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A technological perspective on the lithic industry of the Bailiandong Cave (36–7 ka) in Guangxi: An effort to redefine the cobble-tool industry in South China

Étude dans une perspective technologique de l'industrie lithique de la grotte de Bailiandong (36–7 ka) du Guangxi : une tentative de redéfinition l'industrie sur galet dans le Sud de la Chine

Yuduan Zhou [a,b], Yuanjin Jiang [c], Ge Liang [c], Yinghua Li [a,d,*], Hubert Forestier [b], Huan Li [a], Peng Chen [a,e], Liwei Wang [a], Tingting Liang [a], Chengpo He [a]

[a] *School of History, Wuhan University, 430072 Wuhan, China*
[b] *UMR7194, Muséum national d'histoire naturelle, CNRS–UPVD, 1, rue René-Panhard, 75013 Paris, France*
[c] *Museum of the Bailiandong Cave Site, 545000 Liuzhou City, Guangxi Zhuang Autonomous Region, China*
[d] *UMR 7041 CNRS ArSCAN, équipe AnTET, université Paris-Ouest–Nanterre-La Défense, 21, allée de l'Université, 92023 Nanterre cedex, France*
[e] *Cultural relics and Archaeology Institute of Xinjiang Uygur Autonomous Region, 830000 Urumqi, Xinjiang Uygur Autonomous Region, China*

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ABSTRACT

In South China and mainland Southeast Asia, the lithic industry called the "cobble-tool industry" dominated throughout the Pleistocene and persisted until the middle Holocene. Although this term has long been used to characterize the lithic industry and to compare the Paleolithic cultures interregionally, it is really just a description of the raw material used by the lithic industry, lacking any indication of essential technological information about lithic production. As a result, the term loses utility when we compare the lithic industries of different sites in South China and mainland Southeast Asia, because both regions' lithic industries are characterized by cobble/pebble raw material during their prehistory. In this paper, we studied the lithic collection of the Bailiandong Cave, an important site in Guangxi, southern China, dating back to 36–7 ka, from a new technological perspective, and revealed the *chaînes opératoires* of production and the objectives of prehistoric knappers. After a concise comparison with the Hoabinihian techno-complex in mainland southeastern Asia, the long-lasting suspicion about the Hoabinhian elements in this site was dispelled. So, technological analysis did construct a solid foundation to redefine the cobble-tool industry in South China and to reveal the variability of lithic industries on a larger regional scale. The application of this approach to more sites is expected to help to decipher more clearly the technological and cultural scenario of prehistoric humans in South China and adjacent Southeast Asia.

RÉSUMÉ

Mots clés :
Technologie lithique
Grotte de Bailiandong

Dans la Chine du Sud et le Sud-Est asiatique continental, l'industrie lithique dénommée *cobble-tool industry* a été dominante durant tout le Pléistocène et a persisté jusqu'à l'Holocène moyen. Bien que ce terme ait été utilisé pendant longtemps pour synthétiser

* Corresponding author.
E-mail address: lyhfrance2005@yahoo.fr (Y. Li).

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les caractères des industries lithiques et comparer les cultures paléolithiques à l'échelle régionale, il ne s'agit que d'une description de la matière première, n'indiquant aucune information technologique essentielle quant à la production lithique. En conséquence, il devient inefficace quand on compare des sites différents de Chine du Sud et du Sud-Est asiatique continental, parce que les deux régions se caractérisent toutes deux par cette *cobble-tool industry* pendant la plus grande partie de leur préhistoire. Nous présenterons ici, dans une perspective technologique, les résultats analytiques obtenus sur la collection lithique, datée de 36–7 ka, de la grotte de Bailiandong, l'un des sites importants du Guangxi, dans le Sud de la Chine. Notre étude technologique a permis de mettre en évidence les chaînes opératoires de production lithique et les objectifs des tailleurs préhistoriques. Après une comparaison concise avec le techno-complexe hoabinhien du Sud-Est asiatique continental, le doute longtemps prolongé à propos de l'existence d'éléments hoabinhiens dans ce site a été levé. En conséquence, l'analyse technologique a véritablement permis de construire une base solide pour redéfinir la *cobble-tool industry* dans le Sud de la Chine et révéler la variabilité des industries lithiques à une échelle régionale plus grande. Nous espérons que l'application de cette approche à davantage de sites contribuera à une meilleure mise en lumière du scénario technologique et culturel des humains préhistoriques du Sud de la Chine et de la région adjacente, l'Asie de Sud-Est.

1. Introduction

For a long time, the nature of the lithic industry in South China during the Pleistocene was attributed by many researchers to the so-called "*cobble-toolindustry*," which dominated the lithic assemblages for the entire Paleolithic period, although the core-and-flake industry did emerge for some time during the late late Pleistocene in this large and diverse geographical area (Bar-Yosef and Wang, 2012; Gao, 2013; Qu et al., 2013; Zhang, 1999). Literally, the term "*cobble-tool industry*" implies that the raw materials used to produce tools were river cobbles or pebbles; however, technological information regarding the organization, structure, and methods applied to this type of raw material in the lithic production process is almost totally lost when this term is used. Due to this, cobble tools have usually been studied with a typological method aimed at classifying tools rather than understanding the process of realization of the tools and the real objectives of the prehistoric knappers; thus, comparative study has become difficult if not impossible between this region and the adjacent mainland of Southeast Asia, which was also a world of "*cobble-tool industry*" during the Paleolithic period (Forestier, 2010; Forestier et al., 2017a, b; Li et al., 2019; Pawlik, 2009; Zeitoun et al., 2008). Especially when the widely dispersed Hoabinhian techno-complex in Indochina is concerned (Forestier et al., 2017a; Moser, 2001; Zeitoun et al., 2008), suspicion about its existence/absence in southern China, such as in the Guangxi Zhuang Autonomous Region and the Province of Guangdong, has been aroused (Bowdler, 2006; Dai, 1988; Deng, 1992; Trinh, 1992; Zhang and Qiu, 1998), because these regions are very close to northern Vietnam, where Hoabinhian sites dating to the same period are abundant (Chung, 2008; Colani, 1926, 1927, 1939; Forestier et al., 2017a; Ha Van, 1992; Moser, 2001; Zeitoun et al., 2008). Recent excavation and research suggests that the Hoabinhian techno-complex may originate from the upper reaches of the Mekong River in the Province of Yunnan, southwest China, since about 40 ka, as indicated by the discovery of the Xiaodong rockshelter (Ji et al., 2016), and it is also present at some localities on the western border of the Yunnan area (Collective, 2017), which seems to make South China the potential technological cradle for mainland Southeast Asia's late Paleolithic cultures (Forestier et al., 2017a). However, the question of whether the Hoabinhian techno-complex also expanded to the Guangxi and Guangdong regions of southern China remains to be clarified (Li et al., 2019).

In fact, many cave sites that belong to the late late Pleistocene to the early Holocene (~40-8ka) have been excavated in the provinces of Guangxi, Guangdong, and Hainan, southern China, during the past three decades, several yielding good stratigraphic sequences, dating results, and abundant lithic assemblages, such as the Bailiandong Cave (Jiang, 2009), the Liyuzui rockshelter (He et al., 1983), the Zengpiyan Cave (Collective, 2003), the Yahuaidong Cave (Xie et al., 2018a), in Guangxi, and the Qingtang Cave (Liu, 2019), the Huangyandong Cave (Song et al., 1992), the Niulandong Cave (Jing et al., 1998; Zhang et al., 2013), the Dushizai Cave (Qiu et al., 1980, 1982), in Guangdong, and the Luobidong Cave (i.e., Luobi Cave) in the island of Hainan (Hao and Huang, 1998) (Fig. 1). Some authors claimed that Sumatralith-like tools – the *index fossil* of Hoabinhian culture in the nearby region of northern Vietnam – also existed among these sites of southern China (Deng, 1992; Zhang and Qiu, 1998), but such arguments that were based on simplified morpho-typological comparison and similarity of raw material failed to define each lithic assemblage and to allow one to differentiate the lithic industries of the two regions. As a result, obscurity and ambiguity persist concerning the particularity of the lithic industry in southern China and its relationship with the Hoabinhian techno-complex in the nearby region of mainland Southeast Asia during this transitional period due to methodological difficulties and the lack of technological analysis on the production of tools. So, as one of the

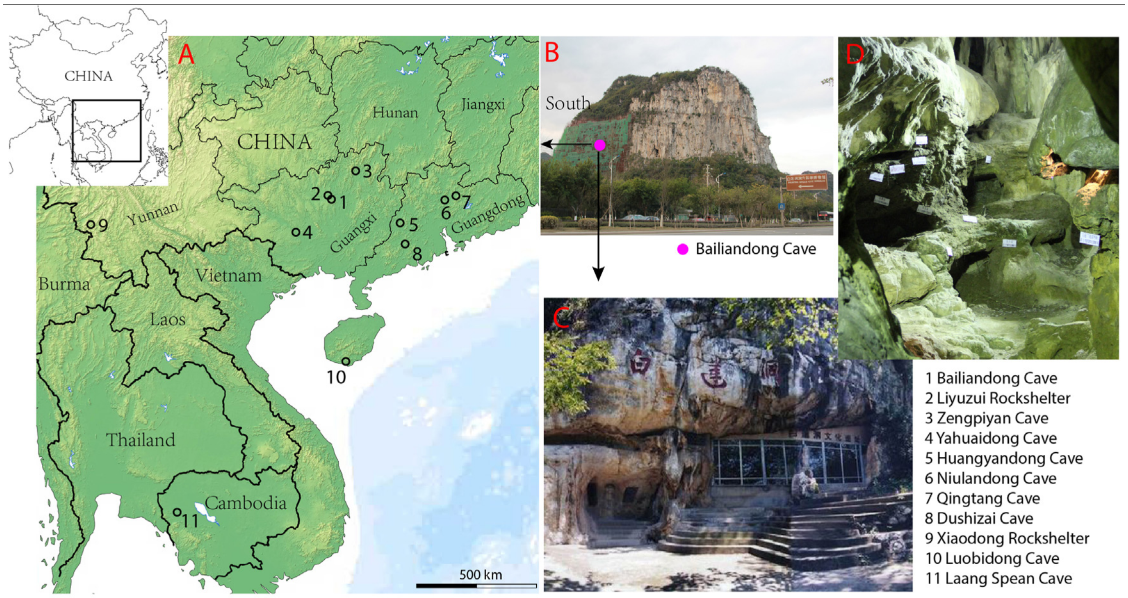

Fig. 1. Location of Bailiandong Cave site and other important sites mentioned in this paper (A: spatial distribution of sites; B: Baimian Mountain; C: Entrance of Bailiandong Cave; D: Inside the cave).

Fig. 1. Localisation de la grotte de Bailiandong et des autres sites importants mentionnés dans le texte (A : distribution spatiale des sites ; B : montagne de Baimian ; C : entrée de la grotte de Bailiandong ; D : intérieur de la grotte de Bailiandong).

first steps toward the construction of a reliable "*cobble-tool industry*" comparison between the two regions, we have chosen one of the most typical and important cave sites, i.e., the Bailiandong Cave in Guangxi, southern China, dated to the late Pleistocene–early Holocene transitional period, and we have studied its lithic industry from a new technological perspective in order to represent the operative sequences and its system of lithic production, and thus to redefine the "*cobble-tool industry*" in southern China. After that, we make a brief comparison of the lithic industry of Bailiandong Cave with the Hoabinhian industry of Southeast Asia to determine the nature of the lithic industry of the former and try to examine the cultural diversity and homogeneity of "*cobble-tool industry*" on the regional scale.

2. Bailiandong Cave: site introduction

2.1. Geographic and geological background

The Bailiandong Cave (24°12′54″ N, 109°25′37″ E) is located 12 km southeast of the city of Liuzhou, (12 km from the city center), Guangxi Zhuang Autonomous Region, and is 123 m above sea level at the entrance of the cave (Fig. 1). The site is about 5 km from the Liujiang River, which is the main river in Liuzhou and is one of the upper reaches of the Zhujiang (Pearl) River. The city of Liuzhou is famous for its widespread and typical karst landscape; the peak-forest plain characterizes this area, which is in fact a small karst basin. Seventy-seven percent of the landform is karst and the rest is a non-karst hilly area. Liuzhou's current geomorphology was generally formed in the early late Pleistocene, when crustal movement and the development of karst landform in this region intensified, and when large-scale ancient underground rivers and water-eroded grooves developed. Around this time, the Bailiandong Cave was formed as the result of the uplift of an ancient underground river. During the transitional period from the late late Pleistocene to the early Holocene, the water level of the Liujiang River decreased because of climate changes, so the erosion force from river water declined. At the same time, the first terrace of the Liujiang River, mainly composed of sub-sandy soil, developed. After that, the Liuzhou Basin was completely formed (Jiang, 2009). The cave is located on the southern slope of the "Baimian Mountain" (White Face Mountain) formed by limestone and dolostone of the Carboniferous Maping Formation, the base of which connected with Huguangyan hills in the north, forming one part of the peak-forest plains. A big, white, lotus-shaped stalactite stands in front of the cave entrance, and it is from this that the cave derives its Chinese name "Bailiandong" (White Lotus Cave). The cave is part of a large, multi-genesis karst system that contains five connected and integrated stacked caves with a total length of 1870 m and an area of about 7000 m^2. The main chamber of the cave system, which has a length of 973.6 m, can be divided into three levels linked to each other by diagonal corridors; the site of the Bailiandong Cave is on the third level and has a recessed rockshelter-like entrance facing south (Jiang, 2009).

2.2. History of excavation and research

The cave site was discovered in 1953, at which time it was reported that the southward-facing cave entrance was about 20 m above the ground, and that there were many mollusk shells and some deer teeth in the hard deposits of the cave. In 1956, led by Pei Wenzhong and Jia Lanpo, the Southern Archaeological Team of IVPP (Institute of Vertebrate Paleontology and Paleoanthropology, Chinese

Academy of Sciences) conducted a field survey aimed at searching for *Giantopithecus* and human fossils in Guangxi. Local farmers guided them to the Bailiandong Cave, where they found four pieces of stone tools, one bone awl, and one bone needle (Jia and Qiu, 1960; Jiang, 2009).

Several periods of small-scale excavations took place in 1973, 1979, and 1980–1981. Organized by the Liuzhou Museum, a formal excavation project was conducted by an archaeological team comprising representatives of both the Beijing Natural History Museum and Liuzhou Museum in 1981–1982 (Yi et al., 1987). Several human teeth, more than 3,550 pieces of mammalian fossils, some bone and antler tools, dozens of pottery sherds, and more than 500 stone artifacts were unearthed from the site according to a comprehensive report published by Jiang (2009). Based on research on lithic typology, plant remains, absolute dating/biostratigraphy, human and animal remains, human subsistence, paleo-environment, etc., researchers proposed that the sequence of the Bailiandong Cave represented a consecutive prehistoric cultural development from the Late Paleolithic to the Mesolithic to the Early Neolithic, and that it could be taken as a typical site in transition from the Paleolithic to the Neolithic in southern China (He and Tan, 1985; Jiang, 2009; Xie and Zhang, 1987; Zhou, 1986).

