; Pautreau 1994; Zeitoun et al. 2008). In general, these definitions stem from two different approaches to lithic assemblages: typological and technological.

1) The typological definition of the Hoabinhian is closely related to the morphology of knapped tools and the typological list of the toolkit encountered at the sites. In the Hoabinhian, the most typical tool is the so-called ‘sumatralith’, which is usually obtained by peripheral unifacial shaping from the plane surface of the cobble, residual cortex is often visible on its upper face. The associated tools usually include short axes, discs, hammers, almond-shaped artefacts, scrapers, and choppers, etc. It is a cobble-tool industry and the tempo-spatial distribution of the Hoabinhian is Mainland Southeast Asia and the nearby regions during the Late Pleistocene and Early Holocene (Collectif 1932; Gorman 1969, 1970; Marwick 2018; Matthews 1966; Pautreau 1994). This typological definition of the Hoabinhian is often criticized because the sumatralith is seen as the hallmark of the Hoabinhian by many researchers, while other associated tools are too often neglected (Marwick 2008; Reynolds 1990; White and Gorman 2004; Zeitoun et al. 2008).

2) The technological approach focuses on the total lithic assemblage rather than on certain typical tools. The first technological approach to Hoabinhian lithic artefacts was conducted by White and Gorman in the 1970s (White and Gorman 2004). However, the late publication of the research results limited the circulation and influence of the study (Marwick 2007). A systematic technological method based on the *chaîne opératoire* was incorporated into research in the early 2000s, after nearly two decades of fieldwork and analyses of Hoabinhian lithic artefacts. A new technological definition of the Hoabinhian was proposed, which can be summarized as follows: The Hoabinhian is a technocomplex comprising several *chaînes opératoires* to produce macro-tools and small tools. These *chaînes opératoires* include: a) a typical shaping sequence to produce chopper-chopping-tools on river cobbles; b) split debitage sequence to obtain half-cobble blanks, these half-cobbles may then be further shaped or retouched into diverse tools; c) a unifacial shaping sequence on cobbles to produce unifaces. Quantitatively, the uniface represents a minority of the artefacts, while split products are often numerous, as at Huai Hin (Forestier et al. 2013) and Laang Spean (Forestier et al. 2015). The most important aspect of the Hoabinhian is the stable and consistent need for a plano-convex structure during a period of time spanning more than 30,000 years, from the Late Pleistocene to the Early-Middle Holocene. This is the binding aspect of the industries which we refer to as Hoabinhian. The sumatralith is just one example of the plano-convex structure, but not the only way of obtaining a plano-convex structure. The Hoabinhian phenomenon appears to be limited to Mainland Southeast Asia and the surrounding regions and is linked to tropical and sub-tropical forest environments (Forestier et al. 2013, 2015, 2017; Forestier 2020; Zeitoun et al. 2008, 2019a).

Compared with the traditional typological definition, the new definition from a technological perspective presents several advantages. Firstly, it circumvents assumptions based on typical artefacts and especially the sumatralith. Secondly, the qualitative and quantitative aspects of lithic industries are described since the totality of the lithic assemblage needs to be studied in order to define it from a technological viewpoint. Thirdly, a detailed technological description of the industries makes comparative studies possible, thus leading to an enhanced understanding of Hoabinhian variability. Finally, the definition of the Hoabinhian in this tempo-spatial area does not exclude technical convergences in other regions of the world. The definition of the Hoabinhian based on raw materials and the sumatralith is not appropriate considering that these aspects contain little technological information and are the result of a broader *concept* in the

knappers' mind. It is the *concept* that determines this production and reproduction, and which is of crucial importance when defining the Hoabinhian. For technologists, the term *concept* refers to the mental representation of the structure, which guides all the knapping operations (Boëda 1991, 1994, 1997). The notion of *concept* concentrates on the intention of the knapper, and is “a technical entity which has fixed characters, well determined, able to generate a diversity of methods of application to obtain identical or different objectives. Each technical structure thus corresponds to a certain number of methods” (Boëda 1991, p.61). Although the *concept* is relatively stable in knappers' minds, a certain degree of variability and flexibility emerges in terms of the methods employed when this *concept* is concretized into structures (lithic objects). The new definition of the sumatralith in terms of the *concept* helps to reveal its real technological nature as a unifacial plano-convex structure/*scheme*, rather than a particular morphology or shape. The sumatralith is just one end product of that concretized plano-convex structure (Forestier et al. 2005; Forestier, 2010; Forestier et al. 2013, 2015, 2017; Zeitoun et al. 2008).

Moh Khiew Cave

Location and history of excavation and research

Moh Khiew Cave is located in the district of Muang Krabi, Krabi Province, on the west coast of the Thai Peninsula (**Fig. 1**). The site situates in the mountainous area of the Khao Nha Shing, and it is a rock shelter of Permian limestone at the elevation 100 m above the present sea level. About 3 km from the site, two major rivers (Khong Krabi Yai in the west and Krabi Noi in the east) yielding river cobbles run from north to south and connect with the Andaman Sea. The site was excavated twice, from 1991 to 1994, and from 2008 onwards by Professor S. Pookajorn and P. Auetrakulvit respectively from the Faculty of Archaeology, Silpakorn University. The detailed description of the site's environmental and geographic context can be found in the final report published by Pookajorn (1994). Two volumes of reports were published on the site. The first volume (1991) concentrated on descriptive data from field studies of the rock shelter (Pookajorn, 1991), and the second volume (1994) focused on the results of the scientific analyses (Pookajorn 1994). In the reports published by S. Pookajorn, rich stone artefacts, faunal remains, human burials, and pottery shards were described, the site sequence was divided into five cultural levels extending from the Late Paleolithic to the Late Neolithic. In 2008, the site was re-opened for excavations in order to reappraise the dating of the burials and layers and to obtain more detailed information on the life of prehistoric populations in Southern Thailand. The sector excavated in 2008 was 1 m to the west of the boundary of the 1991 excavation and closer to the limestone wall. A surface of about 7 m² was excavated. A brief report on the excavation results and a preliminary study of lithic artefact categories was published by Auetrakulvit et al. (2012)

Stratigraphy and chronology

Two sections of the site sequence were revealed in 1991 and 2008 respectively, which correlate well to each other. However, the excavators used different appellations to record natural layers; natural layer 1c in 2008 corresponds to layers I and II in 1991, layer 1b to upper layer III, layer 1a to lower layer III, layer 2 to upper layer IV, layer 3 to lower layer IV; layer 4 to upper layer V (**Fig. 2**). For the 1991 excavation, five cultural levels were defined based on the stratigraphy and cultural remains and thus represent a relative chronology for the site. Since the absolute ¹⁴C dating method was applied on samples from layers III, IV and V, and one sample came from between layers I and II, the age of layer I was estimated by stone tool typology, human skeleton analysis, faunal and floral remains through comparisons to other well-dated sites in Southeast Asia (Pookajorn 1994). The dating results showed good coherence with the stratigraphy.

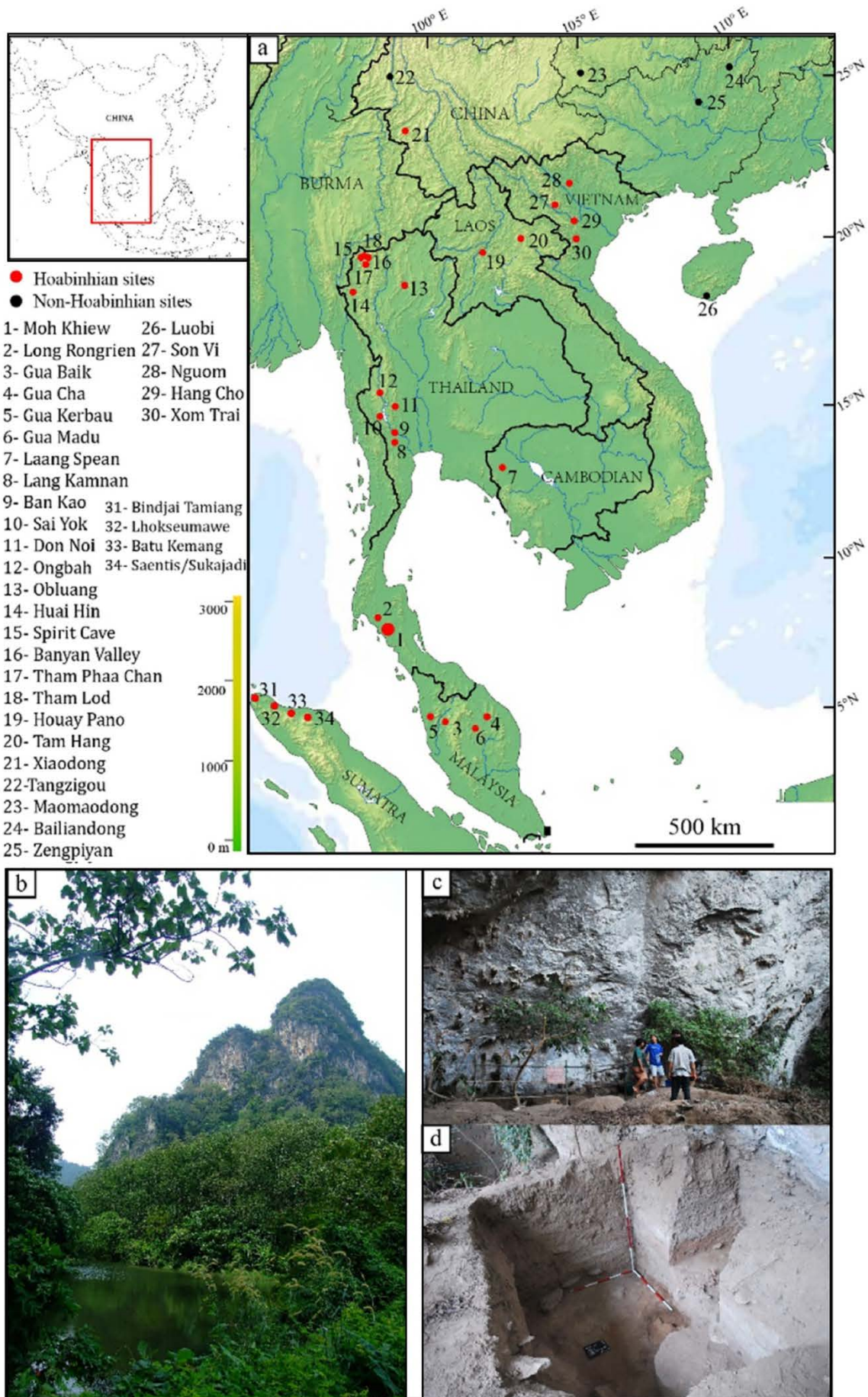


Fig. 1. Location of sites. a. Location of the Moh Khiew Cave and other sites mentioned in this paper; b. Limestone hill where Moh Khiew Cave is situated; c. Excavation area in 2008; d. Stratigraphic profile of the site.

