

# Drilling Tools in Prehistoric China from the Perspective of Experimental Archaeology

Bangcheng Tang<sup>1</sup>, Yan Xue<sup>2</sup>

<sup>1</sup>Department of Archaeology, School of History and Culture, Sichuan University China  
[batang3sheffiele@outlook.com](mailto:batang3sheffiele@outlook.com)

<sup>2</sup>Department of Cultural Heritage and Museology, Baoding University, China.  
[Yanxue202309@outlook.com](mailto:Yanxue202309@outlook.com)

---

## Abstract

*As a type of artifact commonly found in Chinese prehistoric sites, perforated shellfish materials can be classified into freshwater mussel materials and perforated seashell materials, and drilling tools can be classified into single and composite drilling tools. The experimental reconstruction of the two types of drilling tools and drilling methods explored the influence of the composition of drilling tools, drilling methods, and other factors on the drilling process. Meanwhile, the experiments were recorded and analyzed using a stereo microscope. The experimental results show that the composite drilling tools provide better drilling results and more dynamics than stone drill bits. The perforated weight stone stabilized the center of gravity and safeguarded the dynamic performance. The type of drilling tool, drilling method, and characteristics such as smoothness and hardness of perforated shellfish materials significantly impact the drilling effect.*

**Keywords:** Drilling Tools, Perforated shellfish, Experimental archaeology, Prehistoric

---

## Introduction

In China, archaeologists have successively discovered the remains of stone drill bits and perforated weight stones related to drilling technology in Beijing, Hebei and Jiangsu, accompanied by the excavation of perforated freshwater mussel products, perforated seashell products and other remains, and there are evident traces of wear and tear on the excavated stone drills. From the classification situation, drilling tools can be divided into single drilling tools and composite drilling tools. Single drilling tools such as stone drill bits, and composite tools usually consist of a drill shank, drill bits, and perforated weight stones with the ability to rotate the hole.

As far as China is concerned, attention to prehistoric drilling tools has mainly focused on research related to jade and stone tool drilling techniques. In contrast, more research needs to be carried out on prehistoric drilling tools based on excavated drilling tools and perforated shell materials from the perspective of experimental archaeology.

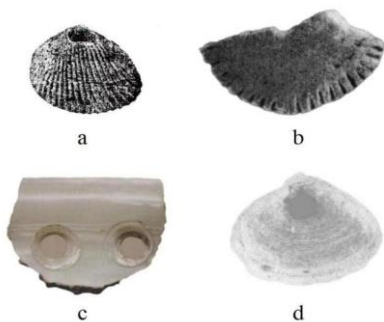
Related experimental studies such as Gu (1986) has argued, made drilling tools, dug holes in mammalian bones and tooth roots, ground holes in shells and gravel for experiments, and sometimes used composite drilling methods, such as chiseling and then drilling holes in shells, and combined with the results of the experiments and the analysis of the microscopic traces, considered that the holes in the decorations made of animal teeth and shells unearthed at the Xianrendong Cave, Haicheng, were mainly drilled with drilling tools.

Through the experimental reconstruction of the drilling tools and shellfish drilling process in prehistoric China, in-depth analyses of the making and use of drilling tools were carried out. The individual feelings of the experimenters

were included in the overall consideration to analyses the relationship between the drilling tools, the drilling tools, and the shellfish drilling materials and provide practical insights for exploring the drilling tools and shellfish drilling process in prehistoric China.

### **Background: Perforated shellfish materials and drilling tools in Prehistoric China**

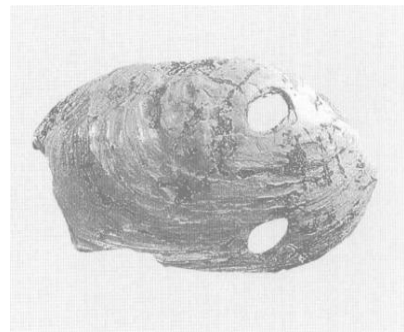
Several prehistoric sites have been excavated in China, and many perforated materials, stone drill bits, and perforated weight stones have been unearthed. The appearance of perforated materials proves that people were able to perforate artefacts during this period consciously. Worldwide, drilling technology originated in Europe during the Middle Paleolithic, and perforated materials of different materials were excavated in China, Japan, and the Korean Peninsula until the Upper Paleolithic, but in smaller quantities (Wang, 2009). In Paleolithic sites of China, many perforated seashell materials and perforated freshwater mussel materials have been excavated, such as shell ornaments excavated from the Shan dingdong Man in Beijing (Figure 1a; Jia, 1951: 70), perforated freshwater mussel shells excavated from the Xianrendong Cave in Liaoning (Figure 1b; Huang et al., 1986), perforated freshwater mussel shells excavated from the Shizitan site in Shanxi (Figure 1c; Song and Shi, 2013), and perforated shells excavated from the Hutouliang site in Hebei (Figure 1d; Gai et al., 1977).



