A Late Acheulean Culture on the Chinese Loess Plateau: The Techno-economic Behavior of the Dingcun lithic industry

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Abstract

The Chinese Loess Plateau is the largest loess area in the world, and covers ~400,000 km², with a loess-palaeosol sequence that is comparable with Marine Isotope Stages (MIS) as a Quaternary terrestrial timescale of climatostratigraphy and chronology. The Dingcun lithic industry was recovered in 1954 in the Loess Plateau, and has been known for its Large Flake Acheulean tools. Technological analysis based on the concept of chaîne opératoire was applied in this paper to update our knowledge of the techno-economic behaviours at this site and in the Loess Plateau area. The results show that there are two chaînes opératoires: 1) one focused on the production of large flake blanks (façonnage) for making Large Cutting Tools (LCTs); and 2) a small to medium débitage to obtain flakes for light duty tools. Experiments were applied to check the knapping technique. The results confirmed the probability that hard hammers were used to produce large flakes on hornfels blanks, and soft-hammer techniques were not used. When compared with the Acheulian LCTs of other sites in China, Dingcun is different from the Acheulian culture of south China (Danjiangkou Reservoir Region [DRR] and the Bose Basin), and more similar to the Luonan Acheulian industry. Therefore, it seems that a Large Flake Acheulean was developed in the Loess Plateau area in the Late Middle Pleistocene.

Keywords: Dingcun lithic industry, Late Acheulean, Loess Plateau area, Chaîneopératoires, Knapping experiment

1. Introduction

Despite several years of detailed research on Chinese Acheulean assemblages, the long-standing debate about the reality of the Movius Line still continues (Movius, 1944, 1948; Huang, 1987; Hou et al., 2000; Kuman et al., 2014; Li et al., 2014; Yang et al., 2014). Recently, the geological and archaeological materials which served as the basis for the Movius Line were checked, and shown to be unreliable (Dennell, 2014a, b). Therefore, it is widely accepted that the Acheulean culture was an Old World phenomenon that persisted for a long period in early prehistory (Goren and Sharon, 2006; Derevianko, 2008; Doronichev and Golovanova, 2010; Lepre et al., 2011; Brumm and Moore, 2012; Bar-Yosef and Wang, 2012; Kuman et al., 2014). After burying the Movius line, we should highlight the need for greater reliance on technological analysis and raw material evaluation for better comparisons between the Acheulean assemblages from China and other regions.

Within the three areas containing the Acheulean or Acheulean like culture in China, the most northerly one is the Loess Plateau area, where the site complexes of Dingcun (Ting-Ts'un) and the Luonan basin (Shaanxi Province) are the representative ones (Fig. 1a). Since discovered in 1954, the Dingcun site has been known for its heavy-duty tools, especially the trihedral picks, which are regarded as representative of a Lower Paleolithic tradition in North China (Jia et al., 1972). Most studies of the Dingcun industry involve typological assignation of the large tools as Acheulean and regional comparisons with other Acheulean sites (Jia, 1955, 1956; in Pei, 1965; Freeman, 1977; Aigner, 1978; Huang, 1987; Liu, 1988; Lin, 1992; Wang, 2006; Yang et al., 2014), while analysis of the chaîneopératoire and the knapping technique were seldom discussed.

In this paper, we have restudied the Dingcun lithic industry, including its raw material sourcing and chaîneopératoire, and conducted knapping experiments (see Yang et al., 2014; Yang et al., 2015). We also take other Chinese Acheulean sites into

account to establish the characteristics of the Acheulean culture in Loess Plateau.

2. Dingcun site and its lithic assemblage

The Paleolithic sites at Dingcun lie in the rift zone of the Fenhe Graben in the eastern Chinese Loess Plateau (Fig. 1a). During 1954-1955, 13 localities were found and excavated, and noted as 54:90-54:102. All these localities lie on the third Terrace of Fenhe River (Fig. 1b). In two years of field work, 2005 artifacts were recovered, of which 225 were from the surface, and the others were *in situ* (Pei et al., 1958). Among the 13 localities, Localities 90, 97, 98, 99, 100, and 102 are located within a few hundred meters (Fig. 1c) of each other. More than 80% of the artifacts were from these localities, and therefore this cluster can be regarded as the central part of the site. Although the first formal report and later study briefly concluded that all the localities were in the same strata and had similar taphonomichistories (Pei et al., 1958; Wang, 2002), there are doubts about these conclusions (Zhang, 1993, 1994).