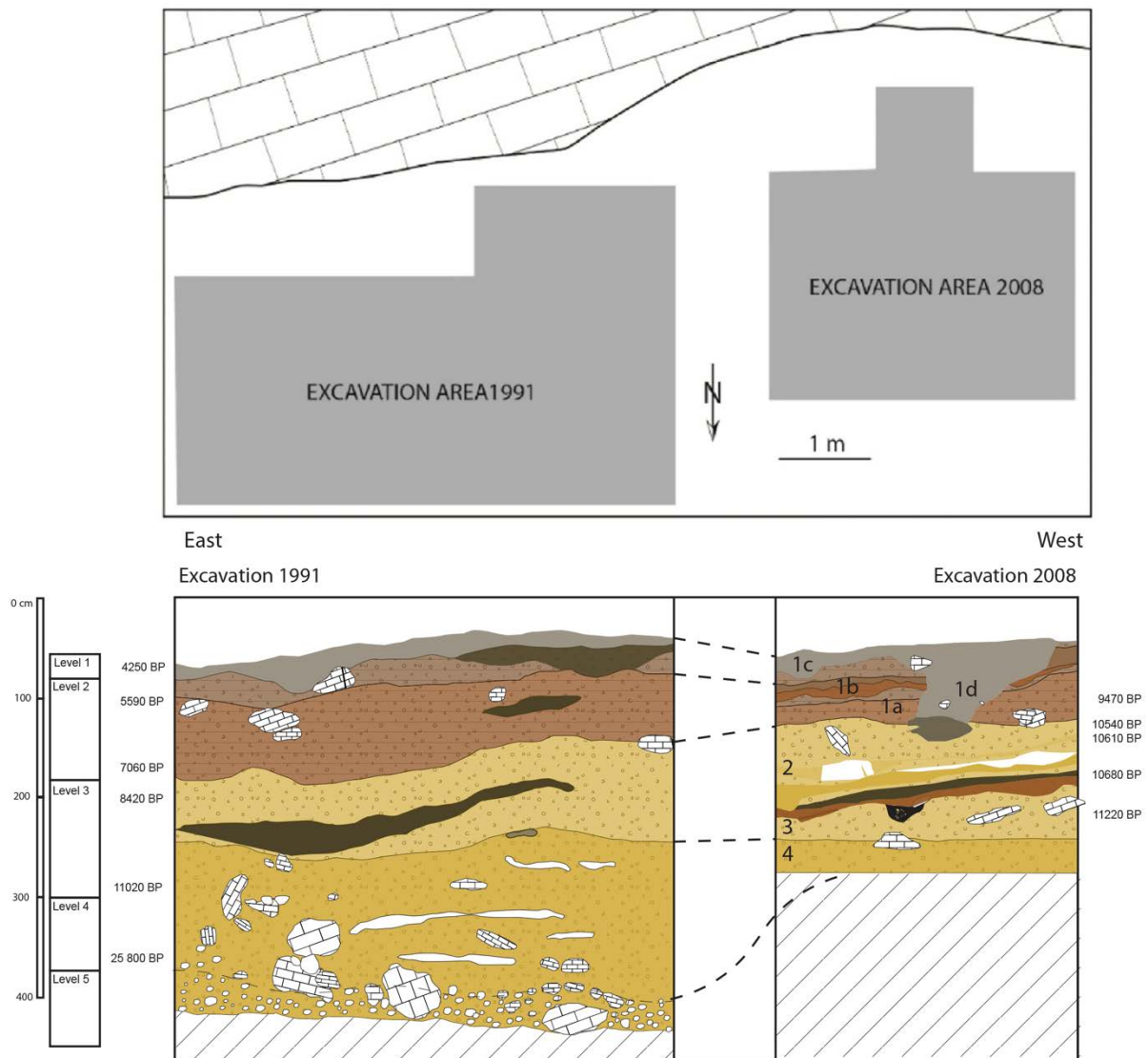


Fig. 2. Comparison of the stratigraphy excavated in 1991 and 2008 at Moh Khiew (top: plan of excavated areas; bottom: stratigraphic sections; the figure is redrawn from Auetrakulvit et al., 2012).

Table 1 presents detailed dating results. According to the final report, lower Layer V was attributed to the Late Paleolithic during the Upper Pleistocene. There is only one dating sample from the bottom of middle Layer V, with a date of $25,800 \pm 600$ BP (TK-933 Pr, a sample from the grave), thus the age of middle Layer V should not be older than 25,000 BP. Upper Layer V and layer IV are dated between 11,000 and 8400 BP, Layer III between 7000 and 5500 BP, Layers I and II around 4200 BP with only one dating sample (Pookajorn 1994). For the 2008 excavation, five charcoal samples, from the newly defined layers 3 and 2 (formerly IV) (**Table 1**) (Auetrakulvit et al., 2012), were dated by the Thailand Institute of Nuclear Technology. New dates from the 2008 excavation yielded an absolute age for layers 3 and 2 between ca. 11,000 and 9500 BP. In comparison with the dating results on the same layers from the 1990s, the age for layer 2 was advanced by several hundred years, while that of layer 3 remained virtually unchanged. With these dating results, layers 3 and 2 defined in 2008 could be securely dated to around 11,000 to 9000 BP.

Burials and human remains

Four burials were excavated in 1991, among which three came from the Layer IV (with dating around 11–8 ka), another originated from the layer below and thus should be older than 11 ka.

The skeletons comprised both adults and children, presenting flexed and extended positions (Auetrakulvit et al., 2012; Pookajorn 1994). New excavations in 2008 also revealed several burials from Layer 2 and 3, including four primary burials, the isolated bones of an immature individual and one skeleton reduction. Detailed descriptions about the burials could be found in Auetrakulvit et al. (2012).

Stratigraphy defined in 1991	Stratigraphy redefined in 2008	¹⁴ C dating in 1991 excavation (Pookajorn 1994)	¹⁴ C dating in 2008 excavation (Auetrakulvit et al., 2012)
Layer I	Layer 1c	4250 ± 150 BP	
Layer II	Layer 1c	(OAEP-1290)	
Upper Layer III	Layer 1b		
Lower Layer III	Layer 1a	5590 ± 70 BP (OAEP-1291) 5940 ± 140 BP (OAEP-1289) 6090 ± 150 BP (OAEP-1278) 7060 ± 100 BP (OAEP-1277)	
Upper Layer IV	Layer 2	8420 ± 90 BP (OAEP-1292) 9670 ± 100 BP (OAEP-1280) 9770 ± 100 BP (OAEP-1279)	9520 ± 420 BP (IHLC2856) 10,590 ± 470 BP (IHLC2857) 10,660 ± 480 BP (IHLC2858)
Lower Layer IV	Layer 3	10,470 ± 80 BP (OAEP-1281) 11,020 ± 150 BP (OAEP-1284) 10,530 ± 100 BP (OAEP-1283)	10,730 ± 480 BP (IHCL2859) 11,270 ± 510 BP (IHCL2860)
Upper Layer V	Upper Layer 4	<25,800 ± 600 BP	

Table 1 Absolute dating results by ¹⁴C and the corresponding stratigraphy at Moh Khiew Cave according to excavations in 1991 and 2008.

Archaeological context and composition of the lithic material (2008)

We observed all the lithic material excavated in 2008, but this study focuses on the assemblages from layers 2 and 3 since layer I contains polished tools and pottery shards, and was defined as early Neolithic by Pookajorn (1994). According to dating carried out by Silpakorn researchers (Auetrakulvit et al., 2012; Pookajorn 1994), the age of the lithic objects from layers 2 and 3 is between 11,000 and 9000 BP. Our technological reading of the lithic artefacts showed that lithic technology in layers 2 and 3 remained the same, with no obvious technological change during this period. Therefore, we decided to present the analysis results as a whole, without separating the two assemblages. Altogether, 10,459 pieces were analyzed (see details in **Table 2**).

Category	Number	Percentage
Cores	4	0.04%
Flakes	2288	21.88%
Flake tools	197	1.88%
Fragments of flakes	1250	11.95%
Shaped tools	46	0.44%
Retouched block	1	0.01%
Split cobble/pebble	4	0.04%
Hammer stones	2	0.02%
Fragments	603	5.78%
Small waste flakes	6059	57.93%
Undetermined pieces	5	0.05%
Total	10,459	100.00%

Table 2 Composition of the lithic assemblage from Moh Khiew (excavation in 2008 by P. Auetrakulvit, Silpakorn University, Bangkok).

Technological analysis of the lithic assemblage

Raw material composition and morphology

The raw material of the lithic assemblage was divided into two groups: group A- river cobbles, and group B- blocks (**Fig. 3b**). The latter is the main group, while the former is rarely used. Only 14 pieces could be identified as cobble material, consisting of shaped tools, flakes, half-cobbles, fragments and hammerstones. Group A-river cobbles may possibly come from the riverbed such as Khlong Krabi Yai and Krabi Noi, which are only 3 km from the site. In general, they are larger than 70 mm, and they were divided into different sub-groups depending on morphology and volumetric structure (**Fig. 3a**): A1 and A2 represent cuboid and globular shapes respectively, and were only used as hammerstones. A3 is quadrangular with a plano-convex transverse section. A4 and A5 are both oval but have different transverse sections; the former presents a symmetric convex-convex section while the latter has a plano-convex section. Group B comprises blocks of various morphologies. B1 represents platy blocks with two parallel surfaces, and includes some weathered shale sheets and siliceous limestone clasts. B2 blocks present a quadrangular morphology and cuboid volume and include shale sheets and limestone clasts. B3 designates an oval morphology with a plano-convex or convex-convex transverse section, and is also mainly represented by shale sheets and limestone blocks. B4 is represented by a single shale block of oval morphology with a convex-convex transverse section. B5 represents a quadrangular mass with a plano-convex section. B6 includes mainly siliceous blocks exposed in rocky outcrops in limestone-forming environments. They are large and thick blocks (usually >150 mm), generally with a round volume, and mostly in chert and flint. The color of these blocks varies greatly; from white to dark, but is most often milky, gray, grayish-brown and rusty-red. They are of very good quality for knapping, however it is not easy to accurately reconstruct whole blocks as no intact pieces were discovered at the site. Most of the B6 artefacts discovered at the site are flakes. Residual cores are rare and heavily depleted to the stage of exhaustion, and flakes with a dorsal surface completely covered by a natural surface on the dorsal face are also rare. Therefore, only a broad outline is presented here and further fieldwork is required to confirm the exploitation of outcrops near the site. A B7 group also appears to exist, consisting of large blocks of different lithology, but their morphology is difficult to discern due to limited information. Regarding raw material composition, the vast

majority of them are siliceous (93%), and the rest are non-siliceous (7%). Cobbles are non-siliceous, including shale, basalt, quartz, limestone, granite, etc. **Fig. 3c** and **d** show detailed information regarding these aspects.

