Chapter

A Macroscopic Perspective on Lithic Technology and Human Behavior during Pleistocene in Zhejiang Province, Southeastern China

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Abstract

Paleolithic archeological remains were not reported from Zhejiang until 2002. Up to now, over 70 Paleolithic sites and/or localities have been recovered through a series of surveys mainly in the north part of Zhejiang. An overview of the Paleolithic record and archeological sequence in this region during the Early to Late Pleistocene are present from a macroscopic perspective in this article, as well as the brief introduction of lithic technology and human adaptation in south China. In general, the lithic assemblages in Zhejiang represent the features of Pebble Industry in south China and show a trend of reduction on the size of stone artifacts since the Late Paleolithic. It is presumed that prehistoric humankind has shown the behavioral strategies as followed: a) exploited local raw material; b) the utilization of core and the degree of proficiency in knapping have been improved gradually; c) the retouching focused on the areas of edges; and d) preferred to use sharp edges of tools.

Keywords: Zhejiang, Pleistocene, lithic technology, human adaptation, pebble industry

1. Introduction

Zhejiang Province (118°01′ ~ 123°08′E, 27°01′ ~ 31°10’N) is a southeastern coastal region of China. Its name derives from the Zhi River, the former name of the Qiantang River which flows past Hangzhou and into the East China Sea (**Figure 1**). The landscape in Zhejiang consists mostly of hills, which reach altitudes of 700 to 1500 meters. Most rivers carve out valleys in the highlands, with plenty of rapids and other features associated with such topography. Its modern weather is dominated by humid subtropical climate, and average annual temperature is around 15–19°C (59–66°F). Pleistocene sediments are distributed widely on the second terraces of rivers with lots of valleys, plains and karst caves, which provided a good natural environment for hominid to live and multiply. However, most regional prehistoric

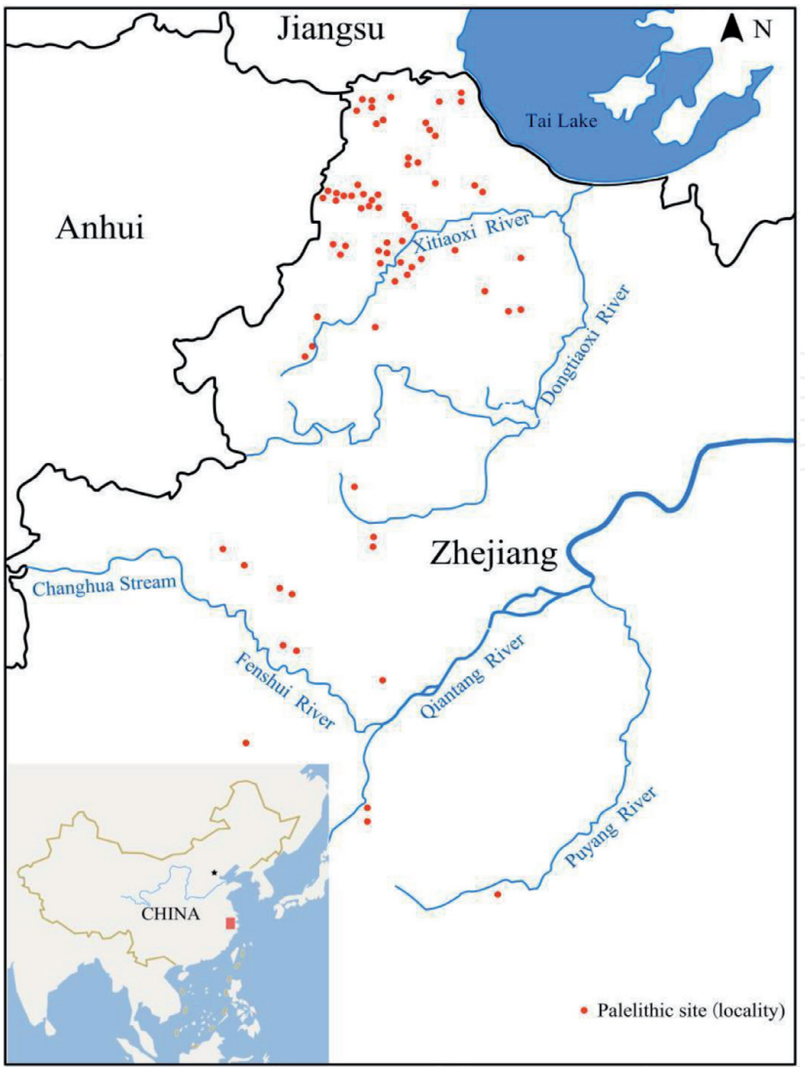

Figure 1.
The distribution of Paleolithic sites and localities in Zhejiang as mentioned.

studies have been about the Neolithic cultures, such as Hemudu and Liangzhu [1–3], one of the origins of rice agriculture in East Asia [4].

Research on the Paleolithic in Zhejiang can be traced back to the 1970s, when a fossil tooth of *Homo sapiens* named as Jiande Man was discovered [5]. However, the new archeological findings in this region were not reported until 2002. Up to now, over 70 Paleolithic sites and/or localities have been recovered through a series of surveys mainly in the north part of Zhejiang (**Figure 1**), mostly open-air sites but also some caves [6]. These archeological records provide new evidence and insights to the prehistory in Zhejiang. During this period, in several important sites test or formal excavations have been undertaken.

The Paleolithic archaeology of Zhejiang is characterized by its geological sediments and it is thus rather difficult to obtain dates. Open-air sites commonly are recovered in strata of reticulate red clay, sparse reticulate red clay and Xia-Shu loess. These stratigraphic layers usually can be used as the standard for dating by scholars. On the other hand, most cave sites were considered being occupied during the Lower Paleolithic period, while some caves might date back to the Upper Paleolithic according to the retrieved fossil fauna and lithic artifacts.

In this article, an overview of the Paleolithic records and archeological sequence in Zhejiang is presented from a macroscopic perspective, as well as the lithic technology and human behavior during Pleistocene as much as possible.