One doubt is that the artifacts from different localities are not of the same size range (Zhang, 1993, 1994). Therefore statistical analysis on the maximal length of the artifacts from different localities has been done (Fig. 2). From the graph, we find that the artifacts from different localities are similar in length, and the ones from the collection are larger. We also evaluated the taphonomic situation of the artifacts (Fig. 3), and the results showed that most of the artifacts are slightly abraded or fresh. The 40 artifacts which are heavily abraded are not included in this study. Regarding the depositional processes of the artifacts, we agreed with some early studies (Pei et al., 1958; Wang, 2002) that the artifacts may have been transported by water over a short distance or immersed in the water for some time, for the artifacts were in the terrace close to the river. The Dingcun sites are placed on a relative scale of the influence of moving water on the assemblages.

Although Pei (1958) stated that Dingcun was Late Pleistocene in age, the cultural layer is below the first paleosol (S1) which is dated to 73-128 ka (Kukla and An, 1989; Ding et al., 1991, 1994; Wu and Liu, 2002), and the U-series dating results of this layer is 160-210 ka (Chen et al., 1984). Therefore, the Dingcun assemblage is dated in

recent work to the Late Middle Pleistocene (Yang et al., 2014). Locality 54:100 (35°49'N, 111°25'E), where three teeth of *Homo sp.* were found, is considered as representative of the others. The archaeological layer is about 4 m thick, and is the upper part of a 20 m thick fluvial deposit. Above the cultural layer is a 10 m thick aeolian deposit that includes the first paleosol (S1) of the Upper Pleistocene (Malan loess) and the Holocene paleosol (S0).

3. Materials and method

3.1 Chaîneopératoire study

Following the chaîneopératoire approach, we regard the production of stone artifacts as a dynamic process, from the acquisition of raw material to the discard of used tools. It thus aims at re-establishing the whole process of the lifetime of the stone tools. In this process, there are four main parts: raw material acquisition, production, utilization, and discard. Some factors make it difficult to determine the utilization and discard of the stone artifacts, especially in Lower Paleolithic sites (Boëda, 1990; Julien, 1992; Roche and Texier, 1995, 1996). Because of the taphonomic situation of the artifacts in Dingcun, it is impossible to study the context of their utilization and discard. Therefore, in this paper, we focus on the acquisition of raw material and tool production.

The raw materials are dominated by hornfels (94.6%), but chert and quartz are also present. The hornfels used in Dingcun lithic industry is from outcrops around Dagudui Mountain, which is 7 km from the Dingcun site (Pei et al., 1958; Wang et al., 1987; Yang et al., 2015). The raw material acquisition of Dingcun is similar to that at other Acheulean sites: raw materials were probably first tested and flaked at the quarry site, and then brought back to the site as prepared cores or large flake-blanks (Texier and Roche, 1995; Inizan et al., 1999). Therefore the large cores for making blanks for large-flake tools such as handaxes or cleaver are almost absent in the site.

Between 2013 and 2015, the artifacts found in situ were analyzed. A descriptive rather than a quantitative approach is adopted to assess the range of variation and to characterize the modes of lithic production. A classification of the cores, which are

particularly informative in assessments of knapping methods and techniques, was performed using the identification of the number of flaking surfaces, the direction of flaking and the preparation of the platform. The analysis of flakes takes into account the type of butt, the number and direction of negative scars on the dorsal face, and the presence of lips. The analysis of large cutting tools (LCT) considers the blank types, the presence/location/extension of *façonnage* and retouch, the presence of standardized shapes and sizes. In addition, the analysis of light duty tools also considers the blank types, the retouch methods and the retouch locations.

3.2 Knapping experiment

Knapping experiments are a vital way to test raw materials and access flaking techniques (Newcomer, 1971; Driscoll and García-Rojas, 2014; Terradillos-Bernal et al., 2014). Here, knapping experiments can show what kind of characteristics hornfels may have had to make it the principal raw material. The knapping technique in Dingcun industry is also a long-standing question, as the large wide flakes were supposedly produced by the block-on-block method (Pei et al., 1958; Li, 1996a, 1996b), and this claim has been supported in several subsequent studies (Liu, 1988; Li, 1992; Wang, 2001). Based on technological analysis of the Dingcun artifacts, we deduced that the hard hammer percussion was in fact the main knapping technique. However, we need to use experiments to demonstrate that possibility, and also establish whether the soft organic hammer percussion was used to produce large flakes on hornfels.