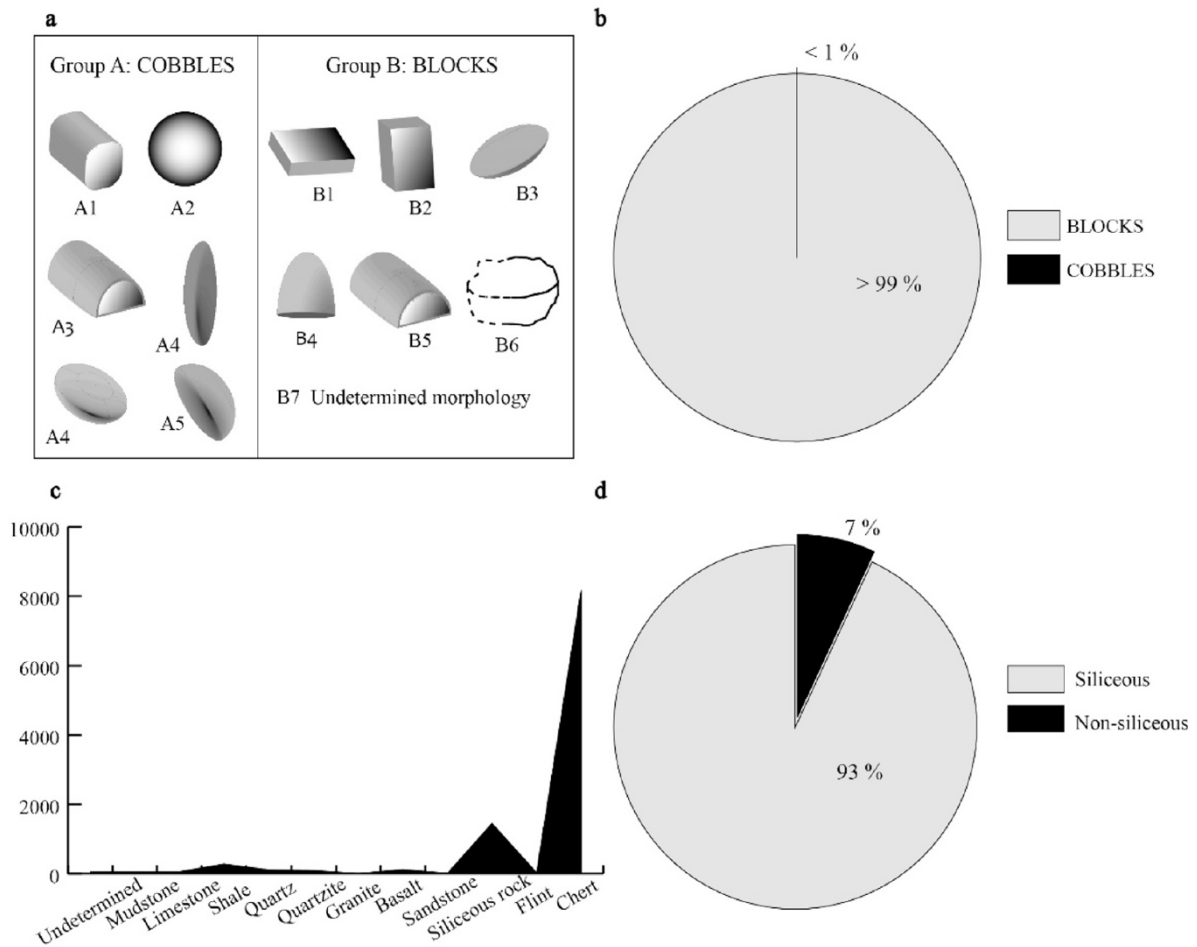


Fig. 3. Lithic raw materials of Moh Khiew. a. Morphology and volumetric structure of the selected raw materials; b. Proportions of blocks and cobbles; c. Detailed raw material composition; d. Percentages of siliceous and non-siliceous materials.

The operational sequence (chaîne opératoire)

At Moh Khiew, blocks and cobbles were selected for shaping and flaking (debitage). Eight operational sequences (OS) of lithic production have been identified (**Fig. 4**):

OS 1 ($n = 9$): a classical shaping operation to produce choppers ($n = 8$, **Fig. 14a, b, e**) and chopping-tools ($n = 1$, **Fig. 5a**) with lateral ($n = 8$) or distal cutting edges ($n = 1$). The blanks are type A3 and type B2/B3 blocks. Partial unifacial or bifacial shaping is usually short and concise and aimed at creating a dihedral structure for the cutting edge, then retouched to regularize the morphology of the working edge.

OS 2 ($n = 5$): bifacial shaping on the periphery of the selected block type, B3. The block is often an oval-shaped weathered shale sheet with a convex-convex or plano-convex section. Three of these pieces are broken in the middle part of the tool. Shaping is usually centered on the block periphery, while the central-proximal part remains natural (**Fig. 12a, b**). More than one cutting edge could be made on the periphery.

OS 3 ($n = 1$): this is a bifacially retouched B4 type block to make a chopping-tool (**Fig. 5b**). Although only one such piece was identified, this sequence denotes the importance of selection during production. The block chosen is of oval morphology with a convex-convex transverse section, and the distal part is bifacially retouched to form a usable cutting edge without changing

the original morphology and structure of the block. This is a very concise operation compared to previous sequences, but more time is required to find such well-suited volumes;

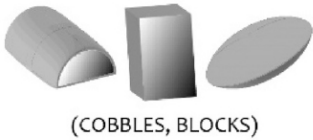
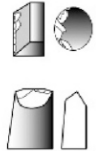
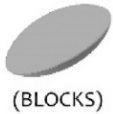





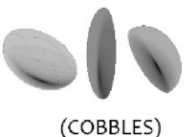


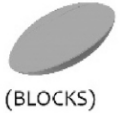

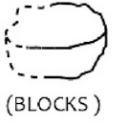
	SELECTION	PRODUCTION	FINAL TOOLS
Operational sequence 1 Selection + partially unifacial/ bifacial shaping+retouch	 (COBBLES, BLOCKS)	Partially unifacial / bifacial shaping	 Choppers Chopping tool
Operational sequence 2 Selection+ fully bifacial shaping+retouch	 (BLOCKS)	Fully bifacial shaping	 Bifaces
Operational sequence 3 Selection+partially bifacial retouch	 (BLOCK)	Partially bifacial retouch	 Chopping tool
Operational sequence 4 Selection+unifacial shaping +retouch	 (BLOCKS)	Unifacial shaping	 Atypical uniface
Operational sequence 5 Selection+bipolar debitage/ split	 (COBBLES)	Bipolar debitage/ split of the cobble 	 Retouched/ utilised flake tool
Operational sequence 6 Selection+discoidal debitage	 (BLOCKS)	Discoidal flaking Producing small flakes	 Small flake tools
Operational sequence 7 Selection+preparation+SSDA flaking+retouch	 (BLOCKS)	Producing big+small flakes	Big+small flake tools (notches, scrapers, denticulates, points halfted tools, etc.) Limaces Unifaces Bifaces
Operational sequence 8 Selection+preparation+SSDA debitage+unifacial/bifacial shaping+retouch		Retouch Unifacial/ bifacial shaping	

Fig. 4. Operational sequences of lithic production at Moh Khiew Cave.

OS 4 (n = 3): the chosen raw material is a platy siliceous limestone block (type B1), with a volumetric structure characterized by the presence of two parallel surfaces. Unifacial shaping on the periphery of the block aims to obtain several cutting edges, but the transverse section and profile of the final tool are always quadrangular, due to the specific volumetric structure of the original block, which makes the tools look like ‘atypical’ _unifaces (Fig. 5c, d) ;

OS5 (n=4) : a typical flaking operation called ‘cobble split’ which involves selecting an oval cobble with a convex-convex transverse section (cobble type A4), and then splitting it on an anvil with the bipolar knapping method using a hard hammer (Fig. 6a, b) ; In ideal cases, the result of splitting yields two similar-sized and shaped half- cobbles, which can then be

retouched or shaped into tools. At Moh Khiew, the knapping direction can be longitudinal, lateral, or multidirectional. In certain cases, the selected cobbles may present a plano-convex structure (cobble type A5).



Fig. 5. Tools from shaping operational sequences. a. Chopping-tool; b. Bifacially retouched block, chopping-tool; c, d. Atypical uniface on block.

OS 6 (n = 1): this is a discoidal flaking sequence (**Fig. 6c**). There is only one piece; a weathered oval shale slab with a plano-convex structure (block type B3). There is no initial preparation of the core before flaking with specific volumetric construction, which explains why there are two non-hierarchized flaking surfaces. These surfaces can alternately be used as the debitage surface and the striking platform surface during flaking. In this way, both surfaces were used in turn as the striking platform and the exploited surface, and two flaking methods were used along the two secant surfaces: on the right part of the slab, the flaking method is alternate; while on the left part, flaking is alternating. The detached elements are mainly small wide flakes with quadrangular and semi-oval shapes with a size of less than 50 mm. These flakes were then used as blanks for small tools.

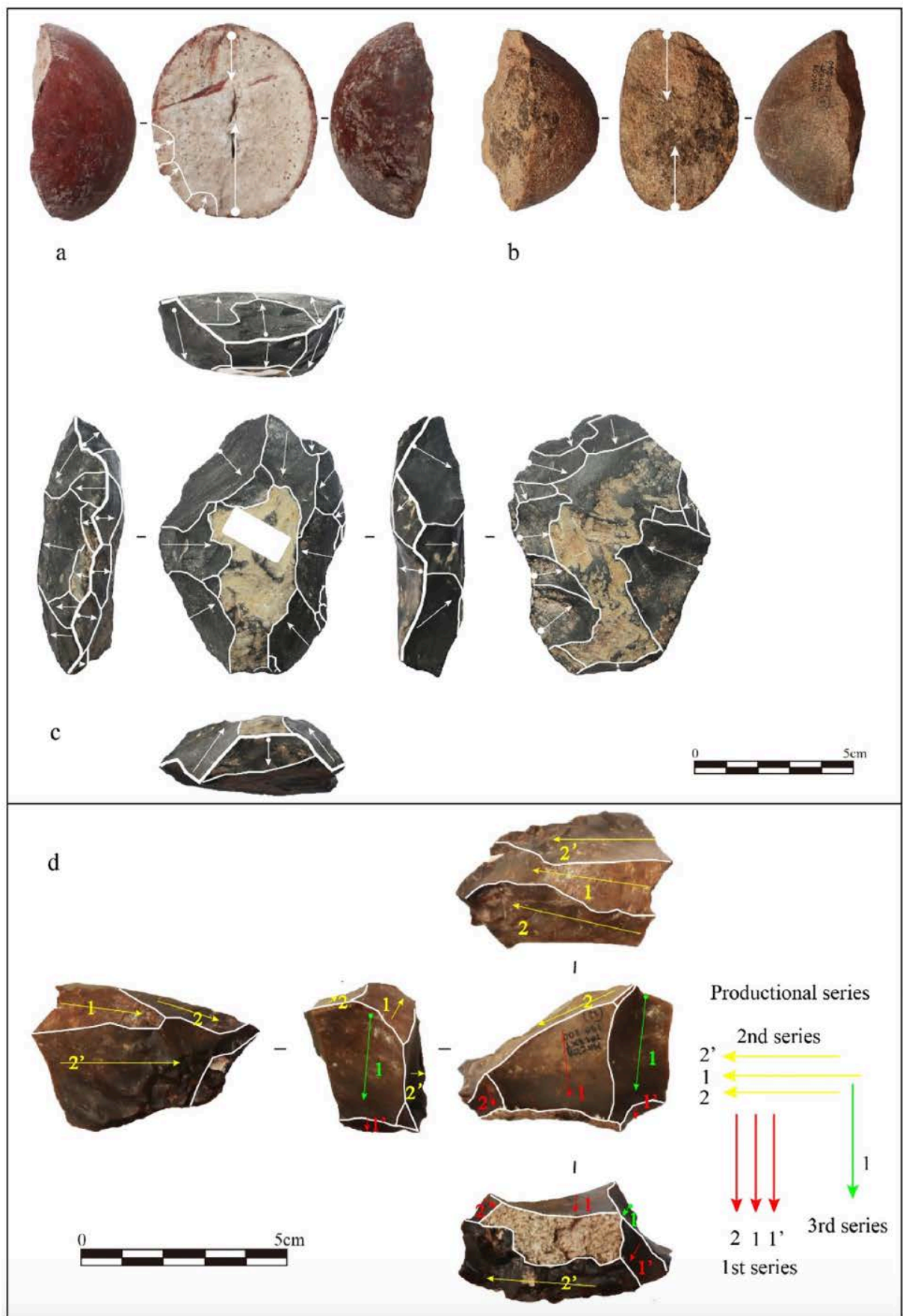


Fig. 6. Examples of cores at Moh Khiew. a, b. Half cobbles; c. Discoidal flaking; d. Algorithm flaking (APS).