2. Early to middle Paleolithic archeological remains

2.1 Localities in Changxing County

Changxing County is located in the northwest part of Zhejiang, in the transitional zone between hilly areas and the Taihu plain. Regional surveys conducted between 2002 and 2006, in total 32 Paleolithic localities were found from tributaries of Xitiaoxi River [7]. Among them, the Qiliting site and Yindinggang site were selected for excavating (described in followed). Besides, 148 stone artifacts were collected from similar stratums at other localities, which are mainly made of sandstones (P = 56.08%), quartz sandstones (P = 27.03%), quartzites (P = 8.11%) as well as a small amount of silicolites and flints. This stone assemblage is dominated by the pebble industry of Southern China [8].

2.1.1 Qiliting site

Qiliting Site (No. CP029, N30°54′58.7″, E119°41′05.1″) is located 1.5 km south to a branch of Xitiaoxi River in Changxing County (see **Figure 1**), was discovered in 2004. An area over 600 ㎡ was excavated during 2005–2006. Its geological age is estimated to between the late Early Pleistocene to the late Middle Pleistocene, with an absolute age of c. 1.0–0.12 Ma BP dating by paleomagnetic method [9]. More than 700 stone artifacts were uncovered, with a majority of big-sized core tools and a few small-sized flake tools (**Figure 2**). The raw material of the assemblage is dominated by quartz sandstone, with a small amount of sandstone, flint and quartzite (**Figures 3** and **4**).

Three cultural layers with a sterile interval were identified from the top to the bottom of the stratigraphic sequence. 180 stone artifacts from upper layer include cores, flakes, chunks and a small number of stone tools, represented by scrapers, chopping-tools and spheroids [10]. Spheroids in this layer can be divided into preliminary processed type and intensive processed type. Preliminary processed spheroids are similar to the double-platform or multi-platform cores; however, their negatives and scars are mostly much smaller. Their length is nearly equal to the width, as is the width and thickness. Intensive processed spheroids have small natural platforms. These two types of spheroids might reflect the technological process of spheroid-making.

434 stone artifacts were recovered from the middle cultural layer, including cores, flakes, chunks, chopping-tools, scrapers, handpicks, points, stone anvils and so on. In this layer, the handpick is an important tool type. Its volume is large and takes up a high proportion of stone tools. Handpicks exhibit three stages of production. The first one is retouching along both sides of pebble or chunk, and converging into a pointed edge; the second one is taking advantage of the natural ridge of pebble and simply processing it into pointed edge; the third one is making use of the sharp edge after core knapping and modifying it into pointed edge. The pointed edge of a handpick has a higher technology requirement than chopping-tools. Processed directly from a pebble will require a greater workload, and its shape will not be regular. Thus, taking advantage of the sharp edge of core will be a better choice. Only one core was unearthed from the lower cultural layer, suggesting evidence of human activity, at least at the beginning of the Middle Pleistocene.

The technology of stone artifacts uncovered from Qiliting Site is overall consistent. Technological development can be seen on the stone artifacts from Middle and Upper layers, and provides clues of the transition from pebble-tool-industry to flake-tool-industry. The main method for of the manufacture of most stone