2.3. Stratigraphy and chronology

2.3.1. Stratigraphy

The Bailiandong Cave site has an area of cultural sediments of more than 150 m^2, in which were deposited human and mammalian fossils and a large number of archaeological remains. In the main chamber of the cave, an extremely thick calcareous plate (i.e., "big flowstone") had formed,extending completely across the area from west to east and separating two units of sediments that were obviously different. The deposits under the plate were composed of russety and tawny sediments yielding fossils of *Homo sapiens* and of an *Ailuropoda–Stegodon* faunal complex of the late Pleistocene; the deposits above the plate were made up of grey–yellow and grey sediments yielding lots of extant mammalian fossils and mollusk remains. Due to the influence of multi-geological action and anthropic disturbance, the deposits in the Bailiandong Cave vary evidently in composition and change greatly both horizontally and vertically. In general, two sets of deposits were concentrated respectively at the eastern and western sides of the cave (Jiang, 2009; Yuan et al., 1995; Zhou, 1986).

The eastern deposit was at a relatively higher level, containing eight layers from top to bottom (Fig. 2):

- East 1(E1), grayish brown calcareous plate and carbonated clay loam, with a maximum thickness of 28 cm, containing mollusk, breccia, and many potsherds;
- East 2(E2), milky white calcareous plate, spreading widely in the chamber and covering the cultural remains;
- East 3(E3), grayyellow clay loam, 30–37 cm in thickness, containing many freshwater mollusk remains and mammalian fossils, as well as polished stones, perforated cobbles, knapped stones, burned bones, and charcoal fragments;
- East 4(E4), tawny clay loam, with carbonated cementation of hard texture, 38 cm in thickness on average, containing many mollusk remains, mammalian fossils, edge-ground stones, knapped stones, and charcoal fragments;
- East 5(E5), off-white calcareous plate, 1–4 cm in thickness;
- East 6(E6), chocolate brown clay loam, 48 cm in thickness, with relatively consolidated and concentrated mollusk remains on its top, and containing knapped stones, perforated cobbles, a few breccia, charcoal fragments, and a few small, red brick blocks;
- East 7(E7), light tawny calcareous plate, 44 cm in thickness. It is integrated into the extremely thick calcareous plate that extends from west to east, and it is divided into three sub-layers. The upper part is light tawny and of compact texture, containing fragments of breccia and few iron-manganese concretions; the middle part is composed of brick-red clay loam, loose in texture; the lower part is chocolate-brown clay loam, composed of pure calcite crystal, with pinch-out at its two ends;
- East 8(E8), russety clay loam, about 100 cm in thickness, containing numbers of breccia ranging from 2–3 to 10 cm in diameter and yielding mammalian fossils and black flint fragments.

The western deposit is at a relatively lower level, and contains 10 layers, from top to bottom:

- West 1, grayish brown clay and clay loam containing mammalian fossils, knapped stone, perforated cobbles, some breccia, blocks of flint, mollusk remains, and burned bones, 20–56 cm in thickness;
- West 2, creamy yellow calcareous plate, mingled with a few mollusk remains and mammalian bones, about 40 cm in thickness;
- West 3, light tawny calcareous plate, 15–35 cm in thickness, connected to East 7 and forming the extremely thick calcareous plate that extends from west to east. Three sub-layers are identified. The middle and lower parts are composed of russety, closely cemented clay loam, yielding numerous mollusk remains, some bone fragments, a few breccia, burned bones, and blocks of flint;
- West 4: light tawny calcareous plate, 50 cm in thickness. It is integrated into the extremely thick calcareous plate that extends from west to east, and it is divided into three sub-layers. The middle part is composed of red-brown, closely cemented clay loam containing some breccia, fragments of calcareous plate, a few iron-manganese concretions, fragments of mammalian fossils, and a few mollusk remains. The lower part is composed of tawny clay loam, containing many fragments of mammalian fossils, mollusks, breccia (the biggest one is more than 50 cm in length), knapped stone (including many artifacts of black flint). Some charcoal fragments are present in the sediments;
- West 5: russety clay loam, 30–55 cm in thickness, containing a few breccia, fragments of calcareous plate,

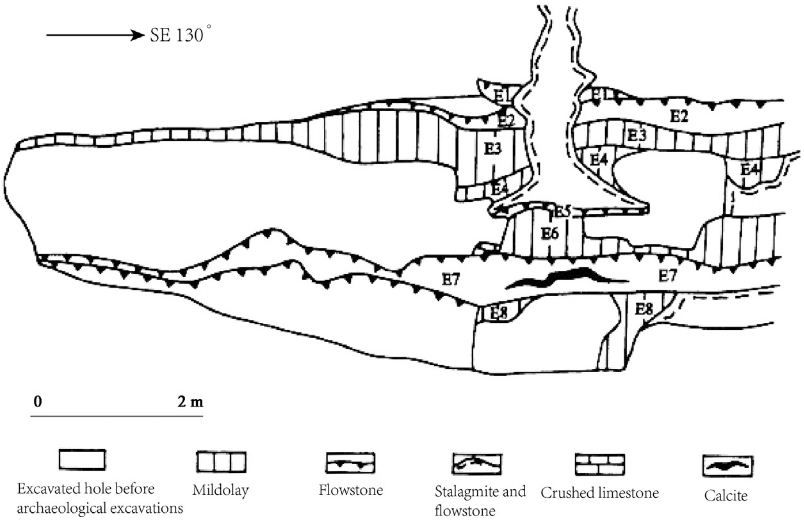

Fig. 2. Stratigraphy of east deposits of the Bailiandong Cave site according to Yuan et al. (1995).
Fig. 2. Stratigraphie du dépôt à l'est de la grotte de Bailiandong d'après Yuan et al. (1995).

mammalian fossils, and knapped stone including some black flints;

- West 6: pale yellow calcareous plate, 10 cm in thickness;
- West 7: tawny clay loam, loose in texture, 18 cm thick, containing breccia of different sizes, a very few iron-manganese concretions, some mammalian fossils, knapped stone, and human teeth;
- West 8: gray-yellow calcareous plate, 10 cm in thickness;
- West 9: chocolate-brown clay loam, 12 cm in thickness;
- West 10: cream-yellow calcareous plate, mingled with clay, occasionally yielding some fossil fragments. This layer has not reached the bedrock of the cave.

2.3.2. Chronology

The bio-stratigraphic analysis indicated that the deposits of the Bailiandong Cave could be divided into two complexes: the one deposited over the extremely thick calcareous plate could be attributed to the early Holocene, and the other one, buried under the plate, to the late Pleistocene (Jiang, 2009; Zhou, 1986).

Several series of dating measurements, including ^{14}C dating and U-series dating analysis, have been conducted on the cave sediments. In the early 1990s, the first conventional ^{14}C dating results were published by the ^{14}C dating laboratory of Beijing University: the deposits from the west side of the cave were dated to ca. 36 ka–20 ka, and the calcite from layer East 7 was dated to 11, 670 ± 150 years (Yuan, 1990a; Yuan et al., 1995).

However, researchers were very skeptical about the dating results, due to uncertainties about the nature of the sample from layer East 7. So, new fieldwork and laboratory work were conducted to determine the stratigraphy and chronology of the site. A series of AMS ^{14}C dating results were thus provided by Yuan et al. (1995). New research also showed that the age of the sediments from East 7 should be 19,090 ± 200 years and that the previous sample (dated 11,670 ± 150 years) was in fact composed of secondary deposits from a younger period (Yuan et al., 1995). So, combined with previous U-series dating measurements on two bone fossils and conventional ^{14}C dating results obtained in 1990, a new chronological framework of 36, 000–7,000 years was established for the site (Jiang, 2009) (Table 1).

To conclude, the current dating data suggest a time range between 36, 000 and 7,000 years ago (about the late late Pleistocene to the early Holocene) for the cultural deposits of the site, which corresponds well to the age of the bio-stratigraphy and can be used as a time framework for human activities in this cave (Jiang, 2009).

2.4. Cultural and animal remains and human fossils

Cultural remains contain 500 pieces of lithic artifacts, including hammer stones, choppers, flakes, scrapers, points, cores, debris, polished stone tools, donuts, grinding stones, perforated stones, two pieces of bone and antler tools, 12 pottery fragments, and two fireplaces. Raw materials of the stone assemblage include silex, quartzite, sandstone, silty metamorphic, diabase, quartz diorite, and siliceous rock, etc. (Jiang, 2009).

The animal remains unearthed at the Bailiandong Cave were generally composed of mammals (23 species), mollusks (5 species), fish (2 species), amphibians (1 species), terrapins (1 species), and avifauna (undetermined). The mammalian remains were separated into two complexes by the thick calcareous plate: one deposited above the plate was attributed to the "extant faunal complex" and includes 15 species, such as *Rhizomys sp.*, *Vespertilionidae gen.* et *sp. Indet.*, *Macaca sp.*, *Sus scrofa*, *Bubalus sp.*, *Pseudaxis sp.*, *Muntiacus sp.*, *Cervus sp.*, *Ovis sp.*, *Paguma larvata*, *Rhinopithecus sp.*, *Martes sp.*, *Muridae indet.*, *Vulpes cf. vulgaris* and *Lijiangocerus speciosus*; the other one, deposited under the plate, was attributed to an "*Ailuropoda–Stegodon* faunal complex" of the late Pleistocene, which included, in addition to 9 species identical to those deposited above the plate, *Hystrix subcristata*, *Ursus sp.*, *Arctonyx collaris*,

Table 1
Dating results of the Bailiandong Cave site.
Tableau 1
Résultats de la datation de la grotte de Bailiandong.

Stratigraphy of the east part	Conventional and AMS ^{14}C dating (yr BP)	Stratigraphy of the west part	Conventional and AMS ^{14}C dating (yr BP)	U-series (on fossils)
East 1	6,880 ± 125			
East 2	9,250 ± 90			
East 3	10,840 ± 580	Upper part of West 1	10,020 ± 290	
East 4	13,170 ± 590			
East 5	13,905 ± 250	Lower part of West 1	17,680 ± 300	
East 6	14,240 ± 230	West 2	12,420 ± 180 19,145 ± 180	
		West 3	17,930 ± 410	
East 7	11,670 ± 150 19,090 ± 200	West 4	Top: 20,960 ± 150 Bottom: 25 920 ± 625	
East 8	20,240 ± 660	West 5		
		West 6		28,000 ± 2,000
		West 7		
		West 8		
		West 9		
		West 10	36,000 ± 2,000	
References	(Yuan, 1990a; Yuan et al., 1995, 1997; Yuan and Gao, 1994)		(Yuan, 1990a; Yuan et al., 1995, 1997)	(Yuan et al., 1990b)

The grey color indicates the thick calcareous plate (big flow stone) across the main chamber of the cave site.

Ailuropoda melanoleuca, *Stegodon sp.*, *Elephas sp.*, *Rusa unicolor*, and *Rhinoceros sinensis*.

Two well-fossilized human teeth were unearthed in the layer of West 7; one was the left lower third molar, and the other was right lower third molar. Except for a very few archaic features, these teeth had no obvious differences from modern human teeth, so they were both attributed to *Homo sapiens* (i.e.anatomically modern human) (Jiang, 2009).

3. Accessibility of lithic material and its chrono-stratigraphic context

Since the lithic materials of the Bailiandong Cave site have already been studied from a typological perspective by previous researchers (Jiang, 2009; Yi et al., 1987), here we focus only on the chipped stones, using a technological approach, and do not consider the polished stones and non-cutting edge tools, only presenting their general characteristics in the lithic industry where necessary.

The lithic collection that was accessible to us is stored in the Bailiandong Cave Site Museum, where we observed 403 pieces in total (not including the non-cutting edge tools and polished ones). Because of the long time they have been stored and the limited conservation conditions in the local museum, some of the stone artifacts have been lost, while others are stored in other institutions and thus are not accessible for study at the moment. During the observation, we found that two broken flakes (in fact it was one flake broken into two pieces) coming from different layers (BLES③ :172, BLES⑥ :177), which could be joined, which may suggest the possibility of stratigraphic mixing during taphonomic process or at the time of excavation.

It is true that these lithic artifacts come from different layers of the site; however, due to the limited number of artifacts, and to the possibility of stratigraphic disturbance of some of the lithic collection in the local museum, we recognized that these artifacts had lost their original precise stratigraphic information, so that we would not be able to study these stone artifacts layer by layer in a detailed way. Therefore, we executed our analysis principally in a macroscopic perspective. In this sense, the previous chronological framework was refined and the sequence was re-divided into two units according to their location with respect to the thick calcareous plate (i.e., big flow stone) in the main chamber of the cave: the upper unit, which was above the calcareous plate, and the lower unit, below the plate. Correspondingly, the ages of the lithic artifacts that we studied were specified by consulting previous dating results and the stratigraphic contexts that they belong to; the chipped stone artifacts from the lower unit have an age ranging from 36,000 to 20,000 years BP, while those of the upper unit range in age from 14, 500 to 9, 000 years BP.

4. Lithic technology

As for the lithic assemblage of Bailiandong Cave, a systematic quantitative analysis was impossible because of the relatively small number of specimens and the presence of a large proportion of broken blocks and debris, which could not provide useful technological information. We therefore conducted a qualitative technological analysis on this lithic collection according to the specimens' stratigraphic units (i.e. the re-arranged lower unit and upper unit) so as to determine the assemblage's operative sequences, i.e. its *chaînes opératoires*, volumetric structures, and the objectives of lithic production.

The total lithic assemblage of the Bailiandong Cave site was classified into different categories. Generally, both *débitage* (flaking) and *façonnage* (shaping) products were present in the lower and upper units; quantitatively, *débitage* could have been the major technical strategy

Table 2
Composition of lithic assemblage from the Bailiandong Cave Site Museum.
Tableau 2
Composition de la collection lithique du musée de la grotte de Bailiandong.