Operational sequences	Category of tools	Number of tools	
OS 1	Shaped tools	9	3.64%
OS 2	Shaped tools	5	2.02%
OS 3	Retouched tool	1	0.40%
OS 4	Shaped tools	3	1.21%
OS 5	Flake tools	3	1.21%
OS 6	Flake tools	0	0%
OS 7	Flake tools	74	29.96%
OS 8	Shaped tools	29	11.74%
Tools on shaping flakes	Flake tools	83	33.60%
Tools on undetermined flakes	Flake tools	40	16.19%
Total		247	100%

Table 3 Number of cutting tools confirmed in each operational sequence.

Category		Number		
Shaped tools	Side choppers	7	2.82%	19.03%
	Chopping-tools	3	1.21%	
	<i>Limaces</i>	16	6.45%	
	Unifaces	7	2.82%	
	Atypical unifaces	3	1.21%	
	Bifaces	11	4.45%	
Flake tools	Flake tools	194	78.54%	80.97%
	Hafted flake tools	6	2.43%	
Total		247	100%	100%

Table 4 Types of Hoabinhian stone tools of Moh Khiew.

OS 7: this is a flaking (debitage) sequence. The selected blocks are mainly B6 type elements, but some are type B7. Before flaking, the knapper prepares the striking platform by opening the block. The intersection of the striking platform (i.e., the plane surface obtained by opening the block) and the rest of the block creates exploitable flaking volume(s) on its periphery. No flaking surface preparation is observed except two flakes which present a prepared crested ridge on the dorsal face. In general, the flaking surface is obtained at the same time as the opening of the block. A block may contain more than one exploitable part, so the knapper can change the striking platform and knapping direction to exploit other useful volumes of the same block. Thus, the final residual core may present several series of flaking. The flaking method is always unidirectional in each series, and can be defined as the algorithm flaking system (Alternating Platform System = APS or SSDA in French see Forestier 1993), also called ‘type C’ cores (Boëda 2013), since the knapper tends to seek out suitable volumes to conduct flaking with the least effort in terms of preparation. However, among the flakes, there are also two cases of flaking surface preparation by bifacial removals to create a ridge consisting of two series of negative bulbs. This ridge guides the flaking of an elongated flake (**Fig. 13m**). This type of preparation is often seen in blade and bladelet debitage (Inizan et al. 1999), but here only two pieces were identified. As no cores could provide supporting information, this mode of core preparation requires further confirmation. At Moh Khiew, residual cores are very rare and only one such piece was identified (**Fig. 6d**). However, some siliceous fragments with cuboid

volume may be residual cores, although it is very difficult to identify the direction and chronology of the scars on these fragments, as prehistoric knappers seem to have completely exhausted the blocks. Some flakes could also yield information about this operational sequence from their dorsal patterning and butt. The blanks obtained in this sequence include large flakes (>100 mm) and smaller flakes with oval, quadrangular or triangular morphologies. Some are elongated, and are further retouched into tools, or shaped into tools in certain cases, as in operational sequence 8. This reduction sequence could not be accurately quantified due to the small number of cores and the difficulty in determining the technical origin of many flakes; OS 8 (n = 29): this is a mixed flaking and shaping sequence. As mentioned in OS 7, some large flake blanks from flaking are further shaped into tools. Three tool types are obtained following different shaping methods: *limaces* (see discussion of tools below, n = 16), unifaces (n = 7), and bifaces (n = 6). In general, *limaces* and unifaces are unilaterally shaped and retouched large tools on the periphery of the blank. Bifaces, on the other hand, are bifacially shaped and retouched on the periphery. In addition to the operational sequences listed above, there is also a unilaterally shaped tool subsequently exploited as a core after its use as a tool. Among the small flake tools, several pieces manifest evidence of hafting (see description of tools below). All the shaping activities could produce flakes subsequently selected as blanks to be retouched into or used as small flake tools. In conclusion, the operational sequence of the lithic industry at Moh Khiew Cave includes debitage (flaking), shaping, and a mixed debitage and shaping sequence. The debitage sequences include at least three modes of exploitation: splitting, discoidal flaking, and the APS /SSDA/ type C. These sequences produce tool blanks of diverse sizes, morphologies, and structures to meet the needs of knappers. The majority of the shaping sequences are unilaminar, while bifacial shaping is also quantitatively important (see discussion of tools below).

Contribution of the different operational sequences

As mentioned previously, flakes with a totally natural dorsal surface are rare. Among the 2453 identifiable flakes (>20 mm), the vast majority (>90%) of them bear no or little cortex, indicating that the primary stages of production took place outside the site. This makes it difficult to accurately evaluate the quantitative importance of the different operational sequences. Among these flakes, nearly 90% derive from shaping activities, which demonstrates the importance of shaping during production. However, flaking (debitage) is also quantitatively significant in yielding flake-tool blanks even though cores are very rare at the site. Debitage and shaping play different roles in producing blanks, and it is difficult to discern which is more important during production at Moh Khiew. However, it is possible to propose a relatively accurate evaluation of the different operational sequences producing cutting tools (**Table 3**). Among the eight operational sequences, sequences 7 and 8 yield far more tools than the other operational sequences. No tool was identified in OS 6 (discoidal flaking), and only one piece was classified in OS 3 (bifacially retouched tool), these two sequences thus seem to be of little importance for production, while the rest are quantitatively more significant. Shaping flakes also contribute to the flake-tools, since quite a lot of them are also retouched into tools or simply utilized. To conclude, the operational sequences of debitage and shaping seem to be equally important at Moh Khiew Cave. There is no obvious preference or exclusiveness, as demonstrated by the mixed operational sequence of debitage and shaping (OS 8), and many flakes from shaping are used as blanks for tools, providing additional evidence of the flexibility of technical behavior, creating diversified objects and operational sequences. Some knapping activities took place outside the site, and some products may have been removed from the site since we identified discrepancies between the numbers of cores and flakes.

Hoabinhian stone tools at Moh Khiew

Different tools were produced by different operational sequences, but in certain cases, different operational sequences yielded the same types of tools, such as bifaces from OS 2 and 8, chopping-tools from OS 1 and 3. The total tool assemblage indicates that shaped tools are far less frequent than flake tools (**Table 4**). Among the shaped tools, *limaces* (~6%), unifaces (~3%), bifaces (~4%), and side choppers (~3%) are the most widespread, whereas only three chopping-tools were identified. Flake tools can be divided into two categories: hafted flake tools and non-hafted tools. From a technological viewpoint, the former category is far less visible in the assemblage than the latter. Flake tool blanks derive from two sources: 39% are from core flaking, 41% are from shaping flakes, while the remaining 20% are from undetermined knapping activities. Altogether, 62% of the shaped tools are on flake blanks, 34% are produced on blocks, while cobbles account for only 4%. Atypical unifaces are only made on blocks, *limaces* and unifaces are only on flake blanks, while bifaces are on both flake blanks and blocks. Side choppers and chopping-tools are made on blocks and cobbles (**Fig. 7**).

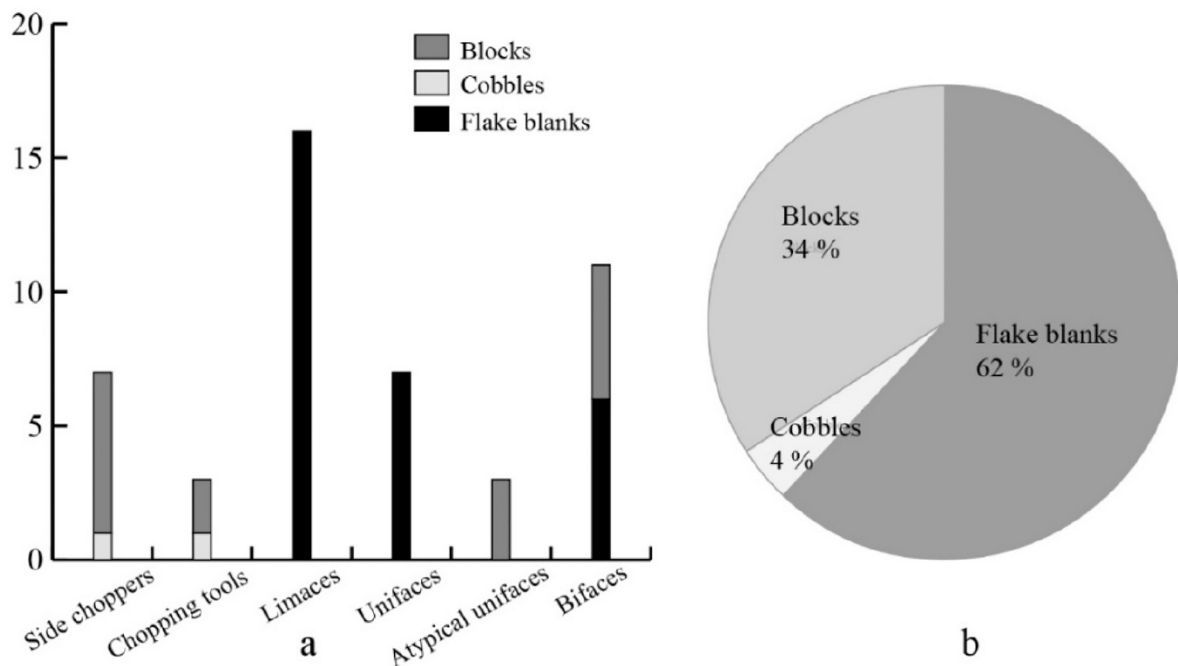


Fig. 7. Blank types of shaped tools at Moh Khiew. a. Blank types for each category of shaped tools; b. The proportion of different blank types among shaped tools.