The hornfels used in the experiment were mainly blocks from the hornfels outcrops around the Daguidui Mountain, but a few were collected from gullies near Dingcun. Two organic hammers were prepared: one was a 2000gm hard box wood hammer, the other one was an antler. Several 2000-500gm hard hammers were also prepared. The participant, who mainly controlled the experiments, is an accomplished knapper with around 30 years of knapping experience.

During the knapping of each nodule, the majority of debitage was collected periodically and bagged, and after the knapping of each nodule, all the cores and

remaining debitage (mainly fragments and <20mmdebitage) were labeled and bagged. After testing the raw materials, the hard hammer and organic hammer were used to produce flakes respectively.

4. Results

4.1 Two chaînesopératoires

Two main chaînesopératoirescoexisted in the Dingcun industry:one was devoted to the production of large flakes that could be turned into LCTs and the other focused on the débitage of small to medium-sized flakes which could be used to produce light-duty tools. We describe the two chaînesopératoires as follows.

4.1.1 Production of large flakes

As mentioned in former studies, the large cores for making blanks for large-flake tools such as handaxes or cleavers are almost absent in the site (Yang et al., 2014, 2015).This is a common situation, as rocks large, heavy, and angular enough to produce large flakes weredebitaged in the outcrops (Texier and Roche, 1995). Therefore in this study, we inferred the production of large flakes by analyzing them and the large flake tools. In the assemblage, there are 48 flakes with a maximal length or width >100mm (8.3% of all the flakes), but no core with negative scars with a maximal length or width >100mm. When analyzing the techniques of producing the large flakes, we consider the LCT tool-blanks. The large flakesare mainly with two kinds of butts: the plain and the dihedral. Most have prominent bulbs, bulb scars, and the waves (or ripple) at the distal parts. In the former studies, several giant core methods, such as the bifacial,sliced slab, opening flake methods, the Victoria West,Tabelbala-Tachenghit and Chirki cleaver core were identified (Sharon, 2007).

From observing the large flakes from Dingcun, at least four kinds of giant core methods were used. The bifacial method is very common in large flake production(Madsen and Goren-Inbar, 2004; Sharon, 2007). In this method, after detaching a primary opening flake, the knapper worked alternately along the core's periphery, removing a series of flakes from both faces of the core, while using the scar of the previously removed flake as the striking platform (Sharon, 2007). In this

situation, the large flakes are always with plain butts or a pseudo-dihedral butts(Fig.4-1/2, N=38, 79%). The sliced slab method is related to the morphology of raw materials, and always used on flat slabs of raw material. As the hornfels are derived from shale or sandy shale, it is easy to find the blocks in flat slabs. Another method may be related to the large flake production in Dingcun is the opening flake method, as it is effective to produce thin flakes with nature dorsal face (the blank of pick, such as Fig.5-b, N=6, 13%).

The most important one is the Chirki cleaver core. The Chirki cleaver core was first named and introduced by Corvinus(1983) in an Indian Acheulean context. A few flakes were at one side and a 'base' was then prepared, which determined the future dorsal face of the cleaver flake(Fig.6, N=4, 8%). Here, we show an example from Dingcun industry. By reading the scars of the cleaver(P0139), we can replay the process of the production of this flake blank (Fig.5-a).

4.1.2 Façonnage of the large cutting tools

The façonnage of the large cutting tools of Dingcun can be divided into two groups. The first group includes the handaxe/cleaver/pick (N=39, 59% of the large cutting tools, details in Table 1). These tools get the morphological standardization in the façonnage process, and the final retouches are taken based on the specific forms. As examples, in Figs. 5-b/c, the pick and biface are with symmetrical. The cleaver is on a Chirki cleaver flake, and retouch is helping to get an equilibrium butt (Fig.5a). The tools in the second group lack morphological standardization: retouch was not undertaken to obtain a specific form such as massive scrapers and denticulates but only to modify the edge (N=27, 41%, see Table 1). These massive edge-tools were not in a standard form. In Fig.5d, two edges were retouched, while another example, specimen P1980(Fig.5e) lost much of its volume, and had a very irregular morphology. Neither example shows an intention of obtaining a standardized morphology.