Category	Lower unit	Upper unit	Total
Cores (*débitage*)	8	11	19
Bipolar-split products (*débitage*)	2		2
Shaped cobble tools (*façonnage*)			
Typical end chopper	2	14	16
Chopper with an abrupt front		5	5
Chopper with a plane front		1	1
Double-chopper	1	1	2
Side chopper	1	1	2
Special side chopper	1	3	4
Chopper of special volumetric structure		4	4
Shaped disc		1	1
Flakes (from *débitage* or *façonnage*)			
Flake tools	39	29	68
Unmodified or unused	110	22	132
Others			
Broken blocks	61	5	66
Debris	73	1	74
Unidentified pieces	6	1	7
Partial and fully polished cutters	1	2	3
Donut stones		5	5
Perferated stones		2	2
Grinding stone		1	1
Total	305	109	414

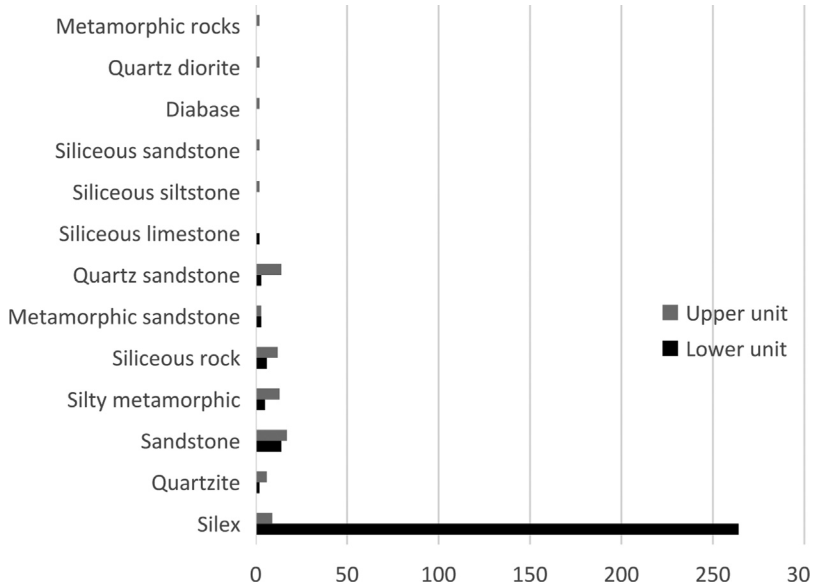

Fig. 3. Raw material composition of the lithic industry of Bailiandong Cave.
Fig. 3. Composition de la matière première de l'industrie lithique de la grotte de Bailiandong.

adopted by the prehistoric knappers in the lower unit, *façonnage* seeming to have been less important; meanwhile, in the upper unit, *façonnage* had a substantial role to play, but *débitage* still had an important place in the lithic assemblage (Table 2). As for the raw materials exploited, they were river cobbles from the terrace of the Liujiang River and silex nodules from outcrops which were at 3–5 km from the site; specifically, silex nodules dominated in the lower unit, while, in contrast, they were very rare in the upper unit; however, the majority of them were broken blocks and debris, which made it difficult to evaluate their real importance when conducting quantitative analysis. Other common raw materials were quartz, sandstone, siliceous stone, and metamorphic rock; raw materials used in the upper unit were much more varied than those of the lower unit (Fig. 3).

4.1. Cores: morphology, volumetric structure and method of débitage

In total, four types of cores, which have different morphology and volumetric structures, were selected and

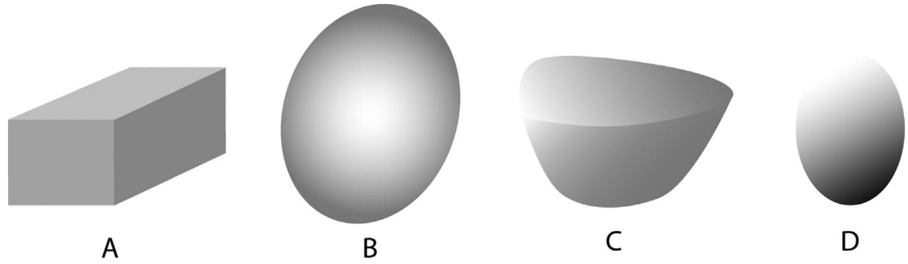

Fig. 4. Morphology and volumetric structure of the raw material selected as cores (A, C; cobbles or silex nodules, B, D, cobbles).

Fig. 4. Morphologie et structure volumétrique de la matière première sélectionnée comme nucléus (A, C, galets ou nodules de silex ; B, D. galets).

exploited (Fig. 4). All the cores were cobbles or silex nodules, to which no intentional initialization or preparation was applied to transform their original morphology and structure for flaking to obtain the desired blanks; instead, the initialization consisted of selecting natural technical characteristics on cobbles and blocks for further reduction, such as a suitable striking platform and flaking surface, providing good lateral and distal convexity. So, during such initialization, selecting raw material was very important , and this is why the volumetric structure of the block chosen should be studied first. Generally, only a small volume of the core was exploited and the core *sensu stricto* (the exploited part of the cobble or block) of each type had a similar volumetric structure, while the morphology of the unexploited part could be very diverse. Usually, prehistoric knappers would search for the exploitable volume on the block until they could not extract useful flakes, then the rest of the block would be discarded or transformed into tools. The morphology of the flakes obtained was thus very varied: big or small, thin or thick. The technique applied for knapping was direct internal percussion with a hard hammerstone.

Type 1 ($n = 10$): this type of core was the most exploited at the site. Although their morphology varies, structurally they present a generally cubical configuration (Fig. 4: A). The useful volume of the cube as a core is on its periphery wherever there is a suitable flaking surface (surface of *débitage*), striking platform, and angle. Usually, there was more than one platform and the striking platform and flaking surface underwent no preparation, that is to say, prehistoric knappers kept changing the platform and flaking surface to find the useful volume on the periphery that was naturally present on the block; the methods of flaking could be mainly unidirectional (Figs. 5, 7, 8), or rarely bidirectional (Fig. 6). The morphology of the flakes obtained was very unstable, including elongated, wide, triangular, quadrangular flakes, and rare blades. Technologically, the majority of flakes have a butt with natural cortex and the direction of negatives on the dorsal face of flakes contain several patterns, such as unipolar and bipolar patterns, and the dorsal face usually bears the residue of the cortex, while sometimes there are no cortices but only negatives.

Type 2 ($n = 1$): although only one piece was discovered, it could represent a different morphology and structure type (Fig. 4: B). The raw material was a big ovoid and spherical cobble (97 × 72 × 61 mm, 419 g, quartz), from which two series of reduction were produced by an algorithmic method(Forestier, 1993). Within each series, the method of flaking was recurrently unidirectional, each yielding three flakes (Fig. 9). The morphology of the flakes thus obtained was relatively wide, and each contained a full or partial cortex on its dorsal face.

Type 3 ($n = 6$): the specialty of this type lies in the fact that the core (river cobble or silex nodule) presents a general plano-convex volumetric structure (Fig. 4C). Usually, the plane surface was used as a striking platform and the convex one as a flaking surface, but occasionally the two surfaces changed their roles. This special structure could provide knappers with excellent part(s) of useful volume on the periphery where the two surfaces intersect, without need for preparing the flaking surface, and the suitable angle for knapping was the main concerns for knappers during the reduction. Recurrent unidirectional flaking method dominated the process of *débitage* (Figs. 10, 11). From this type of core some flakes could be very distinguishing; for example, the flake whose periphery on its dorsal face is circled with the cortex could be produced with a unidirectional flaking method. Other flakes do not present any special morphology or characteristics; they are usually thin and have a cortex on the dorsal face. Additionally, thick flakes could be produced if the internal percussion technique drew back too far from the striking point on the periphery of the block.

Type 4 ($n = 2$): this type of core has a special volumetric structure which is highly integrated (Fig. 4: D). The useful volume of the core equals that of the totally natural cobble. The raw material selected was a flattish ovoid cobble, and the bipolar method was used to split it on an anvil into two half-cobble blanks, which could be used to make different tools as the knappers desired. The cutting edge of denticulate or rectilinear morphology could be obtained in this case (Fig. 12).

To conclude, the organization and management of core reduction in the Bailiandong Cave were mainly based on the idea of selecting raw materials that naturally presented all the required technological criteria for successful flaking, such as the distal and lateral convexity of the flaking surface. Generally, there were 2–3 series of reduction on each piece of core, and no preparation had been conducted for the artificial configuration of the core, which produced predetermined and predetermining flakes at the same time. Most of the cores were retouched or transformed into tools (13 among 19 pieces) after *débitage*. Core types 1 and 3 were the most common ones, appearing in both the lower

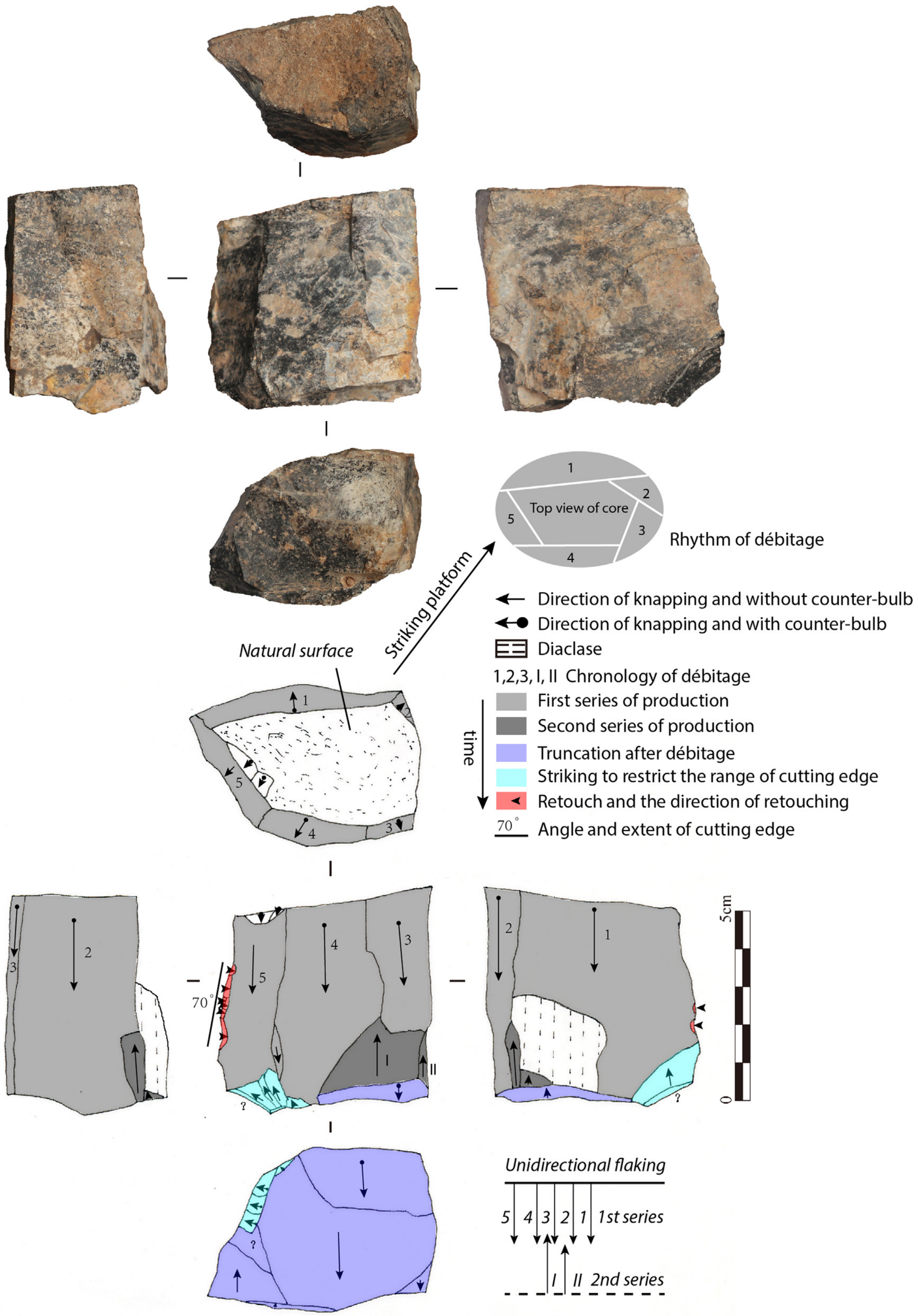

Fig. 5. Photo and diacritic diagram of a type-1 core (unidirectional method).

Fig. 5. Photo et schéma diacritique d'un nucléus de type 1 (méthode unidirectionnelle).

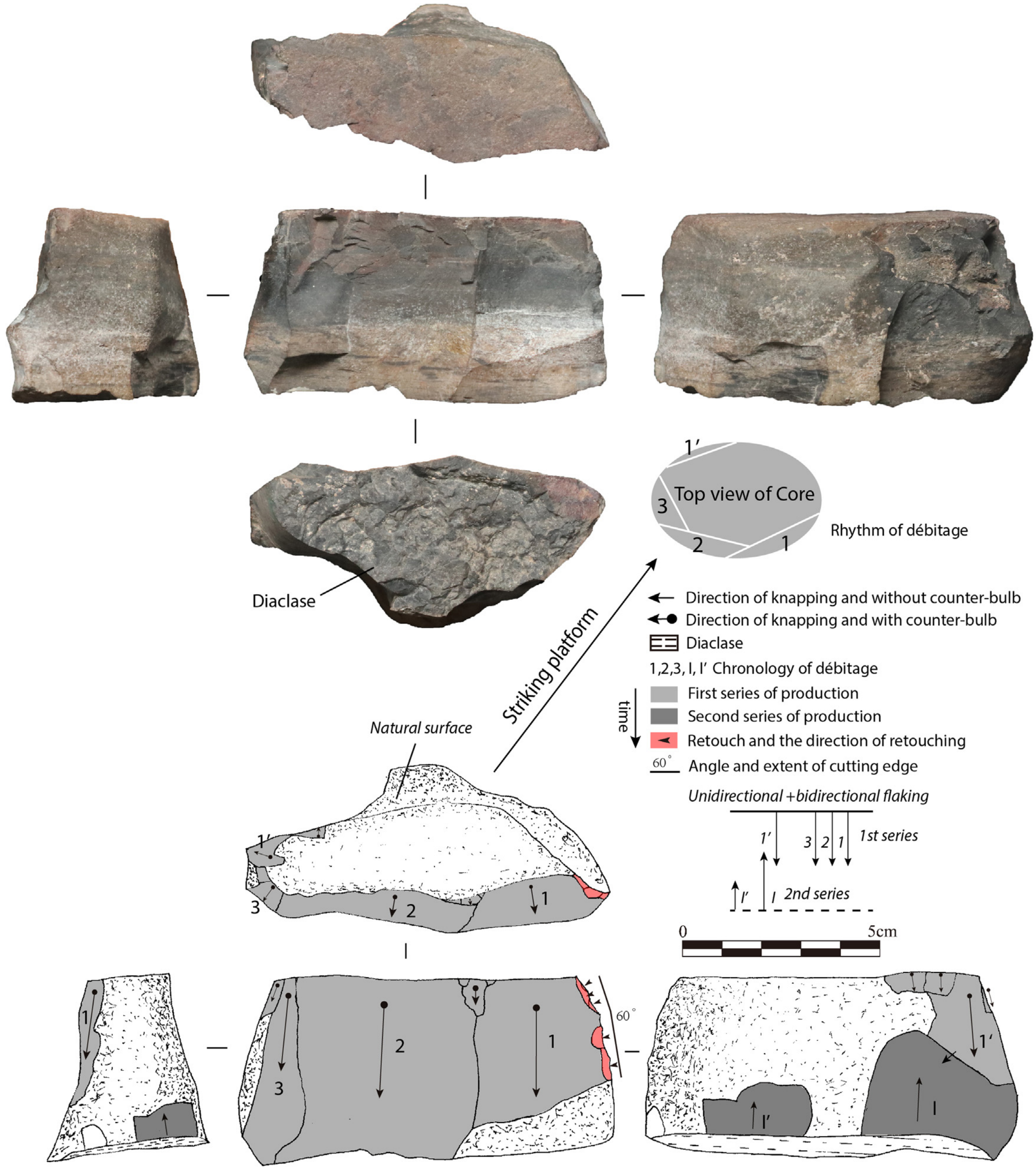

Fig. 6. Photo and diacritic diagram of a type-1 core (unidirectional and bidirectional method).