The metric analysis of the shaped tools reveals that dimensions fluctuate greatly for the same tool type. For side choppers, length ranges from 134 to 56 mm; chopping-tools from 101 to 76 mm; *limaces* from 115 to 71 mm; unifaces between 144 and about 80 mm; bifaces from 107 to 50 mm, while 'atypical' unifaces are generally small tools with a length of less than 70 mm. The average size of large shaped tools indicates that unifaces are the largest tools with an average length of about 111 mm, followed by side choppers with an average size of about 98 mm. *Limaces* and chopping-tools have similar lengths of about 90 mm, but the former are very narrow and often elongated. Bifaces are generally smaller with a length of around 82 mm and they are also much thinner than the other tools (**Fig. 8a**). The length/width and width/thickness ratios of these tools provide further information on their general morphology. Most of these tool types have a length/width ratio superior to 1.5, suggesting that they are elongated to a certain degree. *Limaces* are the most significant examples with a ratio of about 2, whereas chopping-tools and bifaces are generally not elongated. The width/thickness ratio implies that bifaces are very thin (**Fig. 8b**). Flake tools comprise both large and small tools. Large flake

tools are defined here as larger than 100 mm, the rest are medium-small-sized tools. According to this criterion, 97% of the flake tools are medium-small, the rest are macro-tools (**Fig. 8c**)

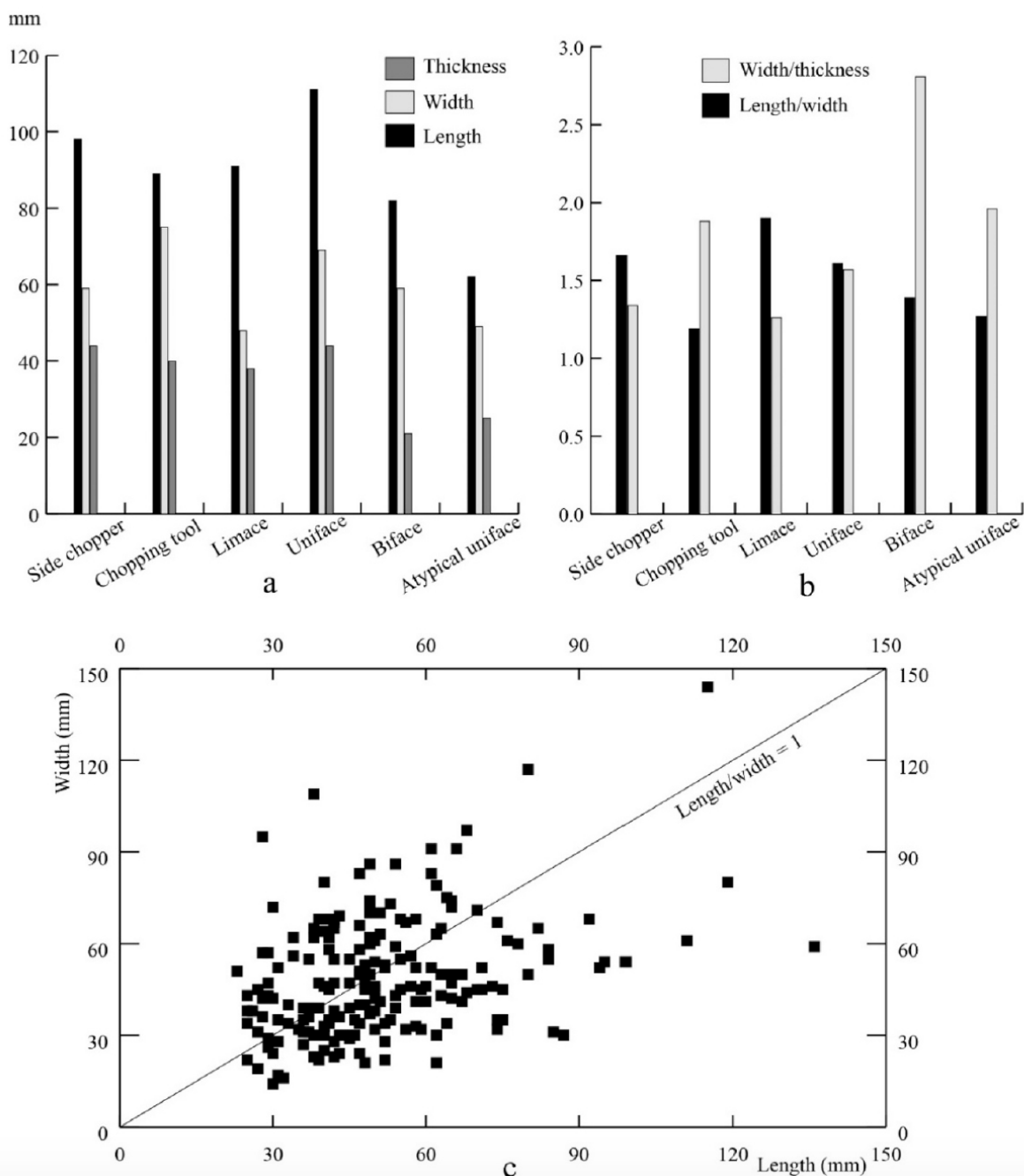


Fig. 8. Metric analysis of the stone tools at Moh Khiew. a. Average size of shaped tools; b. Ratios of length/width and width/thickness of shaped tools; c. Dimensions of flake tools.

Hoabinhian macro-tools

Apart from the chopper-chopping-tools, the Moh Khiew site comprises three categories of macro-tools which distinguish it from other contemporaneous sites: the uniface, *limace* and biface.

1) Unifaces (n =7). The unifaces at Moh Khiew are all produced on large and thick flake blanks (average tool size: 111 × 69 × 44 mm, **Fig. 8a**), issued from an operational debitage sequence, except for ‘atypical’ unifaces on blocks. Flake blanks are produced by OS 8, and the chosen raw materials are mainly siliceous blocks, although shale blocks are also sometimes utilized. We cannot precisely identify dorsal patterning, as shaping transformed most of the original

volume of these blanks. However, the ventral face of the flake is always the knapping platform, and in general, centripetal shaping trims the periphery of the blank, leaving the central part of the dorsal face less transformed, natural and even cortical. Based on this, we can infer that most of the blanks are possibly the first flake detached during core flaking, often of quadrangular or oval morphology. However, in rare cases, there are unidirectional dorsal scars on the flake blank, showing that the blank selected for shaping is not the first flake removed from the core. The volumetric structure of the unifaces is often plano-convex since the ventral face is generally plane (or slightly convex) and centripetal shaping helps to create a convex upper face. Usually, there is more than one cutting edge on the periphery of the tool (**Fig. 9**) and the morphology of the cutting edge is generally denticulate, convex or rectilinear, etc. (**Fig. 10**).

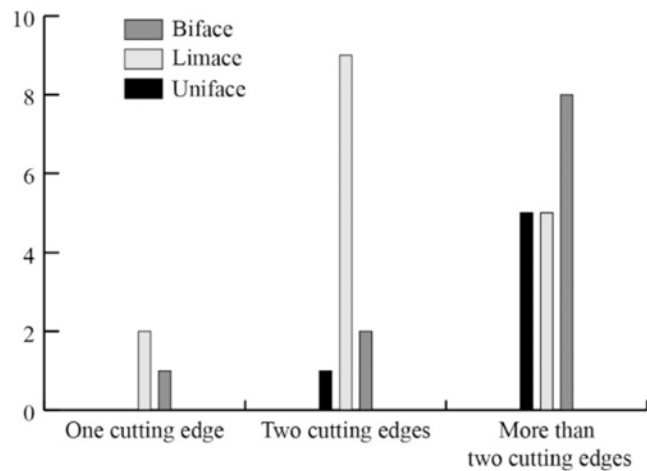


Fig. 9. Number of cutting edges on uniface, *limace* and biface.

This plano-convex structure is a technological innovation with two main advantages. On one hand, multi-cutting edges could be obtained with only one blank, on the other hand, the technological volume could potentially be reworked and re-sharpened several times, and it could thus be ‘recycled’ for utilization while maintaining a plano-convex structure to some extent. This was confirmed by the re-sharpening fragments and flakes discovered at the site. Certain pieces even present different degrees of weathering on the scars, indicating that the tools were reworked and re-sharpened. Therefore, these unifaces are generally tool-blank pieces (see Boëda, 2001, 2013).

2) *Limaces* (n = 16). *Limaces* are undoubtedly the most original tools because they are surprising in a Hoabinhian assemblage in Southeast Asia. The term ‘*limace*’ comes from a tool type from European Middle Paleolithic typology (Bordes 1961; Deb’enath and Dibble 1994). It is generally made on a flake and presents double-stepped retouch (scraper) converging at both ends of the blank. The striking platform is removed or partially removed by flat lateral retouching or simply broken at the proximal part. The distal part of the *limaces* from Moh Khiew is rarely pointed, as in the European Paleolithic, and most often bears an oval, straight-linear, or oblique morphology. The specific feature of this tool is the presence of a thick cortical back with ordinary stepped retouch. Indeed, most of them could be considered as thick convergent scrapers with thickset profiles. Similar tools were also created in Brazilian sites in South America during the Early Holocene (Lourdeau 2015, 2016, 2017). The *limace* tool present in tropical sites during the Holocene period demonstrates the universality of this type of tool outside the European Middle Paleolithic context. In general, the *limaces* at Moh Khiew are of elongated quadrangular morphology but are smaller than the unifaces (**Fig. 11**). The average dimensions of these tools are 91 × 48 × 38 mm, and the average length/ width ratio is about 2 (**Fig. 8a, b**).

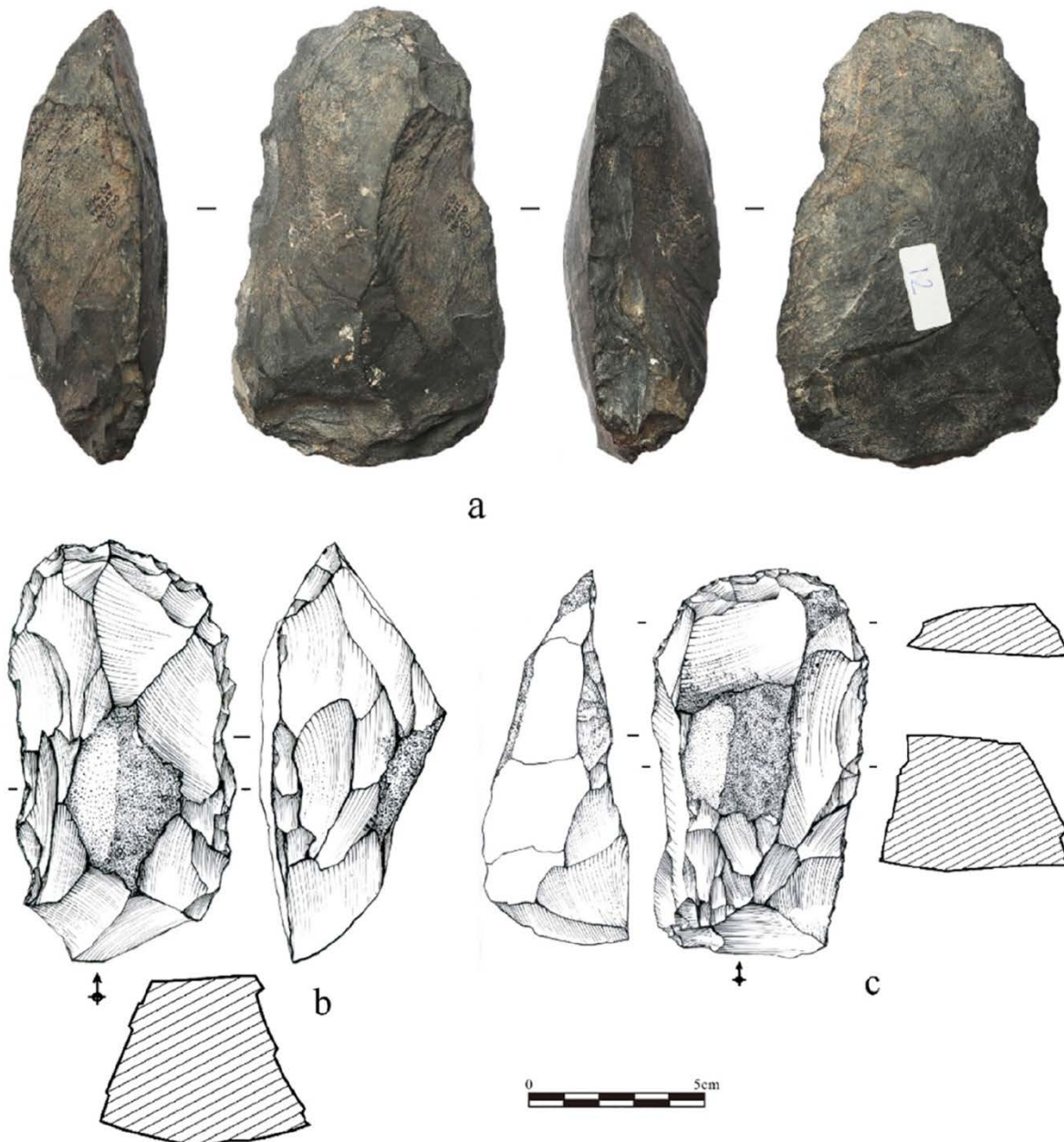


Fig. 10. Unifaces on flake blanks at Moh Khiew.