4.2 Small to medium débitage and light duty tools

A total of 91 cores, 531 flakes, 122 flake fragments, and 163 light duty tools are documented in the second chaîne opératoire. Here, flakes in the small-medium débitage were used to produce light duty tools. The raw materials are dominated by hornfels, while the chert and quartz were also used.

Most of the cores in the Dingcun assemblage have dimensions of ~50 mm, and only few (N=14; 13%) exceed 100 mm. Based on their platforms and morphology, we classified the cores into five types, named as A-E (Fig. 7). Type A and Type E are the commonest ones. The Type A (N=25; 26.6%) is a simple way to exploit the core, and a few (N=8) had retouched platforms. The Type E (N=27; 29.3%, Fig. 12) core is the commonest. This method is very productive and used the former flake scar to produce the next flake (Mourre, 2003; Terradas, 2003; Soressi, 2005). Some have a very discoid outline, when the alternating surface is in the middle of the core (Fig. 8-a/b), therefore in several reports it was called a discoid core. It belonged to an enlarged “discoid” core, as it cannot be exactly categorized into the original definition (Boëda, 1995).

Type B (N=11; 12%) is a bipolar exploited core. These cores have two opposite platforms, and only one with a prepared platform. Type C (N=7; 7.6%) has an orthogonal negative scar pattern, as the débitage happened on one face from orthogonal directions. The Type D (N=21; 22.8%) is a multifacial, multidirectional and irregular core. Core surfaces were alternatively flaked through multidirectional removals without a clear organization of the reduction process.

Most of the flakes in the Dingcun industry are <10 cm long or wide (Fig. 9), and belong to the small to medium-sized débitage (Sharon, 2010; de la Torre, 2011a; Beyene et al., 2013). When checking the length/width ratio, the length of 40% of flakes exceeded the width. The platform angles are 70~90°, and cluster on 75~85°. The butts of the flakes can be divided into four types: plain (67%), dihedral (10%), faceted (19%) and linear (4%).

The dorsal face patterns of the flakes are dominated by multidirectional irregular negative scar patterns (32%), while the scars formed a ridge at the dorsal face. The

other two types constitute a large set and are ones with a natural surface (16%) and unidirectional negative scar pattern(25%). The others types are the centripetal negative scar pattern, the core edge flakes, and the bidirectional negative scar pattern. The broken flakes of Dingcun have a relatively high proportion of “siret” (accidental breakage flakes), which reaches nearly 10%. In a “siret” accident, the flake is snapped into two parts along the percussion axis. This kind of accident is common in hard hammer percussion (Inizan et al., 1999).

In the studied assemblage there are 163 pieces of light duty tools, accounting for 76% of the tools, including scrapers, notches, denticulates, borers, and some unidentified tools. Most tools (>92%) are flake tools, made either on whole or broken flakes. Scrapers form the largest proportion (38.7%) of light duty tools. The small scrapers studied here have a maximal length and width around 50mm, and the ones made on chert and quartz are smaller. Most of the scrapers are made on flakes, including some Kombewa flakes (Fig. 10). According to the number of retouched edges and the shape of the edges, they can be classified into four kinds: convergent, single straight, single convex and single concave. Notches account for 21% of the light duty tools. Most were produced by retouching a notch on one edge of the flake or on both edges. Both Clactonian types and complex notches occur in the Dingcun assemblage (Fig. 10-16, 17); of these, the former is more common (79% of notches). Denticulates are another type of the light duty tools identified at Dingcun. Denticulate sizes are similar to those of the small scrapers. Most of the tools are formed by three to five continuous notches on the edges of the blanks, but some are modified on the transverse distal edges. Most of the retouched edges are slightly abraded, while some fresh ones exhibit an almost serrated edge (Fig. 10-9). Compared to the three types of tools mentioned above, borers usually have a smaller maximal length. In most cases, the tool-makers chose to retouch the distal ends for borer modification, but some retouch occurs on the proximal part. The retouch is always in the same direction on the dorsal or on the ventral surface. Most of these artifacts show simple retouch, but there are some examples with multiple retouches (Figs. 10-7).