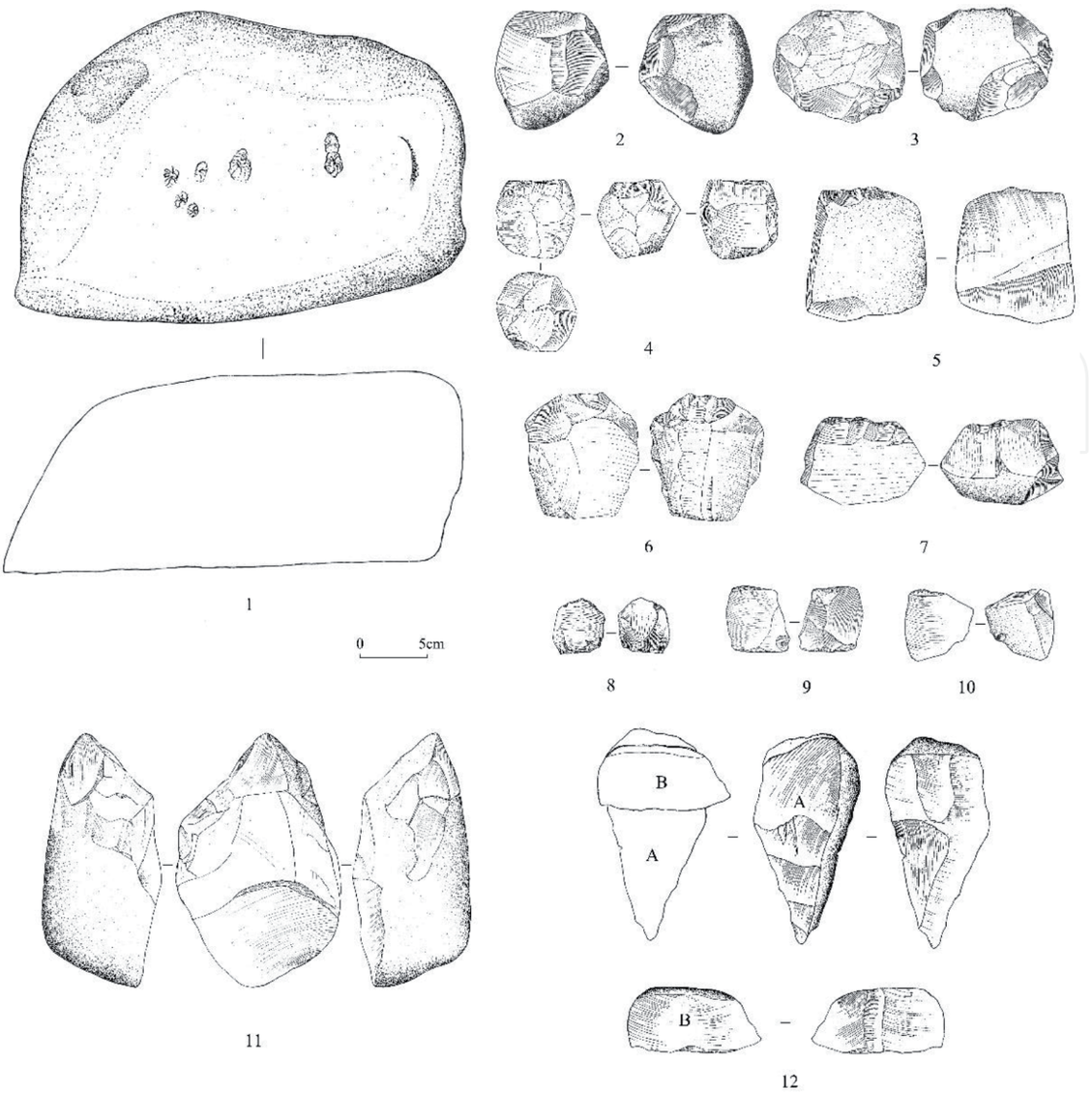

Figure 2.
Stone artifacts unearthed from Qiliting: 1. Stone anvil; 2–3. Core; 4. Spheroid; 5–6. chopping-tools; 7–8. scrapers; 9–10. flakes; 11. pick; 12. refitted flake and flake [10].

artifacts was direct hammer percussion; however, refitting shows a development of knapping skills in the different periods. In the middle cultural layer, four refitting groups belonging to the refitting relation of core to flake were recognized, and they are all in situ. The technique of these stone tools appears as unskillful and unidirectional flaking is in the majority.

The utilization rate of the cores is also low and the striking points are far from the reduction edge of the core. In one refitting group, only a single flake has been removed from its core by the flintknapper. In the eleventh layer, a workshop for lithic processing was possibly identified within the context a temporary camp site. The preparation of the core is crude with many pebble surfaces retained. On the other hand, five refitting groups unearthed from the upper cultural layer of Qiliting site all belong to the refitting relation of core to flake, and they are all single platform cores. Multidirectional flaking from the reverse side has been found on three flakes, which shows the existence of different knapping methods such as one-way, bipolar direction, overturn and multi-direction, which illustrates that the utilization rate of cores in refitting groups are relatively high. By observing the striking point of flakes, it is suggested that their prehistoric manufacturers were able to steadily control the position of the striking point.

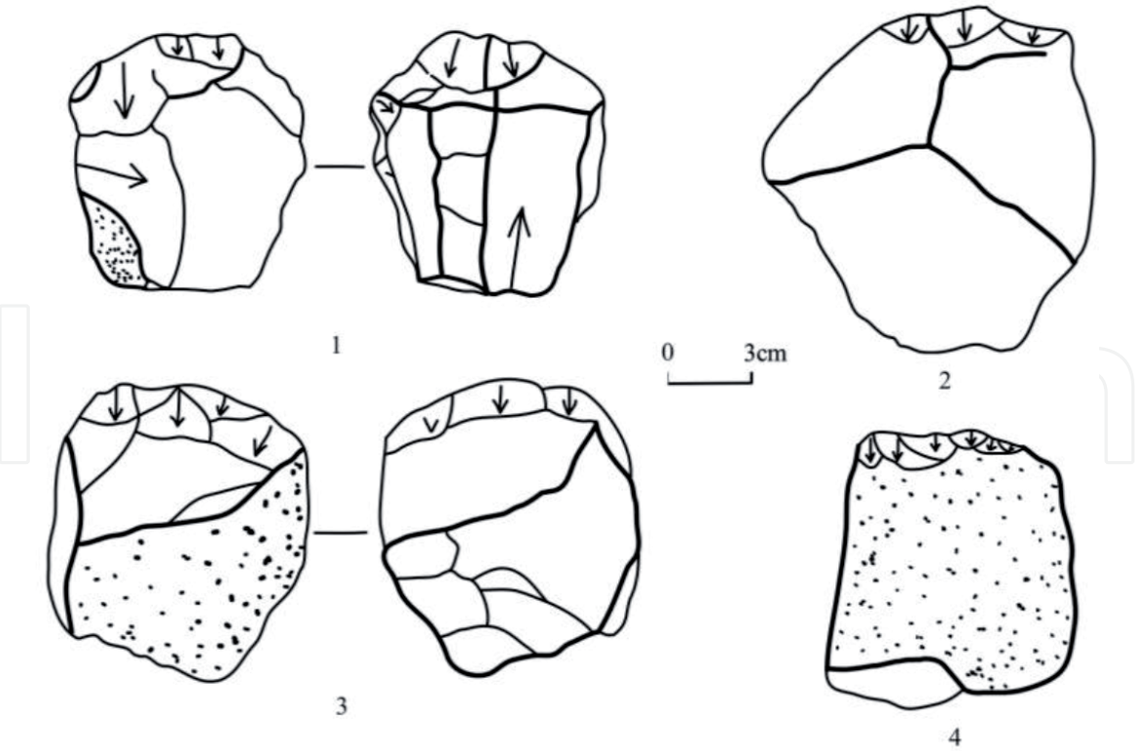

Figure 3.
The chopping-tools from Qiliting [10].