The blanks of these tools also come from core debitage (OS 8), producing large and medium-sized flakes of quadrangular and even elongated morphology. Shaping work and retouch are mainly concentrated on the lateral parts of the blank, and the distal and proximal parts are generally less trimmed or natural, contributing to the elongated shape of the tool. The ventral face of the flake blank is used as the striking platform and the dorsal face as the surface for shaping and retouch, in the same way as for the unifaces. However, the lower face of the blank often shows flexion, torsion and presents the bulb of percussion, leading to the torsion of the final tool in some cases. In particular, the localization of the cutting edges is closely related to these elements. The section of these tools is usually quadrangular/trapezoidal, but is sometimes triangular, semi-circular and mixed (i.e., different section morphologies in different parts of the volume), while the profile is generally symmetric and presents two different cases:

- 1) the thickness of the profile is constant all along the artefact;
- 2) the maximum thickness is in the middle of the artefact and decreases equally toward both ends. This indicates that the upper face of the tool is not a real convex surface but possesses

a certain degree of variability, and differentiates them from unifaces which have a relatively stable convex upper surface. Usually, there is more than one cutting edge on the blank (**Fig. 9**). They are often located on the lateral part(s) of the volume, with morphologies varying from denticulate, rectilinear, concave, to a rounded point. Like the unifaces, *limaces* are also tool-blanks, as the tool could be re-sharpened many times during utilization.

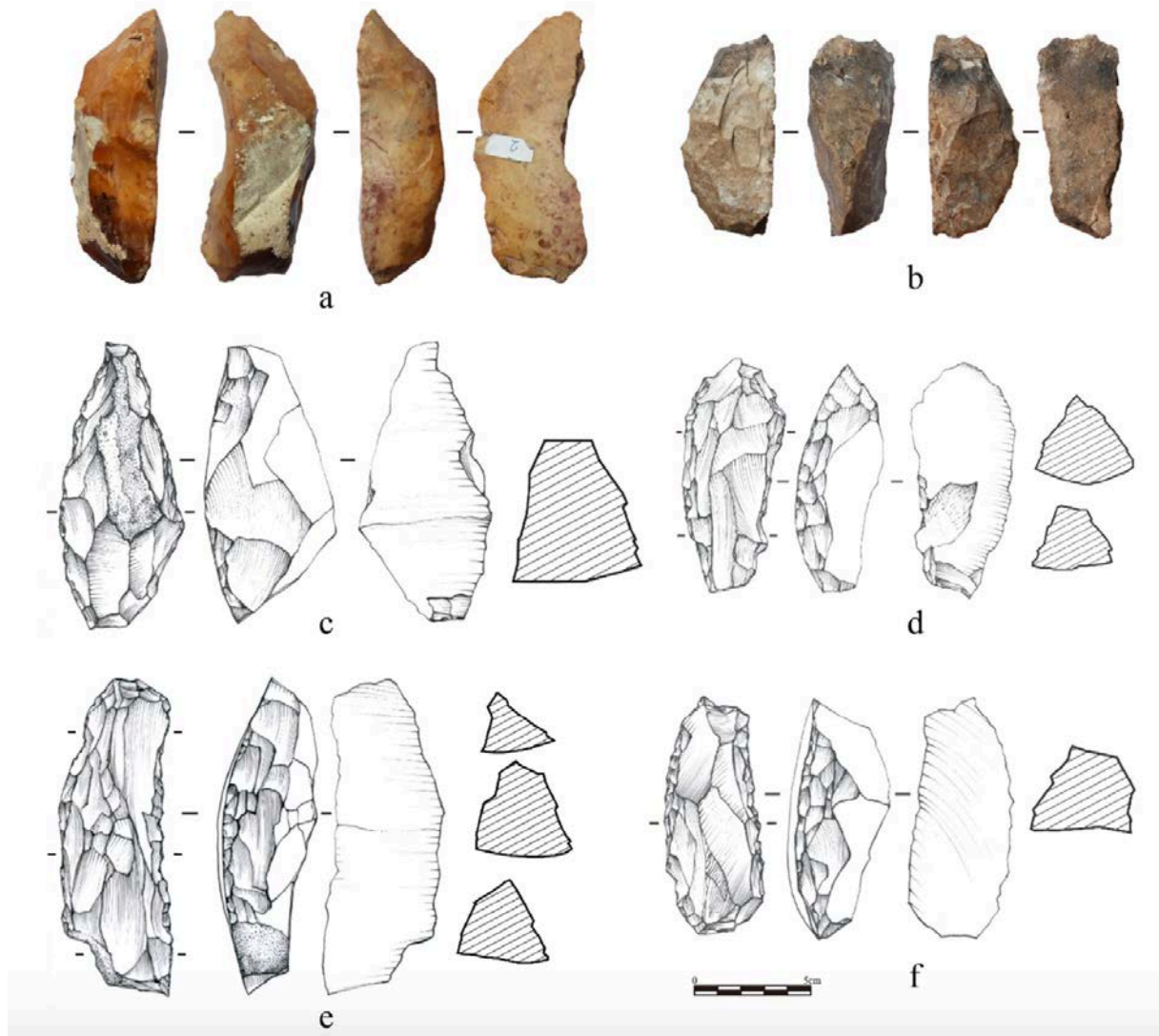


Fig. 11. *Limaces* at Moh Khiew

3) Bifaces (n = 11). The bifaces discovered at the site are made exclusively on shale slabs (**Fig. 12**), blanks are blocks (n=5) and flakes (n=6), with a clear preference for this type of raw material. All the bifaces are oval, quadrangular, and circular, apart from three broken pieces of indeterminate morphology. The average size of the bifaces is 82 × 59 × 21 mm (excluding a mini-biface, 50 × 32 × 12 mm). They are much thinner than *limaces* and unifaces (**Fig. 8a**) and the width/thickness ratio is about 2.8 on average which is higher than for the other shaped tools (**Fig. 8b**). The flake blanks also derive from the debitage sequence (OS 8) and are often very flat. The blocks chosen are generally quadrangular and oval with a flat transverse section. Bifacial shaping work is generally not intensive, and many natural surfaces subsist. Usually, the section of these tools is quadrangular and the profile is either symmetric or asymmetric. These bifacially worked pieces are very different from classic bifaces, which are fully shaped volumetric structures. Conversely, the volumetric structure is not the major

concern of the knappers at Moh Khiew, bifacial working is more a knapping method to obtain cutting edges rather than predetermined volumetric structures. These tools often have two or more cutting edges (**Fig. 9**) located on the periphery of the tool.

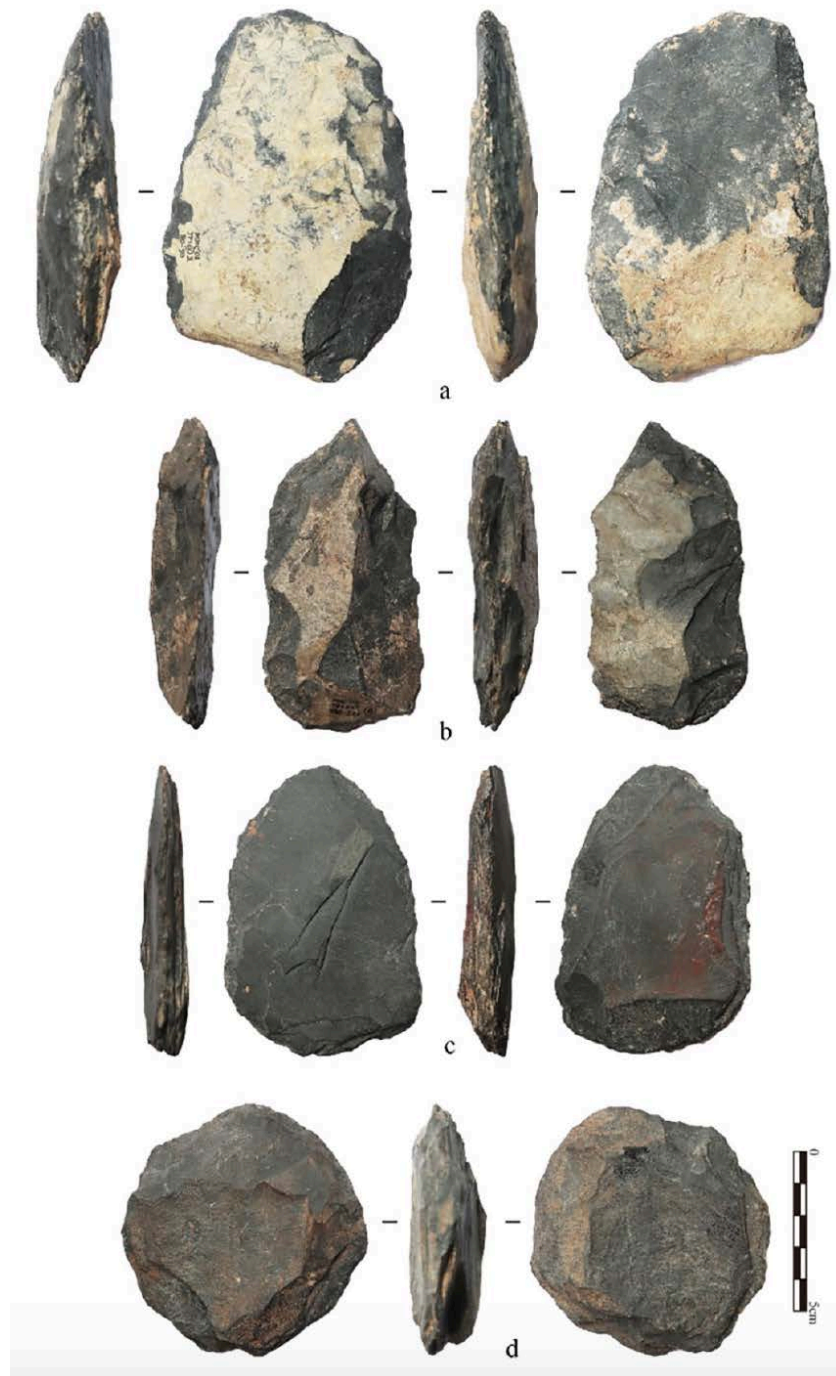


Fig. 12. Bifaces from Moh Khiew Cave. a, b. Block blanks; c, d. Flake blanks.