5. Knapping technique

5.1 Production of large flakes in the Dingcun industry

We considered the possibility that the large flakes were produced by hard hammer percussion instead of the block on block method. A hornfels nodule (45*30*20 cm) was chosen to finish sequential hard hammer percussion. The knapper successfully produced 64 conchoidal flakes (>25mm) and four splinters. We numbered this series of flakes as E-11-1 to E-11-65 (see appendix Table 1 for their dimensions). During the percussion, there were three “siret breaks” (Fig.11). The maximal length and breadth data are shown in Fig.12. It was clear that large flakes which could be used as the blanks of LCTs were successfully produced by hard hammer percussion. When checking the length/width ratio, 33% of flakes had a length exceeding their width, which is close to the 40% in the archaeological assemblage.

Except for the sequential percussion of one core, several other nodules were tested. In the knapping process, we obtained flakes with double cones or strong waves (Fig.13), and all these attributes were deemed to relate to block on block percussion. Here in this experiment, we saw all these in the hard hammer percussion. Therefore the block on block method is not the one we would use to produce large flakes. The existence of the block-on-block method is questioned by many, and it is also regarded as a kind of dangerous method (Bordes and Anderson, 1968; Wymer, 1986; Schick and Toth, 1994; Ranov, 1995).

According to anthropological work in Australia (R. Gould), the block on block method was defined by Crabtree (1975): the knapper threw the lithic material against boulders and then selected flakes with sharp cutting edges to be used, while others were selected to be modified into functional implements. In the former study, there are no really ancient examples of this kind of method (Ranov, 1995).

5.2 Is there organic hammer percussion in Dingcun?

Aiming to check whether there is organic (soft) hammer percussion in Dingcun, we used the stone and organic hammers to produce flakes. First, a 2kg box wood hammer was applied, while it did not really work; second, an antler hammer was

applied, and 24 complete flakes were produced. The flakes produced by the antler hammer were numbered E-3-1 to E-3-24.

After we conducted a comparison among the experimental flakes from the antler and stone hammer, and also the pseudo-organic-hammer flakes from the archaeological assemblage. The platform angles (angle de chasse) of the three groups are compared in Fig. 14: the angles of the flakes from the archaeological assemblage are more consistent with the ones from the hard hammer percussion, and the values are more variable between 70° to 85°, while the flakes from the antler hammer are more stable, and are almost around 80°.

The presence of lips is an important criterion to define the organic hammer percussion. In the hard hammer experiment, the frequency of occurrences of the lips is as high as 37%. Therefore, it is reasonable to find flakes with lips in a hard hammer predominant lithic industry. Then we turn to the missing of the impact points, which we also use as a criterion to distinguish the organic hammer from hard stone hammer percussion. The flakes from the hard hammer experiment also have 10% of the impact points missing. In addition, the morphology of the platforms is observed after the experiment. The platforms from the hard hammer flakes and soft hammer flakes can be distinguished from each other. The soft hammer flakes always have a convex platform, while the hard hammer flakes have plain platforms. Therefore, the experiment result tended to refute the use of soft hammer percussion. The main technique applied on hornfels in Dingcun seems to be the hard hammer percussion.

6. Discussion

6.1 Techno-economic patterns of lithic production at Dingcun

Through detailed studies on the assemblage of Dingcun lithic industry, the techno-economic behaviors of the habitants of Dingcun culture became clearer. The Large Flake Acheulean tool complex is the main part of the culture, but the development of the small débitage and the light duty tools is another important part of the industry. They are the two chaînes opératoires that coexisted in Dingcun industry. Although the limited nature of the early excavation cannot provide us enough

information on the collection of all the debris, the formation of the site and the use wears of the tools, the current restudy of the old collection are still appropriate to evaluate the behaviors of the inhabitants of the Loess Plateau during the Late Middle Pleistocene.