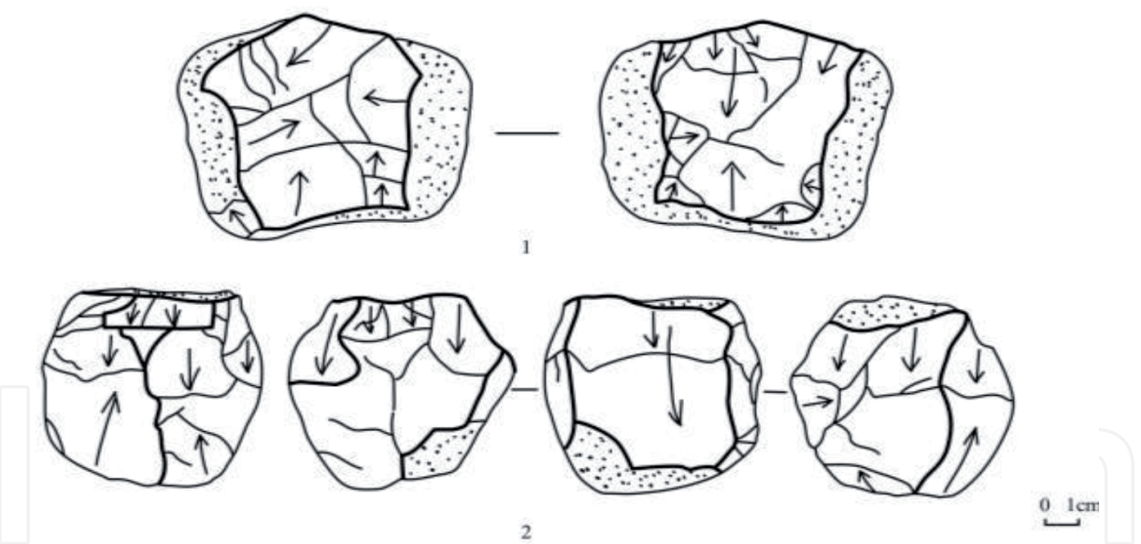

Figure 4.
The spheroids from Qiliting: 1. Preliminary processed type; 2. Intensive processed type [10].

Large tools are the representative types of the lithic assemblage in Qiliting Site, especially chopping tools. These tools are basically made from pebbles. Bifacial retouch is common, with relatively few retouch negatives. Basically, they used the sharp edge of pebbles or cores accompanied with simple processing to produce a useful tool for felling and chopping. Small-sized tools, dominated by scrapers, are made by flakes but also cores, although almost all scarpers from the upper layer are made by flakes. The manufacturing of scrapers is similar to chopping tools, by taking advantage of the sharp edge or the termination of blanks and with simple retouching to make it suitable for scraping. The difference is that most blanks of scrapers are flakes, only a few are made from flat chunks, and the production process is more complicated than for manufacturing chopping-tools. In the Paleolithic sites

of southern China, due to the need of digging and chopping, chopping-tools and handpicks appear in large quantities; small-sized tools such as scrapers take only second place in the activity of production, and as a result, their manufacture is not so delicate.

It is suggested that the upper cultural layer of Qiliting might be a lithic manufacturing place *in situ*, since numerous cores and flakes were unearthed from an area about 30 square meters, and since five refitting groups were identified [10, 11]. According to use-wear analysis, 9 specimens from the upper layer retain positive traces of use (**Figure 5**), while 13 specimens from the middle layer were identified as used tools. Because of the lack of further functional analysis, the exact modes of utilization of these stone tools remains currently unclear, but to some extent, the result of use-wear shows that the knapping followed a purpose related to the function, for example, most of scrapers were retouched intentionally before use [12].

2.1.2 Yindinggang site

Yindinggang Site (No. CP029, 31°04′04.8”N, 119°46′32.8″E), which is not far from the Qiliting site was found in 2005 (**Figure 1**). The excavation with an area of near 560 ㎡ was carried out in 2007, and nearly 300 artifacts and over 200 pebbles were yielded. The deposit can be divided into two cultural layers, in which the lower cultural layer can date back to Late Pleistocene according to the geological sequence [12]. The main raw material consists not only of sandstone and quartzite but also includes flint, which is different from most localities in southern China. The lithic technology is dominated by hammer knapping in association with