Fig. 6. Photo et schéma diacritique d'un nucléus de type 1 (méthode unidirectionnelle et bidirectionnelle).

and upper units of the site, with their quantity being relatively equal in the two units. Type 2, however, was rare and discovered only in the upper unit; type 4 contained two pieces, both from the lower unit. Overall, although there were minor changes in core types from the lower unit to the upper unit, stability in both core types and the idea of organization and management of core reduction in the sequence seem apparent. The flakes obtained could have various morphologies and usually had a cortex on their dorsal face, which seems to indicate that no standardization of flake blanks existed during core reduction. As far as raw material is concerned, silex (nodule) was extensively used for *débitage*, but never for *façonnage*, while cobbles were exploited for both *débitage* and *façonnage*, as we can see below.

4.2. *Shaped cobble tools*

Tools of this type are end products made of cobbles and resulting from *façonnage*. In the case of the Bailiandong Cave, the shaping process was very short and concise, aimed at creating a simple-bevel or, rarely, a double-bevel

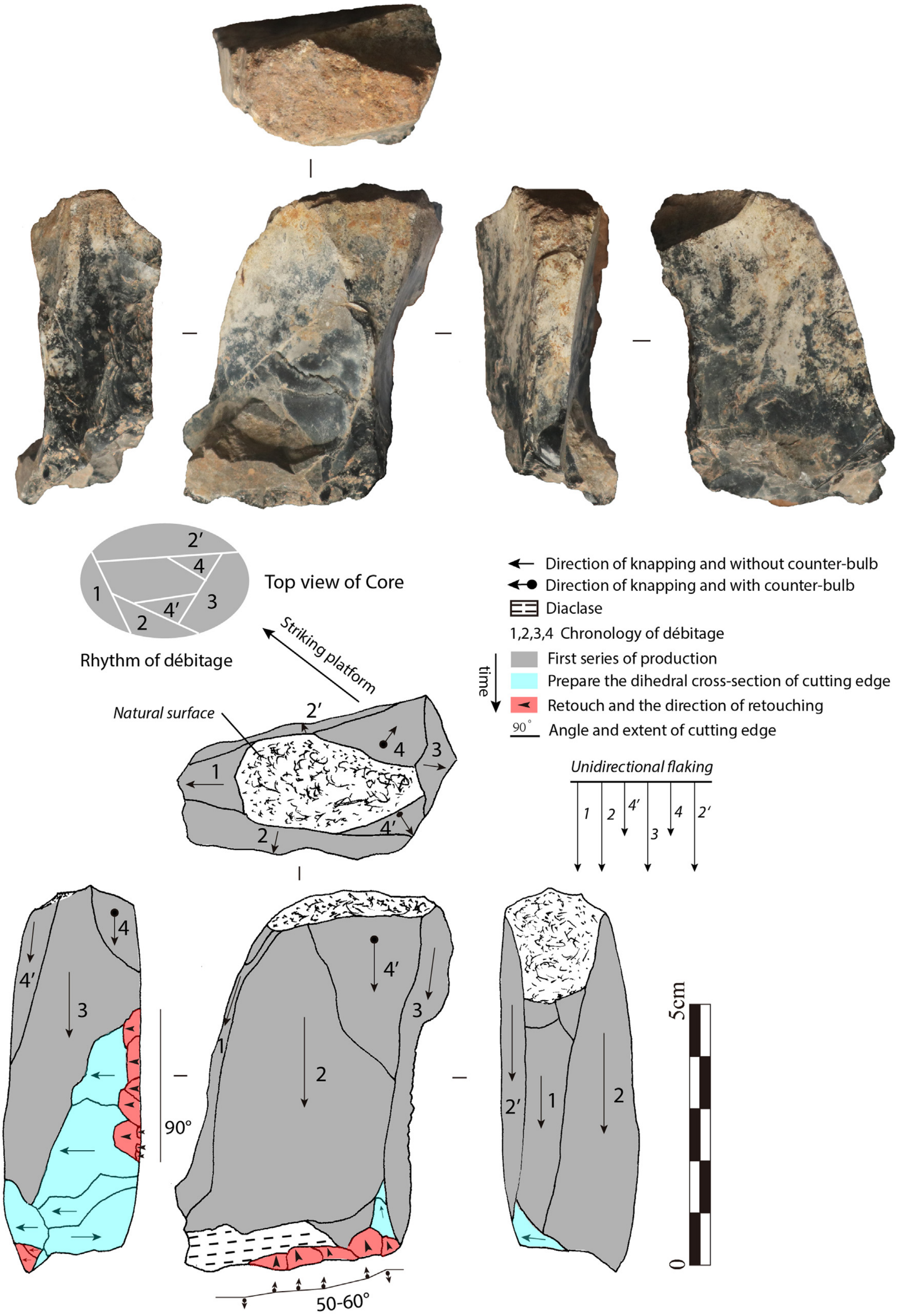

Fig. 7. Photo and diacritic diagram of a type-1 core (unidirectional method).

Fig. 7. Photo et schéma diacritique d'un nucléus de type 1 (méthode unidirectionnelle).

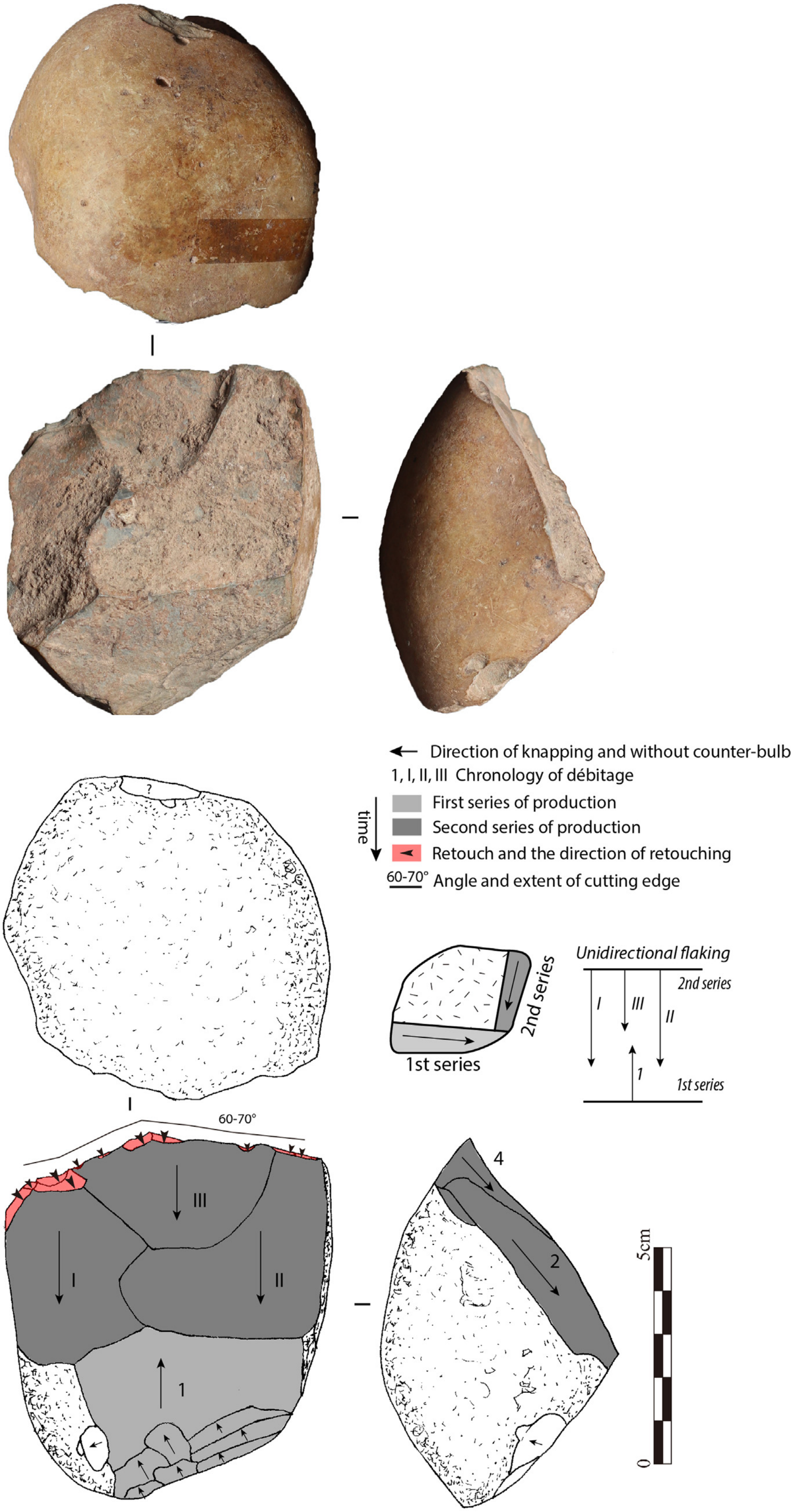

Fig. 8. Photo and diacritic diagram of a type-1 core (unidirectional method).
Fig. 8. Photo et schéma diacritique d'un nucléus de type 1 (méthode unidirectionnelle).

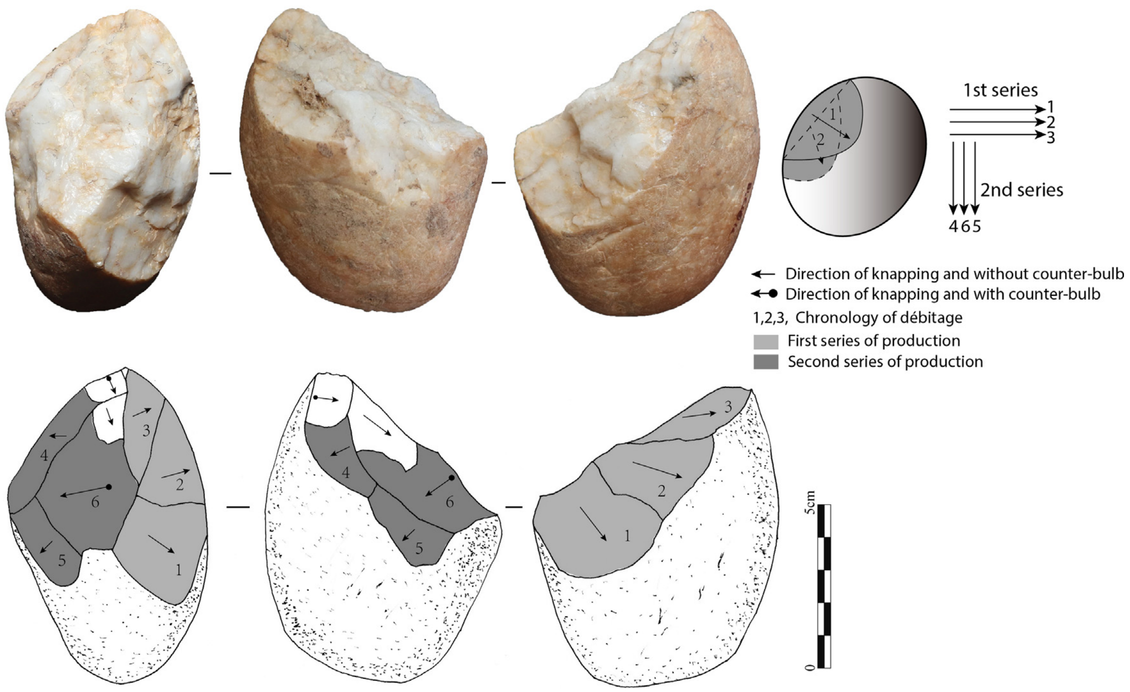

Fig. 9. Photo and diacritic diagram of a type-2 core (algorithmic method).
Fig. 9. Photo et schéma diacritique d'un nucléus de type 2 (méthode de l'algorithme).

structure on the end or the side of a cobble, or sometimes at producing a special morphostructure of the bevel (dihedral cross-section of the cutting edge). According to the location of the cutting edge and the morphostructure of the bevel, different types of choppers could be distinguished, such as an end chopper, a double chopper, a side chopper, a chopper of special volumetric structure, etc. (see Table 1). Prehistoric knappers seem to have well foreseen the desired tool types when choosing the raw material, for the structure of shaped tool was largely integrated into the original volume of the cobble; in other words, the knappers preferred to spend more effort searching for the appropriate cobble in order to find one which satisfied their intention and required less effort on the shaping work. As a result, shaping was merely to create the bevel (dihedral cross-section) for more of a cutting-edge (see Fig. 13), and the prehensive part of the tool usually remained unmodified. As for the cutting-edge, different technological requirements of knappers were manifested by different technical characteristics of cutting-edge, such as its morphology, angle, and position. Generally, retouching on the cutting edge was not very regular or intensive.

4.2.1. Typical end chopper (n = 16)

This type of chopper has its transverse cutting edge on the distal end of the cobble. The cutting edges themselves vary as their morphology and angle change. The raw material selected was medium-sized river cobbles (132 mm in length, 63 mm in width, 39 mm in thickness, > 300 g weight on average) of different lithologies, whose original morphologies were very diverse, such as triangular, oblong, oval, and trapezoidal. The transverse section of the cobble presents mainly two different kinds of contours: a quadrangular one (two parallel surfaces) and a triangular one (plano-convex surfaces). Of these two surfaces, the plane one was usually used as a striking platform for shaping (unidirectional knapping), resulting in a simple-bevel structure on which the further cutting-edge would be formed. After the creation of the bevel, sometimes the cutting-edge came into being directly, sometimes retouching could happen; however, it was usually simple. Among this type of choppers, different techno-types could be identified on the basis of the significant variability presented by the transformative unit of the tool (i.e., the part directly contacted with the materials). The contour of the cutting-edge on the front view could be rectilinear, convergent-point, or concave, and the angle of the cutting edge varies from 50 to100° to meet the needs of a variety of activities (Fig. 14).