The Hoabinhian small tools

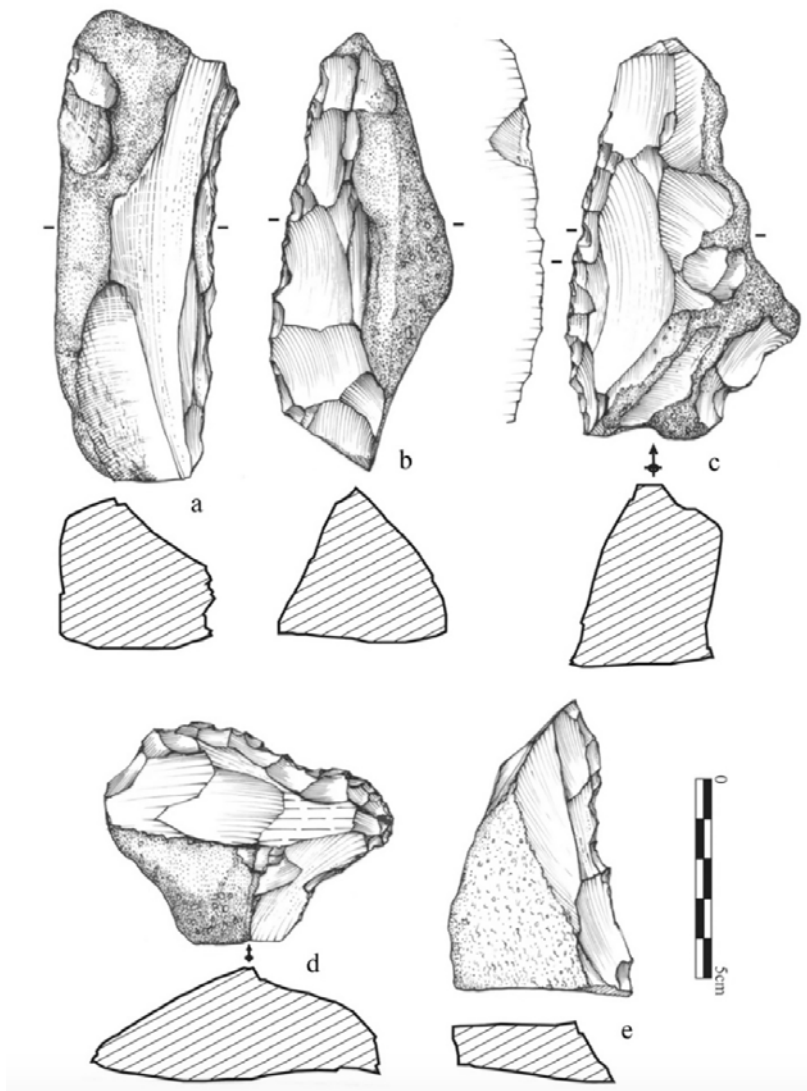
Small tools are mainly small flake tools (**Fig. 13**), but include retouched or utilized flakes derived from debitage and shaping. As mentioned before, some flake tools are very large, with a length of more than 100 mm. The latter only account for about 3% of the flake tools, while the rest are medium-small flake tools (**Fig. 8c**). These tools can be divided into two groups: hafted tools (3%) and non-hafted pieces (97%). The hafted tools are often retouched on one or both sides of the proximal zone to facilitate binding (**Fig. 13j, l**).



Fig. 13. Small-tools of Moh Khiew. a-d. Multi-cutting edges; e.g., Rostrums; h. Multi-notches; i, k. Scrapers; j, l. Hafted tools; m,n. Denticulates. (Note: the black line indicates the location and morphology of the cutting edge, the green line indicates retouch for hafting).

Sometimes, traces of binding can also be seen with the naked eye, these traces are similar to those confirmed in previous related studies (see Rots 2010); although we think they are probably hafted tools, further microscopic and residual examination are still needed to confirm our observation. Most non-hafted tools (79%) have a natural or worked back for prehensive

convenience, with the cutting edge generally located on the opposite or adjacent side of the back. However, it is also sometimes framed by the back. Tools without backs are generally quadrangular, triangular and oval shaped. Nearly 48% of the cutting edges are located on the lateral part of the blank, the rest are on the distal or proximal part. Regarding the morphology of the cutting edge, rectilinear, notch, convergent-point, denticulate, convex, and concave morphologies are frequent. Retouch is mainly simple, and scalariform retouch is rare. In general, most of the small tools have one to two cutting edges, and they are usually much sharper than those of the shaped large tools. These small tools are very well represented in the Moh Khiew assemblage and coexist with heavy or macro tools made on flakes or blocks (Fig. 14). This association and this mix of tools is characteristic of the Moh Khiew lithic assemblage and enables us to review the current definition of the Hoabinhian.



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Fig. 14. Examples of tools made on blocks and flakes at Moh Khiew. a, b, e. block blanks, side-choppers; c, d. flake blank, scrapers.

Discussion

The characteristics of the Moh Khiew assemblage

Based on the above analysis, we can summarize the major characteristics of the lithic assemblage from the Moh Khiew Cave as follows:

1) The exploited raw materials are mainly siliceous blocks from outcrops, while non-siliceous river cobbles are more rarely exploited;

2) Contrasting and diverse *chaînes opératoires* coexist at the site, such as the APS (i.e., alternating platform system) and bipolar debitage (i.e., split) to produce large and small blanks for flake tools, shaping for producing chopper-chopping-tools and bifaces, mixed debitage and shaping for producing *limaces*, unifaces and bifaces, and simple retouch on the block. Debitage and shaping seem to be of equal importance in obtaining tool blanks and tools;

3) Various tool types coexist in the lithic assemblage, chopper-chopping-tools, bifaces, *limaces*, unifaces, flake tools and hafted tools. Among them, unifaces and *limaces* are of particular interest: they are made on thick and large flake blanks (rather than cobbles) by

successive unifacial shaping and retouch. They are plano-convex tools, and also blank-tools with potential for generating more than one cutting edge and could be re-sharpened several times during the course of utilization. They are mainly produced on siliceous rocks.

4) A preference for lateral cutting edges was observed among the large shaped tools. Choppers all have a lateral cutting edge, the cutting edges of unifaces and *limaces* are often located on the lateral part(s) of the volume, and this is also the case for bifaces. Among flake tools, lateral cutting edges are also widespread, with a percentage of 48%.

5) Although flakes and flake tools are quantitatively dominant among the total assemblage, not all of the flakes are from the debitage *chaîne opératoire*. Indeed, the majority of them were produced during the shaping of large tools, since many shaping flakes were also retouched or even used as flake tools without retouch. Thus, the flake-tool industry only comprises part of the technical elements of the assemblage, and we should not therefore define Moh Khiew as a flake-tool industry.

Can the lithic industry of Moh Khiew be defined as Hoabinhian?

At first sight, the lithic assemblage of Moh Khiew seems to be different from the Hoabinhian Technocomplex, which was widespread in the region during the Late Pleistocene-Early Holocene transition, since there are few cobble tools and no typical *sumatraliths*, i.e., cobble tools of plano-convex structure obtained by unifacial shaping at the periphery and the strict selection of river cobbles. The lithic assemblage at Moh Khiew is not a cobble-tool industry, this is an obvious paradox in the light of our previous knowledge of the Hoabinhian. However, the Moh Khiew assemblage illustrates the ‘plano-convex’ morpho-structural scheme for making unifaces and *limaces* via the operational sequence 8 (OS8), and atypical unifaces by operational sequence 4 (OS4). Here, the percentage of unifacial plano-convex tools is high since unifaces, ‘atypical’ unifaces and *limaces* all belong to this technical family. These tools account for about 55% of the shaped tools, but only 10% of the whole toolkit. As discussed above, the general *concept* behind these unifacial tools is to produce a plano-convex volumetric structure to be further shaped and retouched on its periphery to obtain at least one cutting edge. In other words, it is a ‘tool-blank’ (Boëda, 1997, 2001). Moreover, this volume can potentially be reduced and re-sharpened successively at different stages during utilization, while maintaining the homothetic plano-convex structure, which is a major advantage of this tool type. It is a very identifiable volumetric construction: a real Hoabinhian type volumetric construction structured around the ‘plano-convex scheme’ (PCS), guided by homothety (**Fig. 15**). Regardless of the dimensions, thickness, and selected blanks (pebbles, blocks, or large flakes), this scheme could be applied as a pattern. Thus, during the unifacial reduction process, the dimensions may vary (long, large, medium, small)- miniaturization, but the structure does not change, which explains the homothetic character and internal structure of the PCS. There is no major technological difference between the plano-convex unifaces at Moh Khiew and Hoabinhian *sumatraliths*. Moreover, the split sequence is also present at the site and is a remarkable operational sequence at many typical Hoabinhian sites, such as Laang Spean (Forestier et al. 2015), Xiaodong (Ji et al. 2016), Obluang (Santoni et al. 1986) and Huai Hin (Forestier et al. 2013). What makes Moh Khiew special and original is the coexistence of unifaces, *limaces* and bifaces, and the unique method of obtaining these tool blanks. Considering that Moh Khiew Cave is situated in the tempo-spatial range of the Hoabinhian, and that its lithic assemblage displays similarities and at the same time differences with the definition of the Hoabinhian, we tend to conclude that Moh Khiew may represent a local variant of the Hoabinhian in Southern Thailand.

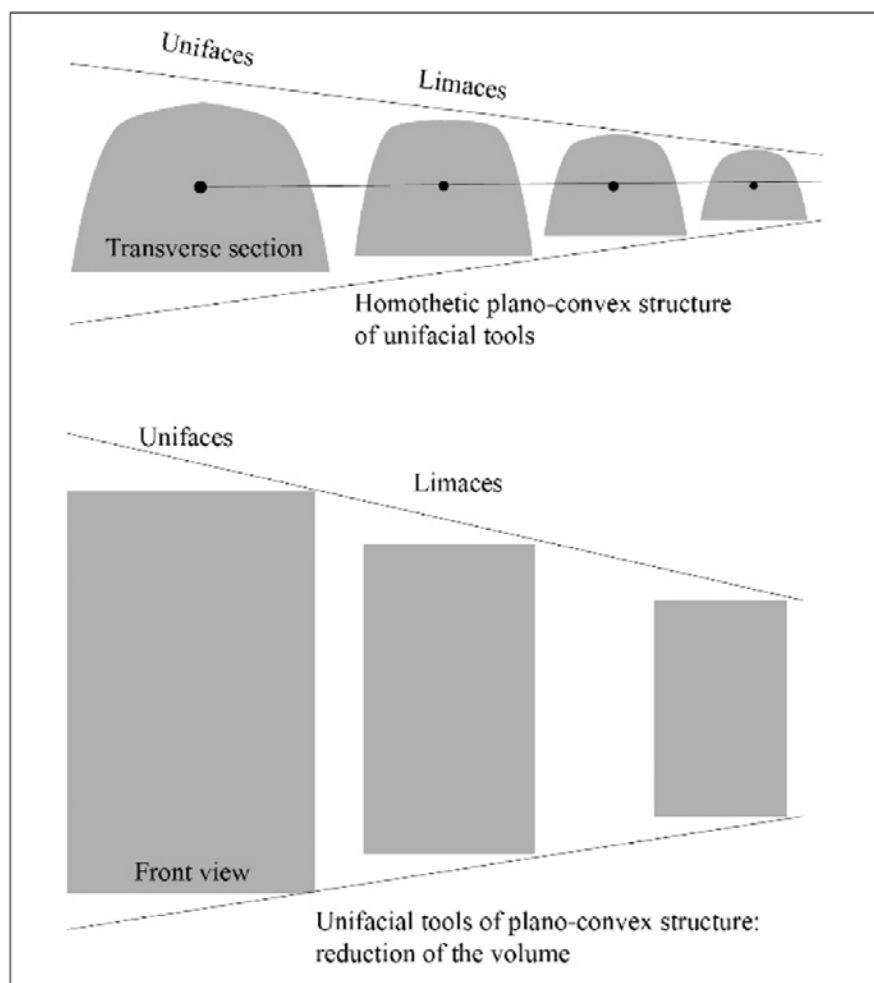


Fig. 15. Homothetic plano-convex structure of unifacial tools at Moh Khiew.