6.2 Large flake production and the Acheulean tools

When drawing conclusions on the Acheulean in China, three representative areas were defined. They are the Loess Plateau area along the Yellow River (Dingcun and Luonan), the Middle reach of the Yangtze River (DDR) and the Bose Basin along the upper Pearl River (Huang and Zhang, 2010). Compared to the Acheulean or Acheulean-like culture reported in South China, the Acheulean LCTs in Dingcun are mostly made on large flakes (e.g., 82% of handaxes on flake blanks, 100% of cleavers on flake blanks). In Luonan the situation is similar (e.g., 65.91% of handaxes on flake blanks, 100% of cleavers on flake blanks) (Wang, 2005, 2006). In Bose, the situation is different, as more than 43% of Acheulean heavy duty tools use a pebble as blank (Li et al., 2014). The Large Flake technique is better documented on the Loess Plateau, especially in the Dingcun industry, while the others rely more on river pebbles, and the Acheulean tools directly retouched on a river pebble or on split pebbles. The form of the raw materials of Dingcun gives the possibility to develop a large flake production technique system (Yang et al., 2015). In addition, the spheroids are present in both Dingcun (see Table 1) and Luonan (Wang, 2005), while this kind of stone tools rarely appear in South China.

The results of this study show that four large flake production methods are applied at Dingcun: the bifacial method, opening flake method, the sliced slab method, and the Chirkri cleaver core. The bifacial method is defined as a technical process predetermining through previous removals the recurrence of the exploitation. The use of the opening flake method means that the knappers can prefigure the result, and take advantage of the morphology of the opening flake. The application of the sliced slab method is to cope with the special shape of some raw material. The most important is the Chirkri cleaver core method, as it is a more complicated and predetermined process

for the production of large flakes. To obtain a cleaver flake with *biseau*, the knapper used the previous removal scar to produce the end.

Two different strategies are carried out during the process of turning the large flakes into Large Cutting Tools (LCTs). In the first one, specific or systematic morphological traits are required. In the second, the retouch occurred only at the very edges of pieces or changed lots of the blank volume to obtain a sharp use end.

LCT is the predetermined production of the first chaîneopératoire in Dingcun. From our data, we can establish the raw material acquisition process (Yang et al., 2015) and the production process as described earlier in this article. The utilization and discard is hard to deduce, given the limitations of the excavation record and the taphonomic situation.

6.3 Small débitage and the light duty tools

Although the LCTs and large flakes are more remarkable in Dingcun, the small débitage and the light duty tools are also major components of the lithic industry. Firstly, they are present in large numbers at Dingcun (see Table 1), and second, they also show advanced production techniques. They formed the other chaîneopératoire which was aimed at producing the light duty tools.

Study of the flakes and cores of the small débitage show that the discoid method (bifacial method) was the main core technique applied. The definition of the discoid had been discussed in several studies (Boëda, 1995). A discoid can be a way to produce flakes and also can be oriented toward the production of points (Bourguignon and Turq, 2003; Mourre, 2003; Terradas, 2003; Soressi, 2005). The situation in Dingcun, the main purpose to use the discoid method is to produce flakes efficiently. In some cases, these co-occur with Levallois cores, which are also a kind of prepared cores that keep peripheral convexity during flaking (Boëda, 1995).

The number of light duty tools is increased and new types appear, and some exquisite scrapers indicate the development of a retouch technique. The increasing number of small scrapers and other light duty tools in Late Middle Pleistocene Acheulean assemblages is a phenomenon reported worldwide. As another Late

Middle Pleistocene Acheulean site complex in North China, the Luonan open air Acheulean sites have several similarities with Dingcun. Not only the African-looking Acheulean tools (Petraglia and Shipton, 2008; Shipton and Petraglia, 2010), but also the light-duty tools accounted for a considerable proportion of the total. The main types include scrapers, points and burins (Wang, 2005). In Africa, Sangoan and Fauresmith sites contain Acheulian and numerous light-duty tools. Several scholars talked about the transition traits of these sites (McBrearty and Brooks, 2000; Clark, 2001a; Tryon and McBrearty, 2002; McBrearty and Tryon, 2006; Van Peer et al., 2003). The Sangoan industry, characterized by heavy duty tools such as picks and core axes, as well as light duty flake tools, has a lot of similarities with Dingcun industry. In both of the two industries, the light duty tools have a rough outline, and most of the retouches are not so regular (Clark, 2001a, 2001b).

6.4 Knapping technique-a comment on the hard hammer percussion

The knapping experiment gives us two important clues about the techno-economic behaviors of Dingcun industry. The first one is the possibility of producing large flake by hard hammer percussion instead of by the block-on-block method. The second is to demonstrate that the organic (soft) hammer percussion was not applied. Thus, hard hammer percussion was the main technique in both the débitage and the façonnage process.