4.2.2. End chopper with an abrupt front (n = 4)

This type of chopper is different from the typical end chopper, because such artifacts usually have a very abrupt front. The cutting edge is also on the end of the cobble, but it is generally more than 90°. The raw material chosen was relatively big and thick cobbles (average weight > 500 g), which often possess triangular or irregular morphology in front view, with a bi-convex but asymmetric transverse section. The knappers usually used the less convex surface as a working platform, with successive unidirectional knapping toward the other surface, in which way an abrupt front (or simple-bevel) at one end of the cobble would be obtained. Retouching seems to have been used to make the cutting edge more obtuse (> 90–100°). Choppers of this

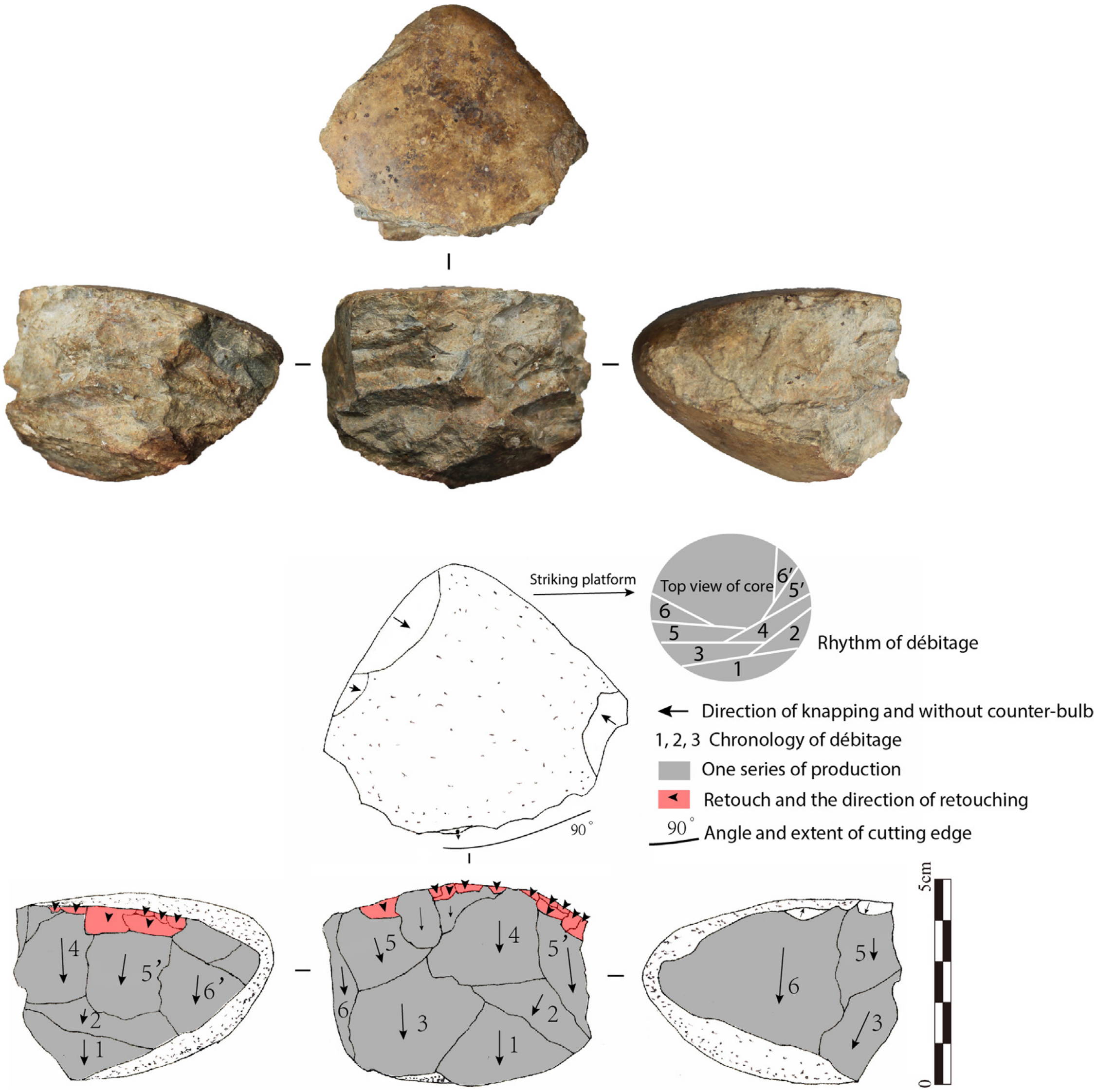

Fig. 10. Photo and diacritic diagram of a type-3 core (unidirectional method).
Fig. 10. Photo et schéma diacritique d'un nucléus de type 3 (méthode unidirectionnelle).

kind often exhibit many traces of percussion on the surface and periphery of its body (Fig. 15).

4.2.3. Double chopper (n = 2)

Choppers of this type contain two cutting edges on the opposite ends of the cobble separately (Fig. 16). Their difference with a previous chopper is not obvious, except that the latter has only one cutting edge on the distal end of the cobble. This type of chopper does present some interesting characteristics. The raw materials chosen are big and heavy river cobbles (74 × 64 × 49 mm, 338 g; 92 × 82 × 51 mm, 606 g) of quartzite and quartz sandstone, and their morphology is a little elongated, with its two sides generally parallel; the section is nearly oblong. One of the two specimens contains a double-bevel on the proximal end of the cobble (Fig. 16:1); the other cutting edges are steep, single-beveled ones obtained by the unidirectional knapping method. After the creation of the abrupt simple bevel, only minimum retouching was carried out. The angle of the cutting edges on the two ends of the cobble is 90° or more, so it is difficult to infer the intention of the knappers for the abrupt bevels and the obtuse angle of the "cutting edge."

4.2.4. Side chopper (n = 2)

There are only 2 pieces of this type, whose cutting edge is on the side rather than on the end of the cobble. Cobbles chosen were elongated with two parallel or plano-convex surfaces, and the plane surface was used as a striking platform. They also have a simple-bevel structure on which is formed the cutting edge, as those we have seen in end choppers. There is no essential difference between these two types of choppers, except for the position of the cutting

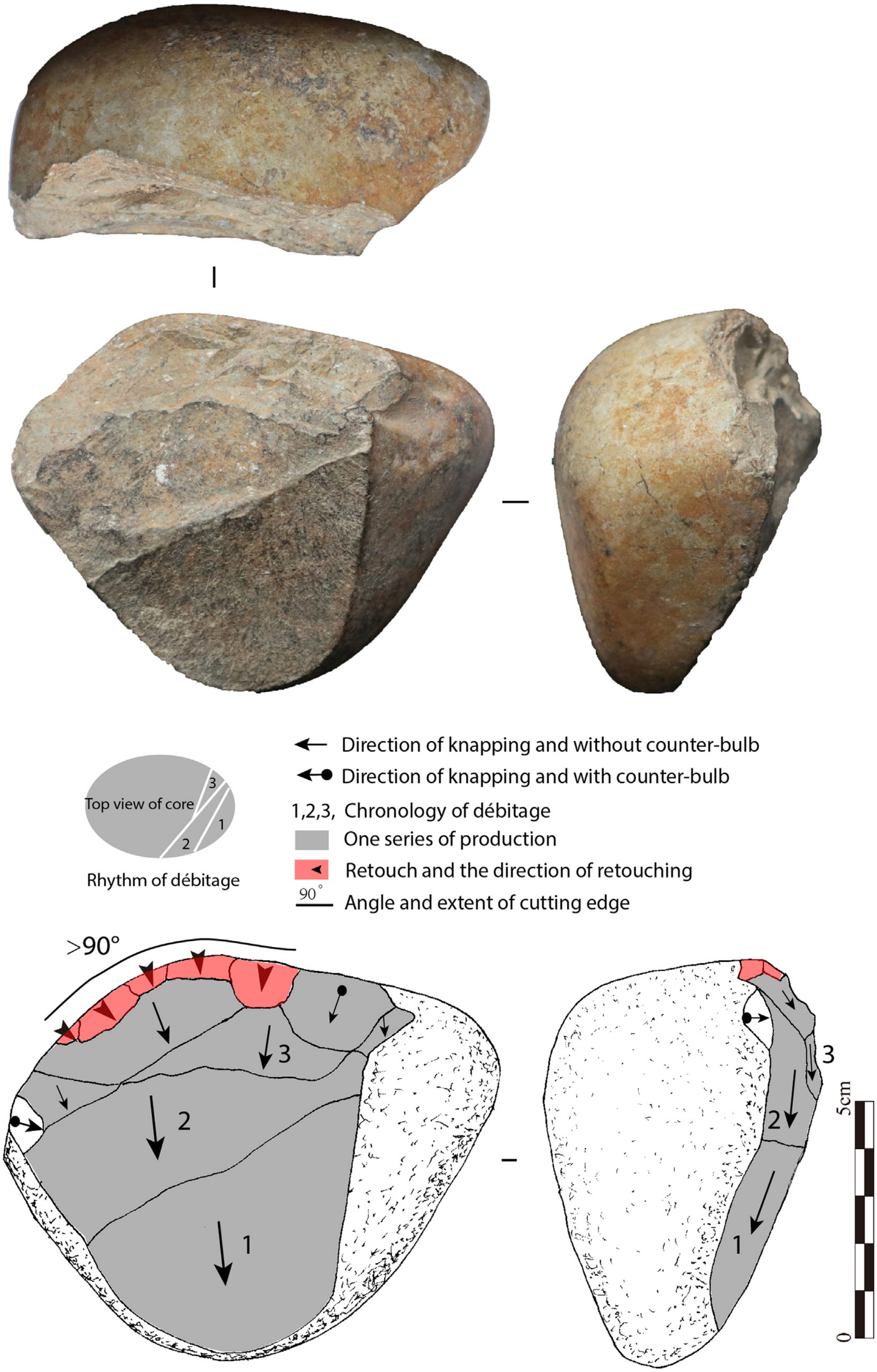

Fig. 11. Photo and diacritic diagram of a type-3 core (unidirectional method).
Fig. 11. Photo et schéma diacritique d'un nucléus de type 3 (méthode unidirectionnelle).

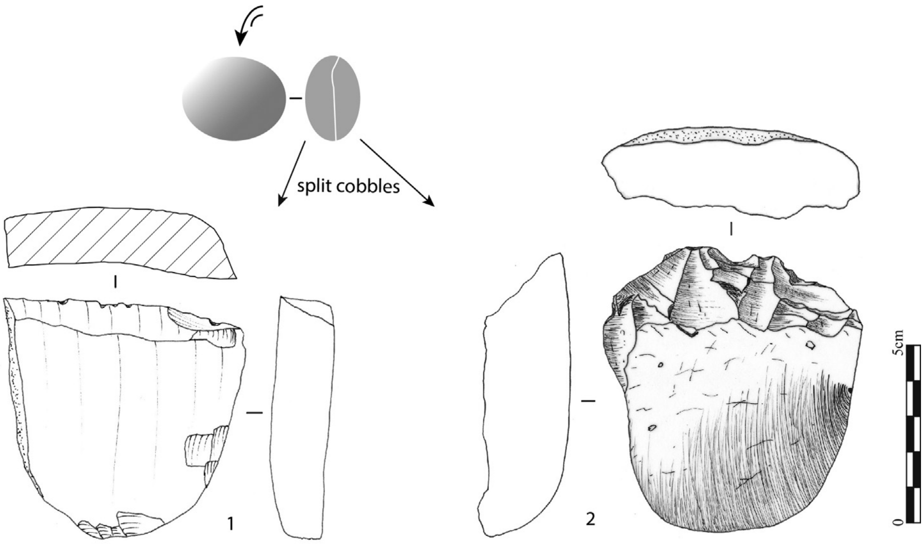

Fig. 12. Drawing of tools with the blank of split cobbles from a type-4 core and the schematic representation of the bipolar method.

Fig. 12. Dessins des outils avec ébauche de semi-galets provenant d'un nucléus de type 4 et représentation schématique de la méthode bipolaire.

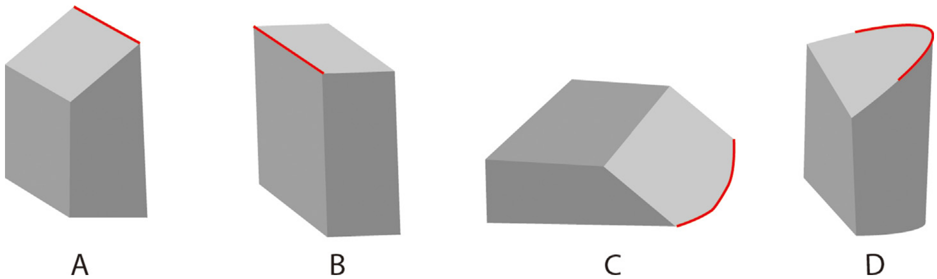

Fig. 13. Schematic representations of the different morphostructures of choppers at the Bailiandong Cave (red line: location of the cutting edge).

Fig. 13. Répresentations schématiques sur les différentes morphostructures de *choppers* de la grotte de Bailiandong (ligne rouge : localisation du tranchant).

edge. The cutting edge is rectilinear in front view, and the angle of the cutting edge is about 60–80° (Fig. 17: 1).

4.2.5. Special side chopper (n = 4)

This type of chopper was made of an ovoid cobble with two convex surfaces, one of which was more convex than the other. Shaping was usually conducted on one side of the cobble from the less convex surface (used as the striking platform) to the convex one. It has as objective to create a simple bevel *sensu lato* and a stage of retouching clearly existed to transform the angle, contour, and dihedral cross-section of the cutting edge. Due to the presence of a convex surface, the cutting edge is more or less curved in transversal view, which makes it different from the previously mentioned side chopper. The cutting edge has a concave, denticulate, or convex contour in front view, and its angle is generally about 60–70° (Fig. 17: 2, 3).

4.2.6. Chopper of special volumetric structure (n = 4)

This type of chopper has a quite different volumetric structure compared with previous types. The raw material is one kind of cobble of medium size (95 × 65 × 47 mm on average) whose section is plano-convex. The shaping also took place on the distal end of cobble. What makes it totally different is that, unlike end chopper makers who utilized the plane surface as their working platform, these knappers used the convex surface as the working platform and thus obtained a special volumetric structure with a triangular section in the distal and middle part instead of a typical simple-bevel (Fig. 13: D). Retouching was also conducted on this type of tool, but usually only a very short cutting edge with an angle of about 80° was obtained (Fig. 17: 4, 5).

4.2.7. Chopper with a plane front (n = 1)

The transformative part of this type of chopper was on one end of the cobble with a plane front. The cobble chosen was elongated and had a square transverse section (quartz sandstone, 96 × 66 × 58 mm, 557 g). The shaping happened at one end of the cobble and the knapper kept changing striking platform and direction of knapping, aiming at producing a plane front. After that, no obvious retouching was conducted. It seems that the prehistoric knappers wanted a plane front rather than a sharp cutting edge, which made it a different tool type (Fig. 18).