**Figure 1.** a. Shell ornaments excavated from the Shan dingdong Man. (Pei, 1951: Figure 38). b. Perforated freshwater mussel shells excavated from the Xianrendong Cave. (Huang et al., 1986: Figure 1-6). c. Perforated freshwater mussel shells excavated from the Shizitan site. (Song and Shi, 2013: Figure 4). d. Perforated shells excavated from the Hutouliang site. (Gai et al., 1977: Figure 2-17).

A number of the Neolithic sites have also recovered large quantities of perforated freshwater mussel materials and perforated seashell materials, such as the Zengpiyan site (10,000-5,000 BC), where a freshwater mussel knife, No. DT6⑤: 007 was excavated and pierced unidirectional through two holes in the middle of the upper middle part of the mussel; the holes are sub elliptical, and the residual length is 6.7cm, the width is 3.7cm in length, 3.7cm in width, and 0.7 to 0.8cm in diameter (Figure 2; The Institute of Archaeology, Chinese Academy of Social Sciences et al., 2003: 107).

**Figure 2.** A freshwater mussel knife excavated from the Zengpiyan site. (The Institute of Archaeology, Chinese Academy of Social Sciences et al., 2003: Figure 19-4).



Located at the Nan Baoligaotu site in Inner Mongolia and dated to about 3,000 BC or slightly later, three shell ornaments have been excavated, made of scallops, with the inside of the bottom end ground into a groove, with symmetrical four circular holes on the two ears of the bottom end, and five circular holes evenly distributed on the surface of the scallops, measuring 13-15cm in length, 13-14.6cm in width, and 0.1-0.7cm in thickness (Figure 3; Ji and Zheng: 2017).

**Figure 3.** Shell ornaments excavated from the Nan Baoligaotu site. (Ji and Zheng, 2017: Figure 38)



The Nibazhai site in Sichuan is a Neolithic (c.8,000-2000 BC) to Zhou Dynasty (1,046-256 BC) site, where a perforated shell ornament, No. NBZC: 1 excavated, white overall, with a mixed blue-violet colour in the middle, oval in plan, hollow, with a jagged centre seam, and with a sub-circular perforated hole in the upper middle of the convex surface, measuring 2.5 cm in length, 1.8 cm in width, 1.1 cm in thickness, and a hole of 0.5 cm in diameter (Figure 4, Chen et al., 2020).