From the experiment, we also learned that the varied attributes, such as the lips, the percussion mark, the platform angles, used to differentiate impact types (knapping techniques) sometimes make more confusion than confirmation (Driscoll and García-Rojas, 2014). In our experiment, we used the results of the knapping experiments to compare with the archaeological artifacts. We hope in this way to find which kind of impact type was actually applied.

7. Conclusions

In this restudy, a detailed techno-economic analysis and knapping experiment were applied to define the main characteristics and the techno-economic of

Dingcun industry. Although the artifacts are from the excavations of 60 years ago and the taphonomic situation is not suitable for establishing the utilization and discard processes, efforts were made to access the chaîne opératoire of the lithic industry.

- 1) It is undeniable that the Dingcun industry belonged to the Late Acheulean. The Dingcun industry maintains a developed Acheulian traditional tool kits, but at the same time the light duty tools are important. The number of light duty tools is increased, and some exquisite scrapers indicate the development of retouch technique. The two chaînes opératoires were paralleled in the Dingcun industry, and the residents had a clear knowledge of both
- 2) The Acheulian LCTs of Dingcun are mainly made on large flakes. It is different from the Acheulian culture of South China (DRR and Bose Basin), while more similar to the Luonan Acheulian industry. Therefore, it seems to us that the Loess Plateau area developed a Large Flake Acheulean in the Late Middle Pleistocene.
- 3) Two different strategies are carried out during the façonnage of LCTs. The first one, the specific or systematic morphological traits are required. The second one, the retouch occurred only at the very edges of pieces or changed lots of the blank volume to get a sharp end for using.
- 4) From the recent knapping experiment, the hard hammer percussion is the main knapping technique applied in Dingcun industry. There is no evidence to emphasize the block-on-block method in Dingcun.

In conclusion, the Dingcun industry documents a developed Late Acheulean Culture, and contained a small to medium flakes tool kit as well. The production of the large flakes and the façonnage of LCTs show its technological flexibility. The light duty tool kit is an important supplement for the industry, and also shows the tendency in the Middle Paleolithic.

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Figure and table captions:

Fig. 1 Location of the Dingcun site and Fenwei Graben: a.Dingcun and other Acheulean LCTs sites groups; b, Geographic map of Fenwei Graben; c. Dingcunlocalities (After Pei et al,1958)

Fig. 2 Maximum length (L) of stone artifacts from different localities of Dingcun

Fig. 3 Physical condition of the artifacts

- Fig. 4 Examples of large unmodified flakes from Dingcun
- Fig. 5 Façonnage (shaping) scheme of the Acheulean large cutting tools (LCT) of Dingcun
- Fig. 6 Cleaver flake from Chirki core of Indian Acheulean (after Corvinus, 1983)
- Fig. 7 Schemes of small-medium cores reduction of Dingcun
- Fig. 8 Illustrations of centripetal bifacial cores of Dingcun
- Fig. 9 Maximum length (L) and width of flakes of Dingcun
- Fig. 10 Drawing of light duty tools in Dingcun
- Fig. 11 Knapping experiment
- Fig. 12 Maximumlength (L) and width of flakes form the hard hammer percussion experiment
- Fig. 13 Samples of the Hard hammer percussion flakes (from experiment)
- Fig. 14 Comparison of platform angles (angle de chasse) of flakes from archaeological assemblage and the two experiments
- Table 1 Tooltypology of the studied artifacts

Figure 1

Figure 2

Figure 3

Figure 4

Figure 6

Figure 7

A

B

C

D

E

Figure 8

Figure 9

Figure 10

Figure 11

Figure 12

Figure 13

Figure 14

Table 1 Tools typology of the studied artifacts

	Typology	Number	% of tools
Large cutting	Handaxe	10	4%
tools (on large flakes)	Cleaver	18	7.2%
	Pick	11	4.4%
	Massive scraper	17	6.9%
	Massive denticulate	10	4%
Light-duty	Borer	26	10.4%
tools	Scraper	63	25.4%
	Notch	34	13.7%
	Denticulate	20	8.1%
	Unidentified	20	8.1%
Others	Spheroid	13	5.2%
	Chopper	6	2.4%
TOTAL		248	100%