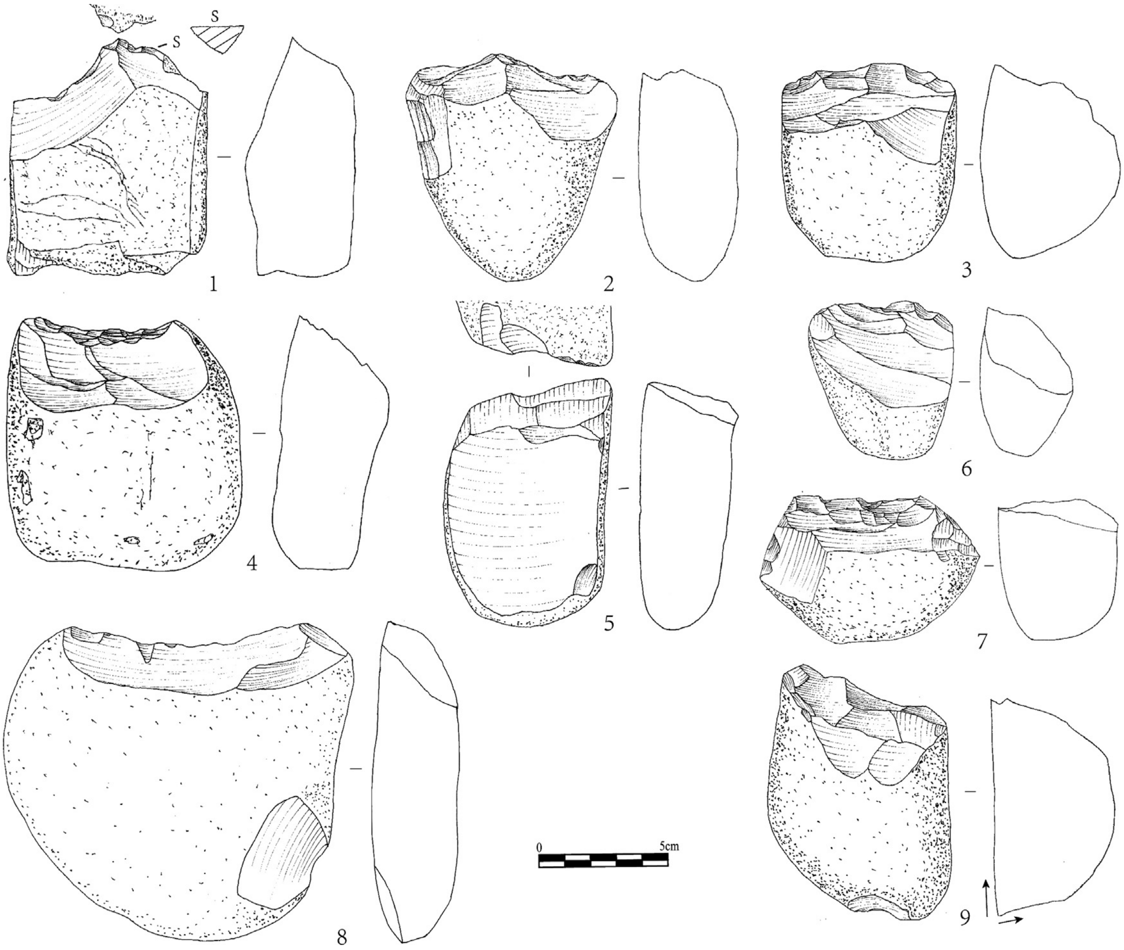

Fig. 14. Typical end chopper from the Bailiandong Cave (cutting edge: 1, 2: convergent-point; 3, 5–7, 9: rectilinear; 4, 8: concave).

Fig. 14. Chopper typique à tranchant transversal de la grotte de Bailiandong (tranchant : 1, 2 : pointe de convergence ; 3, 5–7, 9 : rectilinéaire ; 4, 8 : concave).

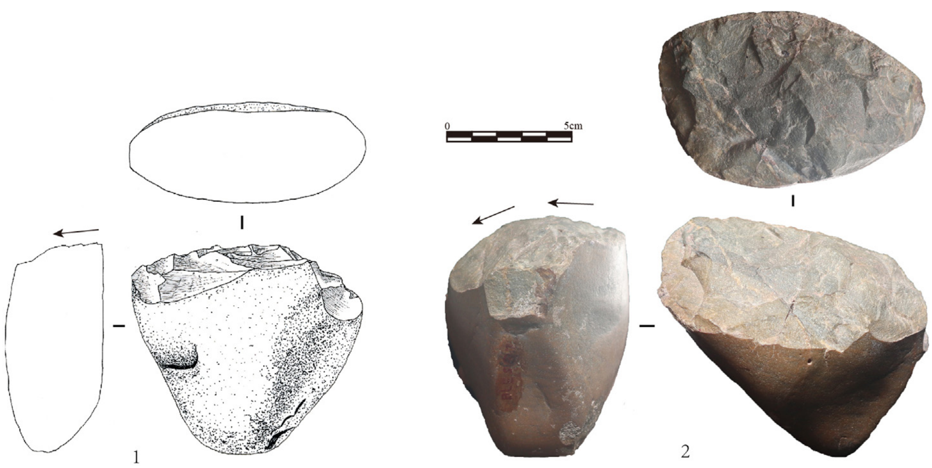

Fig. 15. End chopper with an abrupt front from the Bailiandong Cave.

Fig. 15. Extrémité de chopper à front abrupt de la grotte de Bailiandong.

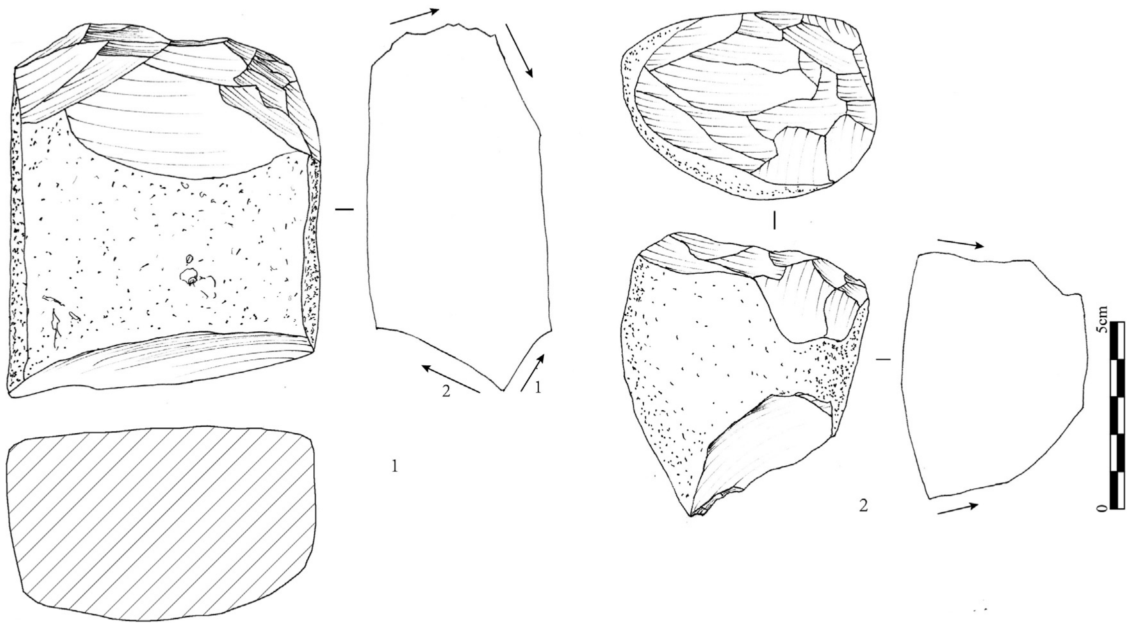

Fig. 16. Double-chopper from the Bailiandong Cave.
Fig. 16. Chopper double de la grotte de Bailiandong.

4.2.8. Shaped disc (n = 1)

This is a special and fortuitous type, since only one specimen was discovered on the site. Its specialty lies in that the cobble was centripetally worked from its periphery, resulting in a disc-like shaped product. The raw material exploited was a very big and thick oval cobble of plano-convex structure (> 89 × 67 × 53 mm, 420 g, quartz sandstone). The plane surface was used as a striking platform and the knapper kept working on the whole periphery of the cobble to produce a special product of shaping, i.e., a thick "disc" with trapezoidal section and profile. The edge along its new periphery is very abrupt (mostly > 90°) and only a small part has an angle of 75° (Fig. 19), which could serve as a cutting-edge. It is difficult to explain the existence of this tool because its peripheral "cutting-edge" is too obtuse for cutting. This tool has even been suspected to be a Sumatralith-like tool of Hoabinhian culture in south-eastern Asia (Jiang, 2009). Morphologically, this tool and a Sumatralith are similar in some aspects, but technologically their structures are so markedly different that they should not be taken as an identical tool from the operational sequences (see below for detailed discussion).

4.3. Flakes and flake tools

There are 200 pieces of flakes and flake tools in total, among which 51 pieces from the upper unit and 149 from the lower unit. However, more than half of the flakes did not provide clear technological information for us to judge the techno-types of the flakes. Based on the relative intact flakes, we distinguished four main techno-types of flakes (45 pieces from the upper unit, and 46 from the lower unit) according to our technological reading of the direction, extent, and order of negatives on the dorsal face of flakes (Fig. 20).

Techno-type 1: flake having no negative on its dorsal face, so it is the "first" flake detached from the cobble or block.

Techno-type 2: flake having one or more negatives on the dorsal face with the same direction as that of the flake itself. The butt is often cortical. The cortex can also be seen on the dorsal face, which can be on the peripheral or distal part of the flake, sometimes on the whole periphery or most of the periphery (Fig. 20-2a). This sub-type of flake was called "*Bailiandong flake*" by Chinese researchers, because it was thought to be a special character of flakes in this cave compared with other cave sites in southern China (Jiang, 2009). It could be obtained during both *débitage* of cores and *façonnage* of cobble tools (example: a shaped cobble tool with a special volumetric structure could have produced this techno-type of flakes during shaping).

Techno-type 3: flake having no cortex on its dorsal face, which is full of unipolar negatives compared with the direction of the flake itself.

Techno-type 4: flake having negatives on its dorsal face with a different direction from that of the flake itself (i.e., convergent or oblique).

Quantitative analysis shows that the trend of distribution of different techno-types of flakes is similar in the lower and upper units, except for flakes of techno-type 3, which are much more numerous in the lower unit because the raw material of this type, i.e. silex dominated in this unit but was rarely present in the upper one. So, generally, the pattern of flaking in both units is similar. Technologically, these flakes could come from both *façonnage* and *débitage* processes, which were attributed to two different *chaînes opératoires*.

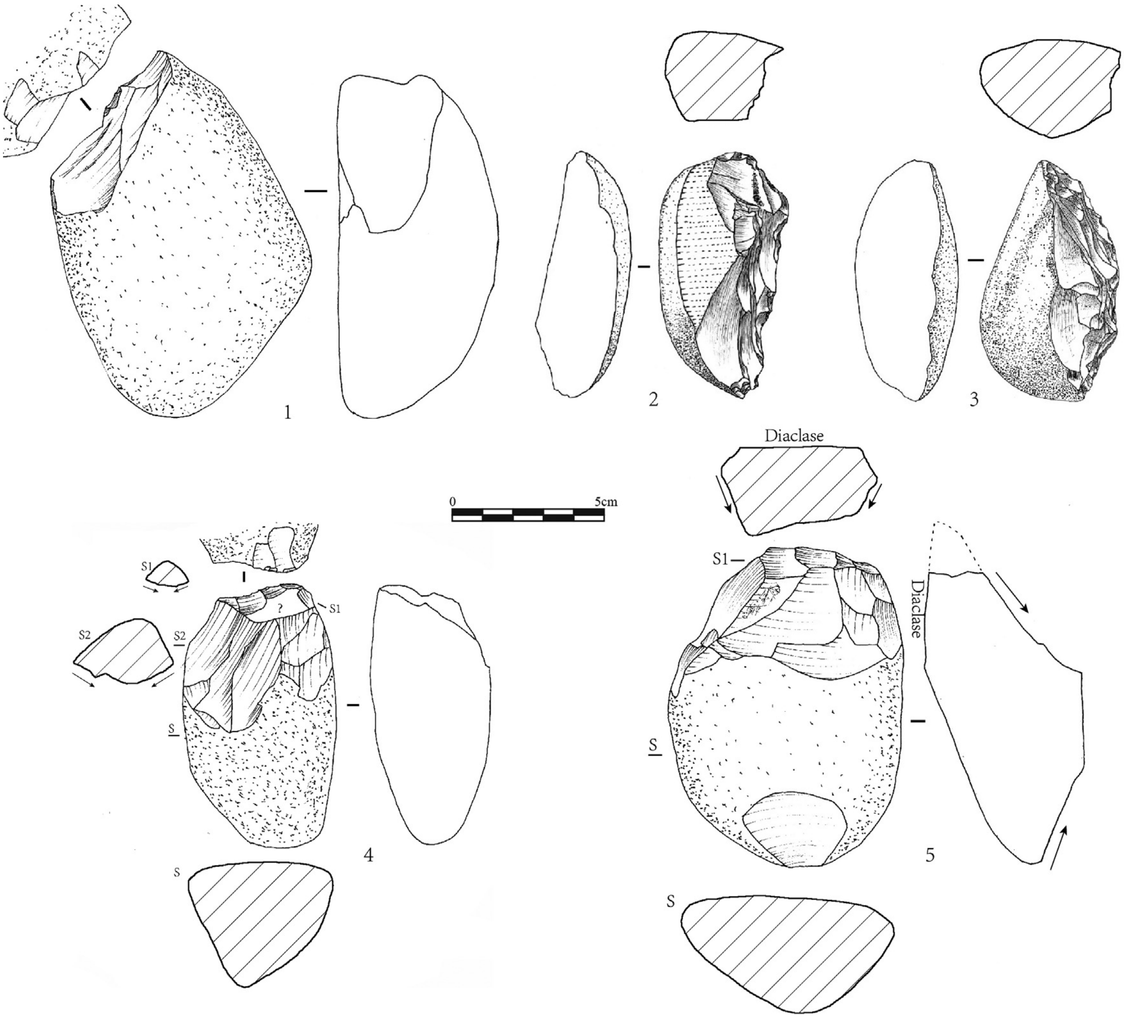

Fig. 17. Different types of choppers from the Bailiandong Cave (1: side chopper; 2, 3: Special side chopper; 4, 5: chopper of special volumetric structure).
Fig. 17. Différents types de choppers de la grotte de Bailiandong (1 : chopper à tranchant longitudinal ; 2, 3 : chopper à tranchant longitudinal spécial ; 4, 5 : chopper à structure volumétrique spéciale).

As for flake tools, 68 pieces show traces of utilization or retouching, among which 39 pieces are from the lower unit and 29 from the upper unit. Structurally, these flake tools could be divided into two categories: tools in the first one were made of big and thick flakes, and most importantly had a simple-bevel structure like end choppers; tools in the second category have no simple-bevel structure, and they can be easily differentiated into several techno-types according to the existence or absence of a back on the flake and to each tool's general morphology. In total, 12 techno-types of flake tools have been identified according to their morphostructural characteristics (Fig. 21). A variety of cutting-edges were realized on different blanks, including denticulate, point, rectilinear, convergent, beak, convex, concave, rostrum, etc. (Fig. 22). Retouching was conducted on some of the flakes to get the desired tools, and sometimes more than two cutting edges were made on one blank. The angle of the cutting edge ranges from 20 to 80°, while the majority are about 50–60°. The idea behind the selection of flakes as tool blanks was mainly to choose those flakes with a relatively thick back, which became the further prehensive part of the tool. The backed flakes generally possessing cortices dominated the tool types in both the lower and upper units, and they were usually directly obtained during production with a certain degree of predetermination. Both *débitage* and *façonnage* could result in this kind of flake (including the so-called *Bailiandong flake*; see the techno-type 2a of flakes), which indicates that the knappers may have applied a free and flexible strategy for selecting flakes as tool blanks to meet their needs.