What site does Moh Khiew look like?

Although the lithic assemblage of Moh Khiew is very original compared with the traditional definition of the Hoabinhian, some other sites in the Malay Peninsula present similar elements with Moh Khiew: the presence of bifaces, the utilization of shale slabs and the lack of sumatraliths, such as Lang Rongrien Rock shelter which is about 40 km from Moh Khiew (Anderson, 1990). Moving southwards from Moh Khiew, the biface seems to be a common element in Malaysian Hoabinhian sites according to Anderson (1990) (cf. Gua Kerbau, Gua Baik, Gua Madu and Gua Cha (Adi 1981; Anderson, 1990)). This phenomenon was called a 'local Hoabinhian', characterized by bifaces rather than sumatraliths, and was related to specific raw materials, in particular slate materials such as shale slabs (Anderson, 1990; Chitkament 2007). However, moving southwards still, when entered the Indonesian islands, such as Sumatra, unifacially shaped sumatraliths made on river cobbles have been found at several sites, and cobble tools are more significant (cf. Bindjai Tamiang, Lhokseumawe, Batu Kemang, Saentis/Sukajadi, et., see Forestier 2000; Forestier et al. 2006; Forestier and Patole-Edoumba 2000; Zeitoun et al. 2008), making them different from the Malaysian Hoabinhian assemblages. Moving northwards from Moh Khiew, more than a hundred Hoabinhian sites have been discovered between the Malaysian Peninsula and Continental Southeast Asia, in Thailand, Cambodia, Laos and Vietnam (Forestier et al. 2017; Moser 2001; Tan 1994; Zeitoun et al. 2008). Some of them are well known to researchers, such as Lang Kamnan (Shoocongdej 2000), Ban Kao (Pookajorn 1984), Sai Yok (Heekeren and Knuth 1967), Don Noi (Bronson and Natapintu 1988) and Ongbah (Sørensen 1988) in Western Thailand; Spirit Cave (Gorman 1970), Banyan Valley (Reynolds 1992), Tham Phaa Chan (Bannanurag 1988; White and

Gorman 2004), Obluang (Santoni et al. 1986), Huai Hin (Forestier et al. 2013) and Tham Lod (Chitkament et al. 2016; Shoocongdej 2006), Ban Tha Si (Zeitoun et al. 2013) and Doi Pha Kan (Celiberti et al. 2018) in Northern Thailand; Laang Spean (Forestier et al. 2015; Mourer and Mourer 1970; Sophady et al. 2016) in Cambodia; Houay Pano (Zeitoun et al. 2019b) and Tam Hang (Patole-Edoumba et al. 2015) in North Laos; Nguom (Ha 1995b), Son Vi (Nguyen 1994a), Hang Cho (Yi et al. 2008) and Xom Trai (Nguyen 1994c) in Northern Vietnam. However, at the moment, it is impossible to compare all these sites with the technological approach, since only several sites have been studied using a *chaîne opératoire* method, including Laang Spean (Forestier et al. 2015, 2017), Huai Hin (Forestier et al. 2013), Tham Lod (Chitkament et al. 2016), Doi Pha Kan (Celiberti et al. 2018), Houay Pano (Zeitoun et al. 2019b) and Tam Hang (Patole-Edoumba et al. 2015), revealing different degrees of typotechnological information. Overall, three major *chaînes opératoires* on cobbles are well represented at Laang Spean (Forestier et al. 2015, 2017), Huai Hin (Forestier et al. 2013), Obluang (Santoni et al. 1986) and Tam Hang (Patole-Edoumba et al. 2015), namely: (1) a *chaîne opératoire* consisting of the unifacial shaping of long cobbles to produce sumatraliths (unifaces); (2) a short *chaîne opératoire* consisting of the partial shaping of thick ovoid cobbles to obtain choppers and chopping-tools; and (3) a mixed *chaîne opératoire* beginning with bipolar debitage (split) to produce half-cobbles, which are then shaped/retouched into varied tools. Despite the homogenous nature of the three *chaînes opératoires* at these Hoabinhian sites, the third *chaîne opératoire* is lacking at Houay Pano, which nonetheless presents three types of large cobble tools: choppers, sumatraliths and *limaces*, thus indicating the variability of the Hoabinhian in terms of tools and *chaînes opératoires* (Zeitoun et al. 2019b). The diversity of *chaînes opératoires* and tools seems to be more limited in the central part of Mainland Southeast Asia compared with those from Moh Khiew and the Malaysian Peninsula. However, considering that the number of well-studied sites is still finite, this assumption requires further verification. Moving even further north, to Southern China, the earliest Hoabinhian was identified at Xiaodong in Yunnan Province (Ji et al. 2016), using the technological method (Forestier et al. 2017; Forestier 2020). In Southern China, dozens of archaeological sites dating from the Late Pleistocene-Early Holocene have been reported by previous researchers in Yunnan, Guangxi, Hainan, and Guizhou, but most of them have not been studied with a technological approach. Preliminary work of this type has been launched in recent years, and several studies of lithic assemblages have been published, such as Luobidong (Li et al. 2019), Bailiandong (Zhou et al. 2019a) and Tangzigou (Zhou et al. 2019b), while Zengpiyan (Collective 2003) and Maomaodong (Cao 1981) are currently being studied. Although these sites include a cobble-tool industry, they could not be defined as Hoabinhian, since the underlying technological concepts and final toolkits are more or less different from those of Hoabinhian sites. These sites display marked quantitative and qualitative diversity in terms of the *chaînes opératoires* and tool types, in the same way as Moh Khiew, in spite of certain similarities between them. Currently, only Xiaodong presents consistent technological structures/concepts with the Southeast Asian Hoabinhian technocomplex. Indeed, like Moh Khiew, Xiaodong also comprises a high diversity of Hoabinhian tools. To conclude, the diversity of operational sequences and tool types at Moh Khiew Cave and in the Malaysian Peninsula raises, once again, the question of cultural variability and different populations in the Hoabinhian technocomplex and during the Hoabinhian period in Mainland Southeast Asia. This has also recently been noted on the basis of cultural, burial and demographic evidence (Forestier et al. 2013, 2017; Forestier 2020; Imdirakphol et al. 2017; Matsumura et al. 2015; White 2011; Zeitoun et al. 2019a). The lithic assemblage of Moh Khiew is reminiscent of contemporaneous industries in Southern China where we observe more diversity than uniformity. Above all, Moh Khiew is characterized by variability and flexibility and by technological, functional and

demographic adaptation to its surrounding environment and culture, in the same way as many contemporaneous sites in Southern China.

Conclusion

The Moh Khiew lithic assemblage is now a very important reference for the Hoabinhian period. On one hand, in this paper we questioned the definition of the Hoabinhian using the typological method, and presented a new synthesis of its definition based on technological analysis. On the other hand, the Hoabinhian should not be considered as a single culture with uniform typical tools. It embodies a certain degree of variability and flexibility. Based on the material from the 2008 excavation conducted by P. Auetrakulvit, the Moh Khiew lithic assemblage was organized into eight reduction strategies (**Fig. 4**): (1) classic unifacial shaping on the lateral or distal part of blocks/cobbles to produce chopper-chopping-tools; (2) bifacial shaping on the periphery of oval blocks to obtain bifaces; (3) bifacial retouch on the distal part of selected blocks to produce chopping-tools; (4) unifacial shaping on the periphery of cuboid blocks to produce atypical unifaces; (5) a bipolar debitage sequence which involves the production of half-cobbles and flakes; (6) discoidal flaking to produce small flake blanks from shale blocks; (7) a simple APS/SSDA debitage sequence to produce large and small flakes, which were then retouched into various large and small tools; (8) a mixed *chaîne opératoire* of debitage and shaping, using the same debitage method as sequence 7, with the selection of some large flakes for unifacial or bifacial shaping, where the final products are *limaces*, unifaces and bifaces. Except for the third and sixth sequences, the rest are quantitatively significant. In this paper, we described six major *chaînes opératoires* at a Hoabinhian site, the presence of bifaces and the lack of sumatraliths, diversified raw material quality, morphology and tools. All these atypical elements raise the question of the definition and variability of the Hoabinhian, which extends over a period of more than 30,000 years in Southeastern Asia (Forestier et al. 2017; Forestier 2020; Zeitoun et al. 2008). Further questions can also be raised, such as; does a typical Hoabinhian exist? Is it a myth or reality? Only the qualitative comparison, i.e., the contribution of technological and morpho-structural data to reconstruct technological processes can be considered as a scientifically valid and objective approach, allowing us to put forward the idea of the significance of variability in lithic production during the Hoabinhian period. We should no longer think of the Hoabinhian as a uniform techno-cultural entity. We do not think that the Hoabinhian technocomplex can be considered as a lithic process, in the same way as Levallois or laminar methods. It is more complicated to define because it is more flexible and less stable, which represents a certain form of modernity in stone knapping. Its modernity and originality are characterized by the unstable technical character of its products (pebbles, cobbles, flakes, fragments of blocks, etc.), and diversified tools but it nonetheless embodies a significant common denominator: the plano-convex structure. Indeed, the 'plano-convex structure' can be defined as the technical scheme of the Hoabinhian: the signature of productions made by these groups of hunter-gatherers from Southeast Asian forests. The Hoabinhians did not strive to produce a single form of tool but rather sought to produce a variety of tools. It is impossible to define the main technological characteristics of a typical Hoabinhian product/tool. For this reason, it is difficult to give a precise definition of what the Hoabinhian really is...! We can cautiously describe the Hoabinhian as a lengthy period of Late Prehistory, ranging from around 40 to 5 Ka, a technocomplex, a technical phenomenon, a way of stone knapping involving three factors: 1) the mechanical properties of the raw material depending on whether it is a cobble, a pebble, a limestone block of siliceous texture, 2) the conceptual capacity of the knapper, 3) and the functional objective expected by the group in response to a specific need. Now that several case studies of the Hoabinhian lithic reduction sequence or *chaîne opératoire* have been completed in Southeast Asia, it is time to compare sites from what we shall call the 'Chinese Hoabinhian Homeland', situated in Southern China, and cave sites from Mainland Southeast

Asia. As soon as modern humans arrived in South Chinese provinces close to the borders of Southeast Asia, Hoabinhian sites are everywhere and are always a little different and a little the same. So, unity and diversity appear to characterize the most important technical assemblages produced by hunter-gatherers in the tropical forests of Southeast Asia. In this regard, Hoabinhian or not Hoabinhian, is it really the question? Human beings are characterized by diversity and instability, and we must thus expect everything to be possible with the Hoabinhian, which is full of possibilities. Finally, the key question is to accurately define the emergence of cobble technology in Extreme Asia at the end of the Upper Pleistocene: were there single or multiple cradles in Southeast Asia and in the neighboring areas?

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