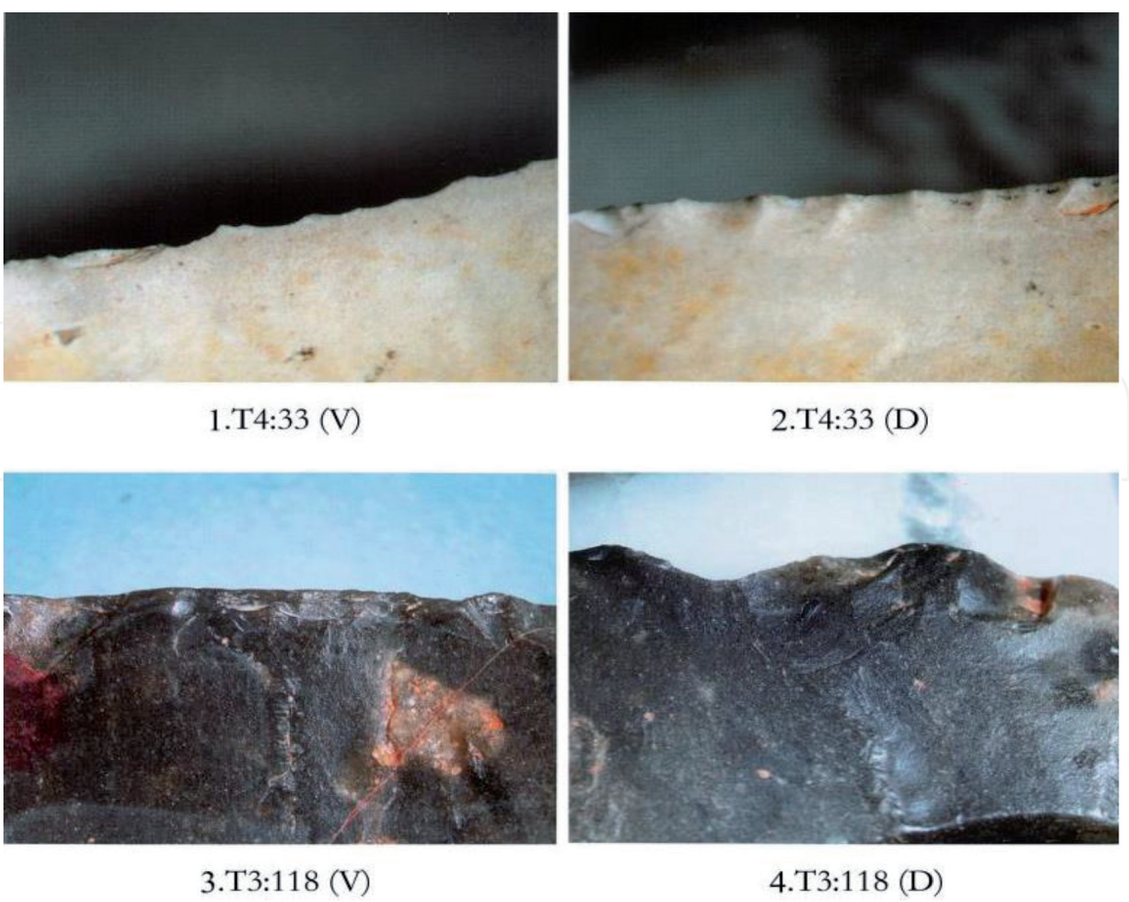

Figure 5.
Use-wear on specimens from Qiliting [12].

bipolar technique (with a ratio of 4:1). It is worth noting that bipolar technique was applied only on flint.

278 stone artifacts were excavated, including cores, flakes, debris, scrapers, chopping-tools and other forms. However, only 6 artifacts belong to the lower layer, the cores, flakes, chunks and points were made of the similar raw material as in the upper layer [13].

The upper cultural layer has discovered 13 refitting groups [12], eight of them have a refitting relation of core to flake, others are core to chunk, core to flake to half flake, core to flake to chunk, core to scraper, and chunks. The first 11 refitting relation (Type I) product were produced during the process of knapping tools from blanks. The twelfth refitting relation (Type II) is the product produced during the process of retouching tools from blanks. The last refitting relation (Type III) is composed of the stone artifacts that have broken off because of the fracture of joint place, the striking force or uneven stress during the process of knapping. Type I and Type II are refitting relations between stone artifacts, these are the result consciously made by prehistoric human, and these relations have reflected the technology of stone artifact processing and their purpose of behavior. Type III is the split joint relation between stone artifacts, an accidental result, which shows that the intended purpose of behavior did not match the result. In general, there are many ways of flake production, such as opposite direction, overturn, stagger, multi-direction, etc. Cores commonly have 2 to 3 scars, at most 9 scars, which means that the utilization of cores was relatively high. The shape of the flake is thick, its platform is wide, the position of striking points is scattered and far from the edge of the blank. It can be suggested that the technique of knapping is unskillful.

In the lower cultural layer of the Yindingang Site, one core to flake refitting group was discovered [10], which indicates that this might have been a place where prehistoric humans briefly stopped and produced some flakes. According to the characteristics of the stone artifacts and their raw materials, two different industries can be identified. One is dominated by artifacts made from raw materials like quartzitic sandstones and sandstones; the other is dominated by artifacts made by flint; these artifacts were much smaller. In general, the average size of the stone artifacts uncovered from this site is smaller than from the pebble industries.

2.2 Localities in Anji County

Anji County is located in the northern part of Zhejiang, south to Changxing County (**Figure 1**). During the field work, 186 stone artifacts from 13 Paleolithic localities were recovered. Moreover, the geological date can be estimated to be from Middle Pleistocene to Late Pleistocene. All of the raw materials are locally available, consisting mainly of sandstones and a few other kinds of rocks, such as trachyte, tuff, quartzite, blastopelitics, siliceous limestones, quartz and flint. A type of single-ended scraper is not common in the Pebble Industry in South China [8].

Shangmakan Site (No. AP003, 119°45′36.3″E, 30°45′19.5”N) is located on the second terrace west to the Xitiaoxi River in Anji County. The sediment can be divided into 5 layers from top to bottom: reticulate red clay, mottled clay, maroon-color boulder clay, taupe-color sandy clay and topsoil. Similar to the dating of Chenshan site in adjacent Anhui province, the age of Shangmakan is dated from ca. 0.455 Ma BP to the Late Pleistocene [14]. 107 stone artifacts were uncovered from the test excavation and investigation in 2002, including cores, flakes, scrapers, choppers, handpicks and spheroids. The majority of them are heavy and thick

artifacts made from blocky blanks. The chopping-tools with blunt cutting edge (most over 70°) are a relatively frequent type in this assemblage.

In the excavation between 2004 and 2005, more than 430 stone artifacts were unearthed in three layers with various types: scraper, chopper, spheroid, awl, handpick, graver, point and so on. The lower layer is characterized by lots of pebbles, and the excavator considered it might date back over 0.78 Ma BP [7].

2.3 Localities in Pujiang County

Pujiang County (119°42′ ~ 120°07′E, 29°21′ ~ 29°41'N) is located at the middle part of Zhejiang. A total of 8 stone artifacts were collected without stratigraphic context from the No. PJ001 site of Daxu Village. The reticulate sediment marks on the surface of some stone artifacts are comparable to those uncovered in Anji and Changxing Counties, thus their age can be estimated to Early to Middle Paleolithic. The raw materials contain quartzites, flints, sandstones and siliceous mudstones. The types of artifacts include core, flake and tool. Flakes are produced by direct hammer percussion, and are commonly thick and heavy. The tool types consist of just chopping-tools and scrapers, which are made of blanks of either pebbles or large flakes. The cutting edges of the tools are often blunt with an edge angle of over 90° [14].

2.4 Localities in Lin'an City

Lin'an City (118°51′ ~ 119°52′E, 29°56′ ~ 30°23' N) is located at the northwest part of Zhejiang, north to Anji County and east to Hangzhou City. Several small rivers cross this region and form developed terraces and diluvia with a thickness of 7 ~ 20 m.

Fragmented fossils of ivory and the limbs of artiodactyl were found at Dadi Cave together with the fossil remains of horse, muntjac, deer, bear, tiger, cattle, monkey and boar were unearthed in Douchuan Cave. However, no archeological remains of hominid occurred.