4.4. Others

Many broken blocks and debris of silex were found in the lower unit, which could indicate that knapping activities happened at the cave. There are also several pieces from which we could not extract technological information because their negatives were heavily wrapped in carbonates. Beside the chipped stone artifacts, there are also a few polished stones tools, donuts, a grinding stone (with ochre

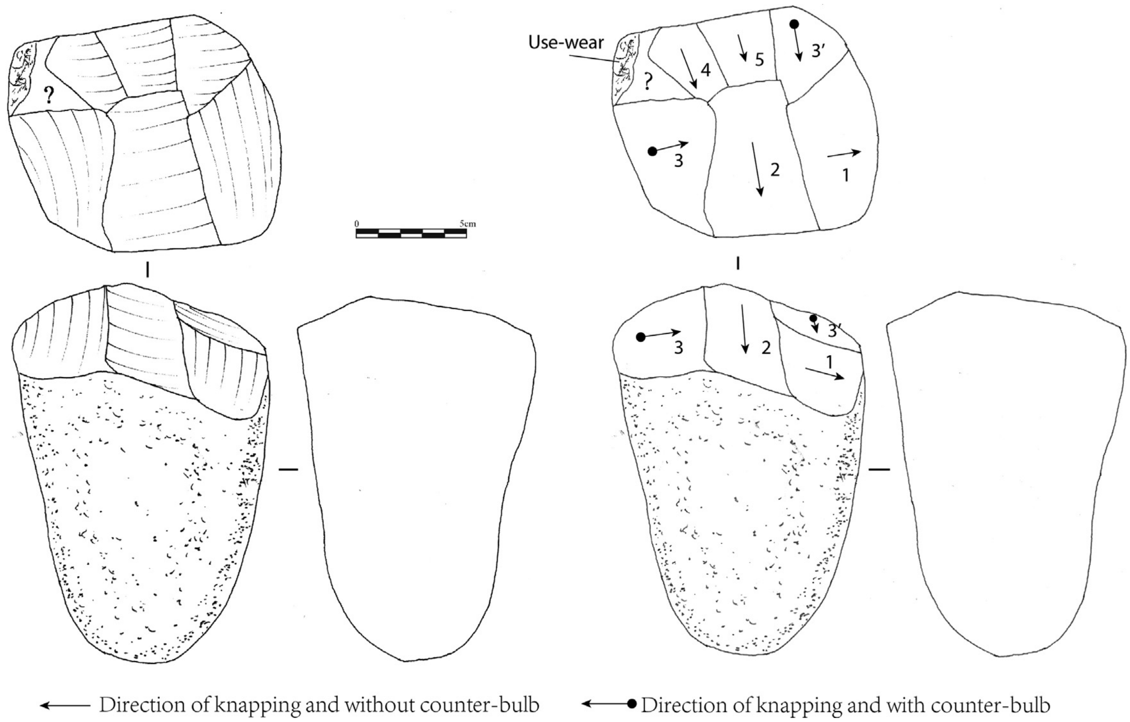

Fig. 18. Chopper with a plane front from the Bailiandong Cave.
Fig. 18. Chopper à front plat de la grotte de Bailiandong.

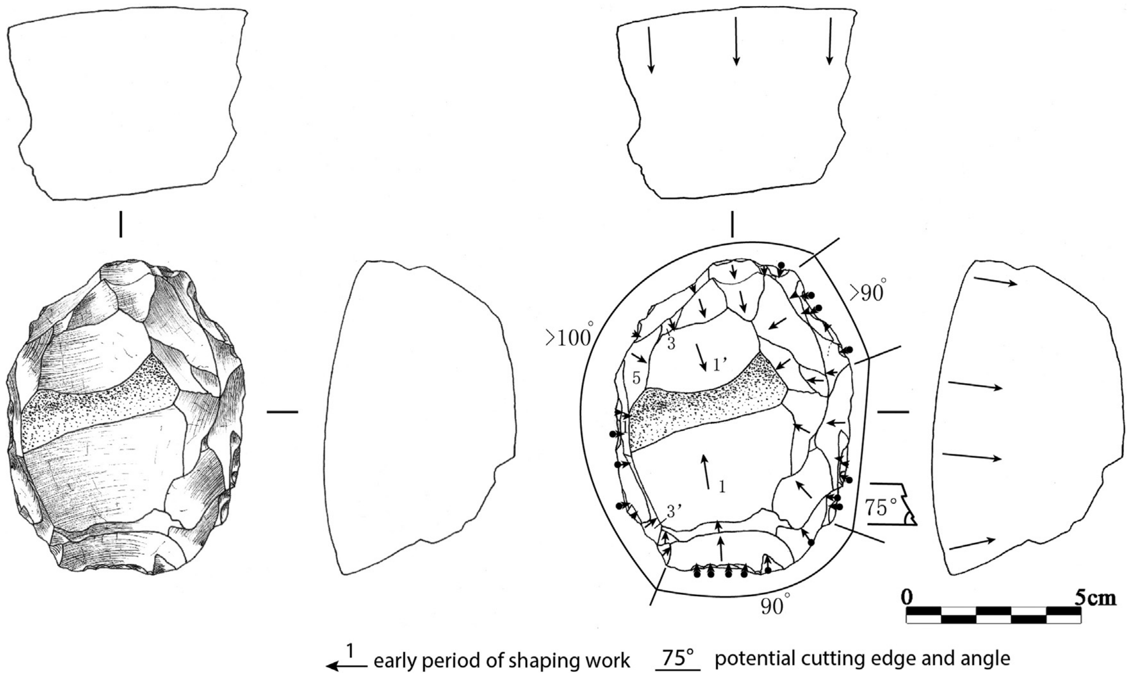

Fig. 19. Shaped disc from the Bailiandong Cave.
Fig. 19. Disque façonné de la grotte de Bailiandong.

remains on it), perforated stones, antler points, and antler spade tools (Fig. 23). The partially polished cobble tool (on cutting edge, BLWS④ :57) first appeared in the lower unit at around 20 ka, and fully polished cutters were found in the upper unit. This possibly indicates that the Bailiandong Cave witnessed the development of the polished stone tool industry during a time period when knapped stone tools were still being produced and dominated the whole lithic

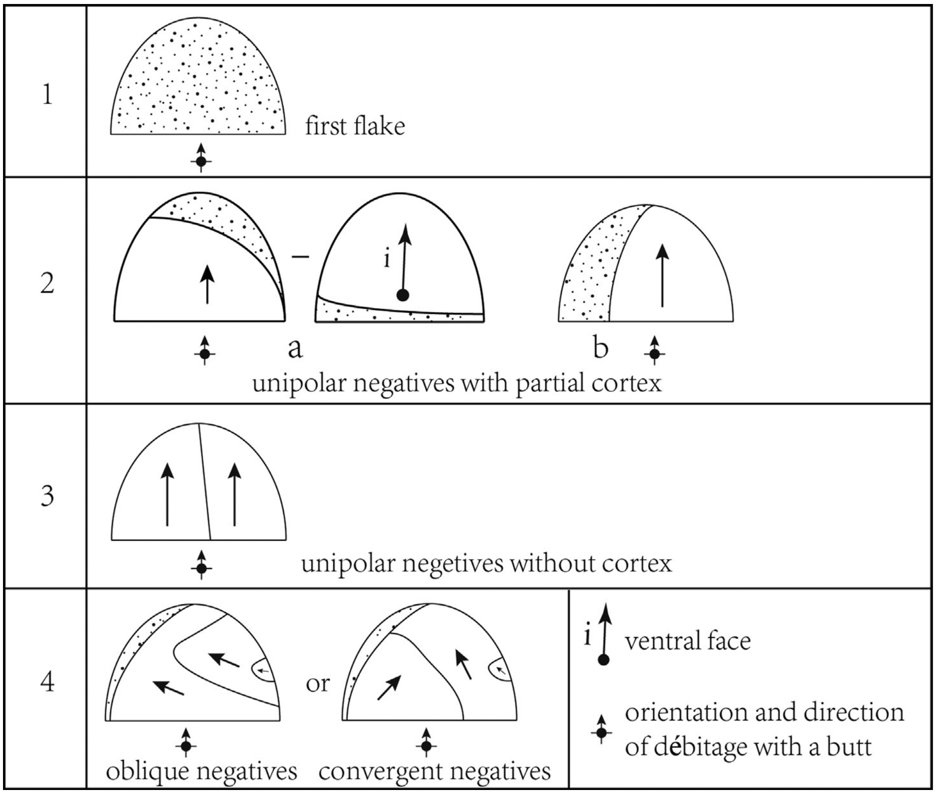

Fig. 20. Techno-types of the flakes at the Bailiandong Cave site. (Note: negative(s) on the dorsal face was (were) removed earlier than the flake itself.).
Fig. 20. Techno-types d'éclats de la grotte de Bailiandong. (À noter : le(s) négatif(s) sur la face dorsale de l'éclat étai(en)t débité(s) plus tôt que l'éclat lui-même.).

assemblage. Bone and antler tools with sharp ends might have been an important component of the whole tool kit of the inhabitants of the Bailiandong Cave. Donut tools and perforated stones should reveal other types of activities in which the inhabitants were involved, and the grinding stone with ochre stigma might bear some social and religious significance, which would mean that human behavior tended to be more complex in the later period of occupation.

4.5. Synthesis of lithic industry of the Bailiandong Cave

After our technological analysis on cores, shaped tools, and flakes, the characteristics of the lithic industry of the Bailiangdong Cave could be summarized as follows.

First of all, although there are four types of volumetric structure of the cores, the idea behind the organization of reduction was very similar for each type. The strategy of exploitation of the cores was to fully take advantage of the natural useful volume for flaking without preparation, and the stage of initialization sought to select raw material of river cobbles or blocks (mainly silex nodules from outcrops) that had suitable striking platforms and surfaces for *débitage*. Once the useful part was exploited, the rest of the core would be abandoned or transformed into tools. Several methods of flaking were applied, such as the unidirectional, bidirectional, and algorithmic methods. Some prehistoric knappers frequently changed striking platform to get favorable volume on the core and thus several (usually 2–3) series of reduction could be identified, and each series was relatively independent. The flakes resulting from *débitage* are not standardized in morphology and often contain a cortex on their dorsal face and butt, which could serve as the back of a further tool. As we can see in the flake tools, backed flake tools played an important role in the composition of stone tools, which seems to indicate that the existence or absence of a back on a flake could be one important technical characteristic that the knappers searched for.

Secondly, the approach to *façonnage* (shaping) appears to have been very stable considering that "simple-bevel" choppers dominated the shaped cobble tools in both the upper and lower units of the site. However, the appearance of several special shaped tool types, such as a chopper of special volumetric structure and a chopper with a plane front and shaped disc, could represent new technological needs in the later period of prehistoric humans' occupation of the site. Generally, all the different types of shaped tools underwent a very short and concise knapping process, which aimed at creating the transformative part of each tool rather than at structuralizing the total body of its cobble, and the prehensive part of the shaped tool was usually left unmodified. Put another way, the final volumetric structure of tools was partially integrated into the original morphology and structure of the raw material.

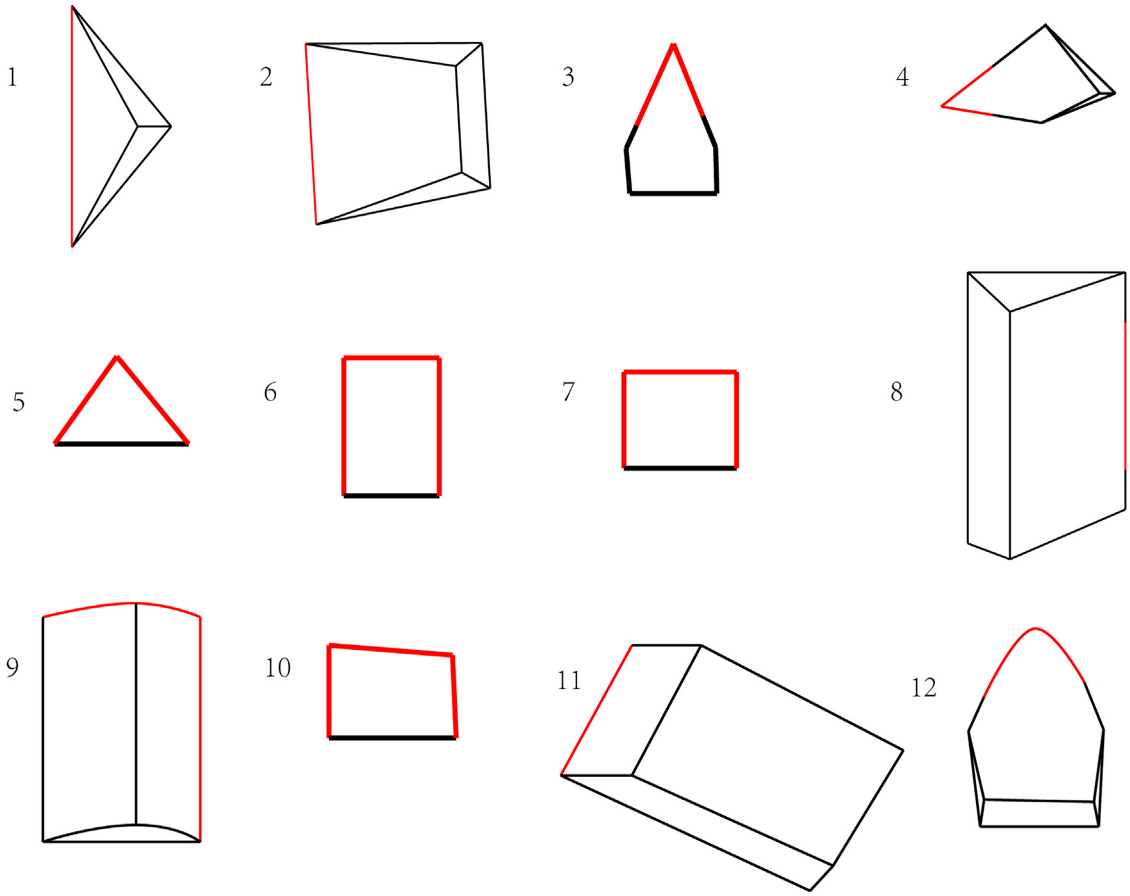

Fig. 21. Morphostructural types of flake tools at the Bailiandong Cave (the red line indicates the location of the cutting edge).
Fig. 21. Types morphostructuraux des outils sur éclats de la grotte de Bailiandong (la ligne rouge indique la localisation du tranchant).

Thirdly, the management of raw material seems to have existed to some extent because prehistoric knappers managed to make different types of shaped tools according to differences in cobble morphology and structure. This can be seen clearly in different types of choppers and in the exploitation of silex, which was not used in *façonnage* but exclusively in *débitage* in the lower unit. So, the organization of the *chaîne opératoire* on the basis of raw material did exist on the site, even if it was not strictly followed by the prehistoric knappers.

Fourthly, the concepts for producing uniface or biface *sensu stricto* do not exist on this site. Unifacial shaping was applied only to get simple-bevel tools. Retouching was not a compulsory stage in the realization of a cutting-edge because sometimes the shaping of a simple-bevel brings at the same time a suitable dihedral cross-section utilizable as a cutting-edge. However, the angle of the cutting-edge of the shaped cobble tools is often larger than 60°.