Five Paleolithic localities have been found on the second terrace of rivers in this area [15]. Among the collection of 22 stone artifacts, only one piece has stratigraphic data. The main raw materials are sandstones and quartz sandstones, in association with a few quartzites. Most stone artifacts are heavy and thick, excepting those quartzite pieces in small size. Hammer percussion is used for flaking and retouching. Most features of this assemblage are similar to the sites in Xitiaoxi River area; however, the amount of thick-flake blanks is much higher.

2.5 Localities in Tonglu County

Tonglu County is located in the northwest part of Zhejiang, at the middle part of Qiantang River. 8 Paleolithic localities were investigated in the area of Fuchun River, including 3 open-air localities and 5 cave sites. Open-air localities are mainly found on the second river terraces, and cave sites in karst area of Fenshui River.

There are 12 stone artifacts gathered from the open-air localities. The reticulate marks on the surface of stone artifacts help us to date them into the Early to Middle Paleolithic. The main raw materials are quartz sandstones and sandstones, as well as several siliceous mudstones. The types of the stone artifacts are simple cores and tools. Direct hammer percussion is the main knapping method. The lithic artifacts are made from massive pebbles or cores as blanks. Only two kinds of tools were found, scrapers and points [16].

3. Upper Paleolithic archeological remains

3.1 Hexidong cave site

Hexidong Cave Site, located in 1 km distance from Yindinggang Site, was excavated from 2007 to 2010. Paleolithic remains were uncovered from five localities of this site [16]. According to the types of faunal remains and the stratigraphic sediment, the age of Hexidong Site can be placed into the Upper Paleolithic, though no C14 dates are reported yet and we do not know the exact date of the site.

Locality 1 is the main locality of Hexidong Site. Its 8-meter thick deposits can be divided into 6 cultural layers. A large amount of Quaternary faunal fossils, bone fragments, stone and bone artifacts were unearthed from the third to fifth layer. The great quantity of fragmentary bones might evidence food processing. In the fourth layer, a possible hearth feature was discovered. Moreover, lots of bone artifacts or bone pieces with cutting marks were discovered from Locality 2 and Locality 3.

A total of over 1000 stone artifacts were retrieved from the Hexidong Site. The raw materials include sandstone, quartz sandstone, quartzite and flint. The types consist of chunks (N = 30), cores (N ≈ 450), flakes (N ≈ 190), scrapers (N ≈ 300), chopping-tools (N ≈ 80), points (N = 30) and stone hammers. The technique applied for flaking and retouching is mainly direct hammer percussion, while several flakes exhibit features of anvilflaking. This is the first appearance of this technique in Zhejiang.

3.2 Cave sites in Tonglu County

As mentioned above, five cave sites were identified in Tonglu County. Some flint stone artifacts were collected from Longdong Cave, Hongshidong Cave and Longdongbeidong Cave. Huidong Cave and Heshangdong Cave discovered few Quaternary faunal remains, including the teeth of sika deer, the shinbone of a deer and the phalanx of roe deer. These artifacts are highly possibly as the Upper Paleolithic remains, though the exact C14 dates are not available yet.

10 stone artifacts were collected from the former three caves, with the types of cores, flakes and tools. They are made of siliceous mudstone mainly, and of a few quartzites and quartz sandstones. Hammer percussion is used to produce flakes and retouch tools. The tools are dominated by scrapers, and in association with a few chopping-tools. Most tools are retouched both sides on the massive blanks. The occurrence of small-sized stone artifacts is different from other localities in Zhejiang region [16].

4. Discussion: lithic technology and human behavior

Lithic technology, as defined by Odell (2001), incorporates the various processes that lead to the production of stone tools, including strategies of modification and reduction sequence, knapping equipment, as well as knowledge of raw materials and operative forces [17]. In this regard, lithic technology is an important method to understand the behavior of prehistoric humankind, their societies and history [18]. For the lithic technology during the Early to Middle Paleolithic sites here, we can assume they are products of early to archaic *Homo* species such as *Homo erectus*, while the lithic materials from Upper Paleolitihic sites (Hexidong Cave and some cave sites in Tonglu), they can be recognized as products by *Homo sapiens*.

However, with the limit of direct C14 dating of each site, it is yet hard to discuss the change and develop of lithic technology during the Pleistocene from the view of human evolution and behavior here. Thus we focus on lithic technology and human behavior in general by applying the concept of *Chaîne Opératoire*. This concept was developed to attempt describing and understanding the processes of culture transformation [19], so that it emphasis on the dynamics [20]. The analysis based on the concept of *Chaîne Opératoire* should consider the lithic artifacts as a life-cycle human being, and all of stages from raw material procurement to tool modification, utilization, maintenance, and finally discarding should be included [21].

4.1 Raw material procurement

The types and distributions of raw material at the Paleolithic localities in Zhejiang are recorded in **Table 1**.

A large number of pebbles were mostly found from open-air localities in Zhejiang, indicating that numerous pebbles were used as raw material for stone artifacts. Meanwhile, some sites also used sandstones and quartz sandstones or flint as raw material to stone tools. In general, raw materials are limited, and most of them can be found in the river or nearby outcrops. Thus, it is suggested that these raw materials come from the local river bed, bench land and stratum. Some excavations did not reach the bottom of the pebble deposits, but by comparing with the lithology and nearby stratum, the stratum with the same lithology as the stone artifacts and unearthed pebbles could be identified, which further proves the feature of local material use.

Considering the weight of stone artifacts, there is indication of artificial selection. For instance, the lithics unearthed from the upper cultural layer of the Qiliting

Locality	Major raw material (%)	Minor raw material (%)	Source
Qiliting Site (Changxing)	Quartz sandstone 92.91–98.1	Sandstone, flint, quartzite 7.09–1.9	Pebble from river
Pujiang	Quartz sandstone, sandstone, flint, siliceous mudstone		
Yindiangang Site (Changxing)	Flint 44.2, quartz sandstone41	Sandstone, quartzite	Pebble from bedrock; Flint from basin
Shangmakan Site (Anji)	Sandstone	Quartz sandstone, dolomite, granite, siliceous rock, quartz, igneous rock, quartzite	Pebble from river
Lin'an	Sandstone, quartz sandstone	Quartzite	Pebble layer
Open-air localities (Tonglu)	Quartz sandstone, sandstone	Siliceous mudstone	Pebble from bedrock (probably)
Caves (Tonglu)	Siliceous mudstone(flint)	Quartzite, quartz sandstone	
Hexidong Site (Changxing)	Quartz sandstone, sandstone, flint		Pebble from bedrock; Flint from basin (probably)

Table 1.
The types and distributions of raw material at the Paleolithic localities in Zhejiang.

Sitehave are basically similar in size and weight. Such tendency suggests that the craftsmen might have a strong selectivity of blanks for the lithic production. While the artifact weights in the middle cultural layer are scattered and show a strong randomness [10]. It is worth noting that stone artifacts unearthed from the localities such as Yindinggang, Hexidong and the cave sites in Tonglu County produce flints of good quality as their raw material, which might indicate that prehistoric human including both archaic Homo species and *Homo sapiens* might consciously choose better raw material.

4.2 Primary flake knapping

Cores and flakes are the production of flake knapping. Take the single platform Type I core [9] as example, after the first flake knapping, some cores were discarded as they lost the potential for further knapping. Flakes made by these simple cores have a natural platform and natural dorsal face, and generally they do not have much value in use. Some flakes that have a sharp edge can be directly used as tool. Thus, on some specimens, use-wear traces have been found. Some sites such as Qiliting Site have a high proportion of single platform Type I core, which is on one hand due to the choice of raw material, and on the other hand it is because the knapping technology of local craftsman was immature. In the upper cultural layer, the ratio of faceted platform has increased, numbers of wide and thick type flake have dropped, the ratio of long type flake as well as the overturn knapping has increased, which demonstrates the improvement in knapping technology and utilization rate of core.

Single platform Type II core [10], double platform core and multi-platform core can reflect certain procedures of flake knapping. When knapping single platform Type II core, craftsmen choose the flat plane as platform, and flaked along the edge in clockwise or counter-clockwise direction, then choose the platform that has a ridge on the lower part and continue knapping. They tried to take advantage of the longitudinal ridge to convey the hitting force, and thus some relatively long flakes are produced, and the level of core utilization is thus increased. Double platform cores have an increased area of platform as well as more suitable striking points, which raised the output of flakes, and thereby increased the knapping efficiency of the core.

The knapping of multi-platform cores basically follows the overturn knapping method, which means turning the blank 90° and then knap again. This knapping method is suitable to the condition that when the first knapping sequence becomes unsatisfactory the craftsmen do not need to discard the blank, but can still select other suitable striking points. The striking orientation from right to left of the reverse side of flake shows the knapping situation before, and the flake being peeled off successfully also took advantage of the longitudinal ridge form in previous knapping.

Refitting groups of flakes reveal the strategy of continuous knapping. The observed data of Qiliting Site show that the maximum number of scars on the core from the upper cultural layer core is more than nine, and the maximum number of scars on ridges of dorsal face is more than five [12]. Many double platform cores from the upper cultural layer are knapped from opposite directions, with one of the end platforms fully utilized, and the body of the core has some small scars. In terms of the size of scarring, the shape and structure of small flakes are cluttered and unsuitable for usage. If we keep on knapping the core, the shape of the blank will be like a sphere, and at last become a spheroid. Some multi-platform cores may have also transformed into spheroids.

Five refitting groups were identified from the upper cultural layer of Qiliting site that belong to the refitting relation of core to flake, and they are all single platform cores. Negatives in different directions from the reverse side have been found on three flakes, which shows the existence of different knapping methods such as one-way, opposite direction, overturn and multi-direction, which illustrates that the utilization rate of cores in refitting groups is relatively high. By observing the striking point of flakes, it is suggested that *Homo sapiens* were able to steadily control the position of striking point.

Four refitting groups were unearthed from the middle cultural layer of the Qiliting site, which are all in situ, and belong to the refitting relation of core to flake. The technique of these stone tools is unskillful and one-way knapping is in the majority. The utilization rate of the cores is also low and striking points are far from the cores' edges. In one refitting group, a single flake has been removed from its core. In the eleventh layer, a flintknapping workshop or lithic processing place can be preliminary inferred, which could be a temporary camp of prehistoric humans. The preparation of the cores is crude with many pebble surfaces retained.

From the upper cultural layer of Yindiangang Site, 13 refitting groups were discovered [12], and the eight of them are the refitting relation of core to flake, others are core to chunk, core to flake to half flake, core to flake to chunk, core to scraper and chunks. The first 11 refitting relation (Type I) products were produced during the process of knapping tools from blanks. The twelfth refitting relation (Type II) was produced during the process of retouching tools from blanks. The last refitting relation (Type III) is formed by the stone artifacts that have broken off because of the fracture of joint place, the striking force or uneven stress during the process of knapping. Type I and Type II is the refitting relation between stone artifacts, these are the result consciously made by prehistoric human, and these relations have reflected the technology of stone artifact processing and their purpose of behavior. Type III is the split joint relation between stone artifacts, an accidental result, which shows that the purpose of behavior did not match the result. In general, there are many ways of flake knapping, such as opposite direction, overturn, stagger, multi-direction etc. Cores commonly have 2 to 3 scars, at most 9 scars, which means that the utilization of core is relatively high. The shape of the flake is thick, its platform is wide, the position of striking points is scattered and far from the edge of the blank. It can be suggested that the technique of knapping is unskillful.

Lower cultural layer of Yindiangang Site has discovered one core to flake refitting group [10], which indicates that this might be a place prehistoric human produced flake or briefly stopped.