Fifthly, although they are only in very small quantity, the tools made of bone and antler might be an important component of the whole tool kit considering that the flake tools with sharp ends and the heavy shaped cobble tools with points are quite rare. Other lithic tools, such as donut stones, are only found in the upper unit, which means that new technical activities might have appeared from then on. The early presence of a partially polished tool in the lower unit and the intensification of polishing on the whole body of a tool in the upper unit should be evidence of the gradual establishment of a new type of lithic technological system that coexisted with chipped stone tools for more than 10,000 years on the site.

Finally, there are both similarities and differences of lithic technology in the lower and upper units. On the one hand, *débitage* and *façonnage* coexisted in the two units, perhaps as complementary technical solutions for a variety of subsistence activities; on the other hand, some differences did exist between the two units; *débitage* seems to have been more important in the lower unit, although *façonnage* was also present; while in the upper unit cobble tools resulting from *façonnage* have a higher proportion, flakes tools and cores are numerous there as well; there are more techno-types of shaped cobble tool in the upper unit than in the lower unit. Overall, technologically the tradition of lithic industry in the lower unit continued to exist in the upper unit to some extent, while the whole technological system in the upper unit seems much more complex, developed, and diverse due to the presence of differently shaped tools, bone and antler tools, donuts, and fully polished tools.

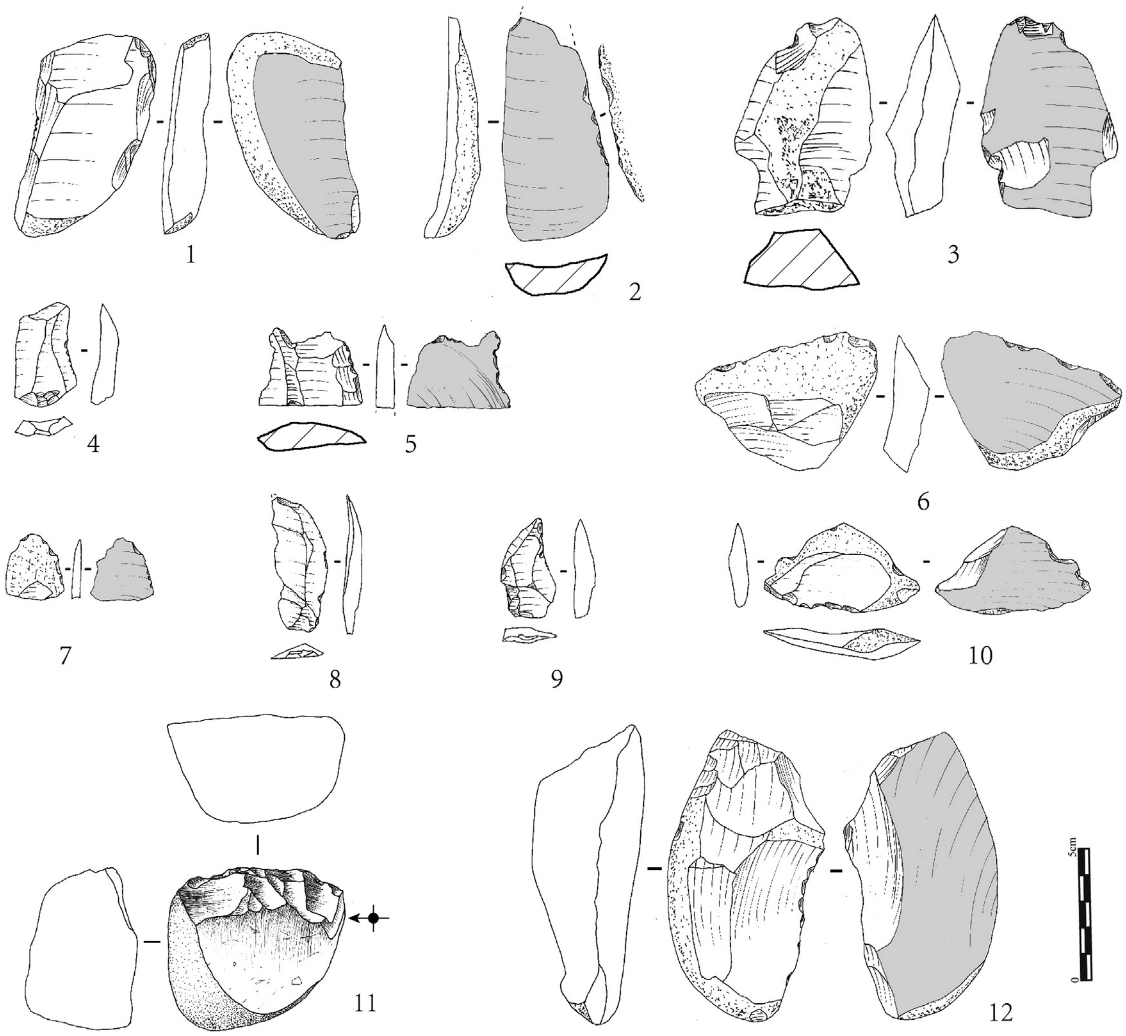

Fig. 22. Flake tools at the Bailiandong Cave. (Note: the color grey indicates the ventral face of the flake).

Fig. 22. Outils sur éclats de la grotte de Bailiandong (à noter : la couleur grise indique la face inférieure de l'éclat).

5. Discussion and conclusion

Although the relatively small number of artifacts and the macro-stratigraphic division of two units of the site make a quantitative analysis less meaningful, technological analysis from a qualitative point of view has yielded new insights about the lithic technology of the Bailiandong Cave from the late late Pleistocene to the early Holocene. Unlike previous research that defined the lithic industry of the Bailiandong Cave as small flake-tool industry in the lower unit and large *cobble-tool industry* in the upper unit and drew the conclusion that a significant change in lithic production had taken place from the lower to the upper units (Jiang, 2009; Wang, 2005, 2016; Zhou and He, 2016), our technological analysis has revealed that the nature and characteristics of lithic industries could have been much more complex than previously perceived, and we prefer not to take the flake-tool industry as an isolated technological phenomenon, but as one coexisting with shaped cobble tools during this period at the Bailiandong Cave site. The coexistence of two concepts (i.e. *débitage* and *façonnage*) and associated products is possibly a regional fact in southern China as some authors have recently claimed (Xie et al., 2018b). It is true that river cobble was an important source of raw material for prehistoric knappers in southern China, but diverse *chaînes opératoires* could be applied on them including *débitage* and *façonnage*, and more specific operative sequences, as shown by four types of cores and several different structures of shaped cobble tools, have also been employed in tool production. So this analysis provides us with a much more complex picture of the technical behavior of prehistoric humans exploiting the cobble materials. In light of this, we may need to further question what the real meaning of "cobble-tool industry" might be, if not abandon the terminology entirely, since it does not and cannot provide us with clear information about lithic production, but only gives us a description of the raw material utilized. The terminology also renders comparative study difficult on a regional scale, especially within southern China and the neighboring mainland of Southeast

Fig. 23. Other tools found in the Bailiandong Cave (1,7: donut stone; 2: partially polished tool; 3: fully polished tool; 4: antler point; 5: antler spade; 6: special perforated stone; 7: grinding stone with ochre traces on it).

Fig. 23. Autres outils de la grotte de Bailiandong (1,7 : pierre perforée ; 2 : outil partiellement poli ; 3 : outil entièrement poli ; 4 : pointe en bois de cerf ; 5 : spatule en bois de cerf ; 6 : pierre perforée spéciale ; 7 : galet à broyage avec des traces d'ocre).

Asia, where river cobble was also frequently used during the late late Pleistocene to the early Holocene (Forestier, 2010; Forestier et al., 2017a, b; Li et al., 2019; Pawlik, 2009; White, 2011; Zeitoun et al., 2008). A technological perspective appears to be an efficient and concise way to clarify the ambiguity surrounding the so-called "cobble-tool industry," as indicated by a detailed technological analysis of the Hoabinhian techno-complex in Southeast Asia during the past 20 years (Forestier, 2000, 2010; Forestier et al., 2015, 2017a; Forestier and Zeitoun, 2005; Zeitoun et al., 2008). Therefore, our analysis not only represents one of the first steps toward comparative study in southern China, where technological analysis has just taken an initial step (Li et al., 2019; Zhou et al., in review), but also contributes to the comparison between the lithic industries of southern China and Southeast Asia.

In light of our technological analysis of the lithic industry of Bailiandong Cave, the possibility of the existence of a Hoabinhian techno-complex at the site could be excluded, so the previous suspicion about the Sumatralith-like tools in this assemblage based on some morphological similarities with real Sumatralith in mainland Southeast Asia could be clarified. As previously summarized, the lithic industry of Bailiandong contains products of both *débitage* and *façonnage*; although unifacial shaping was practiced on all types of choppers, there still exists no real uniface (Sumatralith in this context) in the lithic assemblage, and split cobble tools are also very rare (tools made on half-cobble blanks that are obtained by a bipolar method to split the cobble into two half-cobbles, with or without use of an anvil); in contrast, the Hoabinhian industry is characterized by the presence of three main *chaînes opératoires* (operational sequences): the uniface (Sumatralith) usually coexists with numerous split cobble tools and choppers, as we have seen at the typical Hoabinhian site of Lang Spean Cave in Cambodia (Forestier et al., 2015, 2017a; Forestier and Zeitoun, 2005; Zeitoun et al., 2008). However, the potential existence of Hoabinhian in southern China can be verified only by extensive analysis and comparison on the basis of the same technological criteria. To answer this question, the main authors of this paper (Yinghua Li and Yuduan Zhou) have conducted a quick examination of the lithic collections of some important cave sites from southern China, which yielded relatively solid stratigraphy and reliable age (from the late late Pleistocene to the early Holocene), including the Liyuzui rockshelter (He et al., 1983), the Zengpiyan Cave (Collective, 2003), the Yahuaidong Cave (Xie et al., 2018a) in Guangxi, the Huangyandong Cave (Song et al., 1983, 1992), the Huangmenyan Cave 2 (Qingtang site) (Deng et al., 2019; Liu, 2019), the Dushizai (Qiu et al., 1982) and Niulandong Caves (Jing et al., 1998; Zhang et al., 2013) in Guangdong, and the Luobi Cave on the island of Hainan (Hao and Huang, 1998; Li et al., 2019) (Fig. 1). This examination indicated that all the artifacts in these collections lack the critical facies of the Hoabinhian techno-complex and that some of them seem to be more like artifacts of the Bailaindong lithic industry, while the artifacts of other sites look similar to those of the so-called "Son Vi culture" (Nguyen, 1994) in northern Vietnam, which is characterized by the presence of an abrupt side-chopper with obtuse angles coexisting with shell tools. However, for the time being, our quick examination of the concerned lithic assemblages in southern China represents just a macroscopic impression, and whether or not Hoabinhian culture dispersed into southern China (i.e. into the Guangxi and Guangdong regions) and how it evolved during the late Late Pleistocene to the Early Holocene remain open questions, which should certainly be explored in the future considering the extremely small distance (ca. 100 km) between northern Vietnam (yielding about 300 Hoabinhian sites, pers. commun. with Dr. Pham Thanh Son) and the border area of Guangxi. Moreover, only a very small quantity of cave sites have been excavated and analyzed in the latter. We expect that further fieldwork in the border area of Guangxi will clarify this question, since Hoabinhian hunter-gatherers inhabited northern Vietnam for more than 10, 000 years (about 20–8 ka BP) (Chung, 2008; Nguyen, 2008; Yi et al., 2008; Zeitoun et al., 2008), and it seems odd that they did not move a little toward the north as neither geographic nor political barriers existed at that time.

The monotonous persistence of cobble-tool industry in southern China from the early Pleistocene to the early Holocene does not mean that the technical behavior of humans was also changeless and simple. Particularly during the period of site occupation of the Bailiandong Cave, the hunter-gatherers, who were totally anatomically modern humans, may have experienced a great change in technical systems, as indicated by the development of polished stone tools and donuts, which might echo the appearance of totally new rules in lithic production and their social life, and by the emergence and invention of pottery in some caves of southern China (not including several discoveries from the nearby northern Provinces of Jiangxi and Hunan) (Boaretto et al., 2009; Cohen et al., 2017; Hung et al., 2017; Sato and Natsuki, 2017; Wu et al., 2012a, b). The other tools made of new raw materials including freshwater mollusk shell (Collective, 2014; Jing et al., 1998; Liu, 2019; Xie et al., 2018a), bone, antler, and possibly other organic materials, suggest in combination that the technological system was becoming more and more complex. The development toward more complex behavior was not an insular phenomenon at the Bailiandong Cave, but was a fact and a trend in many cave sites in southern China from the terminal Pleistocene to the early Holocene (Chi and Hung, 2012; Dikshit and Hazarika, 2012; Wang, 2016; Zhang and Hung, 2008). Although the concept and knowledge about chipped stone tool production at Bailiandong Cave were relatively stable from the lower unit to the upper one, some major transformation, manifested in other technological parameters in the overall subsistence system, still did happen during this period. So lithic industries, i.e., mineral tools should only be taken as one part of the whole technological system used by these hunter-gatherers if we seek to judge their technological ability. Also, it may be more appropriate to interpret human behaviors and cultures in a comprehensive perspective rather than in an isolated way.

Recently, subtropical South China has attracted more and more international concern because many new sites have been excavated and analyzed, providing reliable or controversial data on several important topics, such as the Acheulean-like industry in the Bose basin of Guangxi (Hou et al., 2000), the so-called Levallois technology in Guizhou (Hu et al., 2019; Otte et al., 2017), the Hoabinhian techno-complex in Yunnan (Ji et al., 2016), the early presence of modern humans in several cave sites (Bae et al., 2014; Cai et al., 2017; Liu et al., 2010, 2015; Shen et al., 2002; Zhao et al., 2016), etc. However, as many authors have claimed, the paleo-history in this area could be very different from that of the western side of the old continent based on archaeological and human fossil records, so the uniqueness of the technological development and human evolution in the eastern world could be better understood from a local perspective rather than by citing old-fashioned paradigms and prejudging (Boëda et al., 2013; Boëda and Hou, 2011; Gao, 2013; Li, 2011; Liu et al., 2016; Wei et al., 2017). As one part of that endeavor, technological analysis on the lithic industry in southern China would be one of the most productive approaches that could produce new insights about the history and prehistory of humans, since abundant data have been, are being, and will continue to be discovered in this area.

To conclude, as one of its initial practices in applying a technological method to the lithic industry in southern China, this research revealed the *chaînes opératoires* of the lithic collection of an important site in southern China dating to the late Pleistocene to the Early Holocene. This provided us with general structural information about lithic production and tools made from cobbles and other raw materials. This is an important step toward further systematic comparative study on a larger inter-regional scale to clarify these tools' relationship with the nearby Hoabinhian techno-complex. Considering that many sites in this area are still lacking accurate stratigraphic and dating data, more fieldwork and laboratory research needs to be conducted in the near future to construct more reliable time frame and to redefine the complexity of "cobble-tool industry" in both a synchronic and a diachronic way. Other work, such as ancient DNA analysis, needs also to be carried out to help us better understand the difference/affinity between prehistoric humans of southern China and Southeast Asia if human fossils of good quality are available on the sites.

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