4.3 Retouching

Chopping-tools from Qiliting Site are all made from pebbles. Bifacial retouching is common, and the retouch scars are relatively few. Basically, they used the sharp edge of a pebble or core accompanied with simple processing to match the need of felling and chopping.

Spheroids in the upper cultural layer from Qiliting site can be divided into a preliminary processed type and an intensive processed type. Preliminary processed spheroids are closed to the double-platform or multi-platform cores; however, most scars are much smaller. Their length is nearly equaling to the width, and so as the rate of width and thickness. Intensive processed spheroids have small natural platforms, a big angle between dorsal and ventral without larger negatives. These two types of spheroids might reflect the technological process of spheroid-making.

In the middle cultural layer of Qiliting site, the handpick is an important type. Its volume is large and takes up a high proportion of stone tools. Handpicks show

three stages of manufacture. The first one is retouching along both sides of pebble or chunk, and converging into a pointed edge; the second one is taking advantage of the natural ridge of pebble and simply processed it into pointed edge; the third one is making use of the sharp edge after core knapping and processed it into pointed edge. The pointed edge of a handpick has a higher technology requirement than chopping-tools. Processed directly from pebbles may cost great workload, and such production way is hard to make pointed edge regularly. Thus, taking advantage of the sharp edge of core can be a better choice.

The process of producing scraper is similar to that of chopping-tool, which takes advantage of the sharp edge or far terminal of blanks.. The difference is that most blanks of scrapers are flakes, only a few are trimmed by flat chunks, its procedure is more complicated than chopping-tools. In the Paleolithic sites of southern China, chopping-tools and handpicks appear in large quantities; and small-sized tools such as scrapers take second in the activity of production, as a result, their manufactures are not so delicate.

4.4 Utilization and maintenance

After preliminary examination, the 9 stone artifacts uncovered from the fifth layer and the 17 artifacts from eleventh layer of Qiliting were selected for use-wear analysis, which include flakes, scrapers, points and chopping tools. The analytic results suggest that all of the 9 specimens from the upper layer retain positive use-wear. The 13 specimens from the middle layer were identified as used pieces. The result of use-wear analysis shows that some flakes with sharp edge are used directly as tools without any retouching. It is suggested that most of scrapers were retouched intentionally before using, indicating that the knappers might have possessed some purpose related to the function during the tools manufacture. For points, use-wear was found on the tip and side edge [12].

5. Summary

Up to now, the archeological research of the Paleolithic sites of Zhejiang province focused on the counties along the borders of southern Anhui province, southern Jiangsu province and northern Zhejiang province. The second terrace of rivers and cave sites are the main target of surveys [22–23].

The types of raw materials and their physical limitations could have led the occupants to develop local technical solutions, and they reflect the level of lithic knapping technology. A large number of pebbles were found from open-air localities in Zhejiang, indicating plenty of pebbles were used as raw material of stone artifacts. Stone artifacts of this area were mostly unearthed from the reticulate red clay of the second to fourth terrace of the river. As most sites are in situ, we preliminary deduce that raw materials are from the river pebble or outcrop nearby. Meanwhile, some sites also used sandstones and quartz sand-stones or flint as raw material to stone tools. It is worth noting that stone artifacts unearthed from the localities such as Yindingang, Hexidong and a cave site in Tonglu County produce flint that have a good quality as their raw material, which might indicate that prehistoric human including both archaic Homo species and modern human consciously choose better raw material. But the relation between raw material and lithic technology is complex, thus more study is needed to be done in the future.

From the view of lithic industry in Pleistocene south China, the raw materials of these stone artifacts are limited, hammer percussion is the main knapping technique

and bipolar method appeared in Upper Paleolithic age and they were possibly produced by modern human or *Homo sapiens*.

Stone artifacts from Early and Middle Paleolithic were made of quartz sandstone and sandstone; direct hammer percussion was used during flake knapping and tool retouching; the utilization of the cores is low; most cores have a single natural platform; faceted platforms are rarely observed. The retouch is crude; one-way retouch and alternately retouch are common; and there are also reverse, stagger, both side and overturn retouching. Most stone tools are heavy and thick, with a length more than 100 mm. Tools smaller than 40 mm are rare, and most blanks are massive. Heavy-sized tools appear in larger numbers than small-sized tools. Chopping-tools are the main tool type, and handpicks and spheroids are also commonly seen. Stone tools in this period basically belong to the industry of southern China [24, 25]. The use of flint increased in the Upper Paleolithic; bipolar method gradually appeared; and the proportion of scrapers also increased; flakes became the main blank form. The trend towards tool miniaturization increased and the characteristic of stone tools gradually approached the flake-tool-industry that is commonly seen in northern China.

In conclusion, the Pleistocene lithic industry in Zhejiang province basically belongs to the industry of southern China [11, 16]. Accompanied by the transition from pebble-tool-industry to flake-tool-industry possibly started by early and archaic Homo species, raw material procurement, the knapping methods and lithic assemblages also changed gradually. The basic characteristic of the lithic industry in Zhejiang is similar to the southern Anhui province and southern Jiangsu province. But some regional differences are also seen. For example, in Early and Middle Paleolithic sites, small-sized and heavy-sized stone artifacts are similar in numbers, and the proportion of spheroid is lower than surrounding areas. Short handpick is also a unique tool type of this region. In Upper Paleolithic sites, on the other hand, flint was used as the main raw material, and with hammer percussion, bipolar method was also widely used. Such new lithic production technology could be introduced and practiced by modern human, though the details are yet unclear.

In terms of human adaptation, most raw materials were gathered locally; the utilization of cores and the degree of proficiency during primary flake knapping improved gradually. Retouching is mostly found on the sharp edge or distal end. The sharp edges of blades are frequently used. Flake refitting and use-wear analysis provided useful information about the manufacture and utilization of tools. As current investigation and material are not comprehensive enough, the archeological investigation of the Paleolithic sites and prehistoric human behavior of Zhejiang province in regard with human evolution and migration during the Pleistocene is an ongoing research.

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