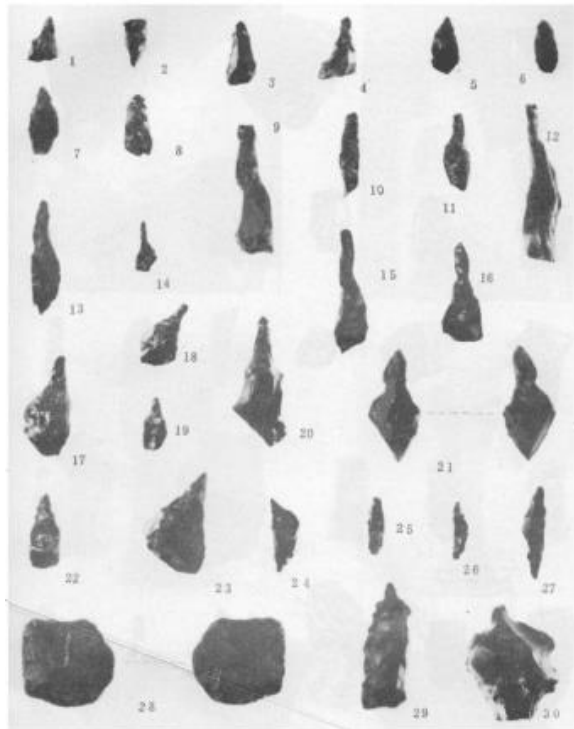


**Figure 4.** *Perforated shell ornaments collected at the Nibazhai site. (Chen et al., 2020: Figure 5).*

From the point of view of piercing methods, the piercing methods used for different textures of perforated materials are different, and the perforated materials are also affected by the drilling methods, resulting in different shapes of drilling traces. For example, perforated bone materials and perforated freshwater mussel materials are mostly drilled by cone drilling technique, and the shape of perforations made by this method is more rounded, which is caused by drilling tools or pointed artifacts, while some perforated mussels are also perforated by the bipolar technique, and the perforations made by this method are more irregular (Chen, 2009). Perforated shellfish materials, on the other hand, are mainly drilled by means of cone drilling techniques and sometimes by grinding drills.

In addition to the material with holes and the drilling method, the drilling tool is essential in the drilling process. The drilling tools in the prehistoric period are mainly composed of two cases: single drilling tools and composite drilling tools. From the point of view, single drilling tools, such as drill bits, as a kind of single drilling tools, usually consist of stone, freshwater mussel, and bone. For example, the stone drill bits excavated from the Mopandun site in Jiangsu, a Late Paleolithic site, can be divided into triangular drills, leaf-shaped drills, chisel-shaped drills, long-bodied drills, short-bodied drills, thin-waisted flat-bodied drills, and two-headed drills (Figure 5; Zhang et al., 1985). Some of the stone drill bits have small shanks and are short-bodied stone drills, which is also consistent with the characteristics of shank binding (Chen, 1986). The stone drill bits were probably used as part of a composite drilling tool and were bound to other components using shank binding.

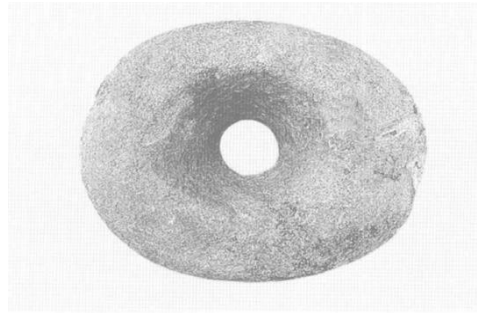
**Figure 5.** Stone drill bits, excavated from the Mopandun site, 1-4 triangular drills, 5-8 leaf-shaped drills, 9-11 chisel-shaped drills, 12-16 long-bodied drills, 17-20, 22, 23 short-bodied drills, 21 thin-waisted, flat-bodied drills, 24-27 two-headed drills. (Zhang et al., 1985: Figure 8)



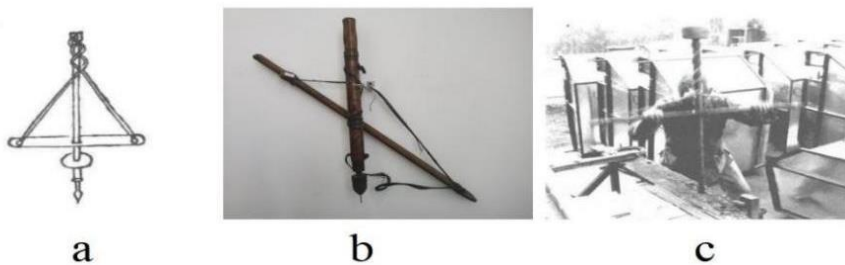
During the Pre - Peiligang culture (12000-8500 BC), drilling technology began to develop in China, and the number of sites where perforated artifacts were unearthed increased dramatically (Wang, 2009). The use of composite tools also promoted the diversification of perforation technology, providing an effective way for ornaments, production tools, and other artifacts.

In terms of composite drilling tools, it may be possible to speculate on the composition of their components from archaeological finds, such as perforated gravel tools, also known as "Perforated stone" and "Weight stone", which can be used as part of a combination of tools to increase weight (Pei, 1935; Zhou, 2007). From the point of view of geographical distribution, perforated stones with different hole diameters have been unearthed in North China, South China, and other regions, and some of the perforated stones have moderate hole diameters, which are suitable to be mounted in a wooden stick, such as a perforated stone No. SBK:492 unearthed in the Zengpiyan site in Guangxi, which has a greyish-brown fine sandstone texture and a rounded, thick body, with the centre of the tool being drilled and ground through and pierced by the counterbore method, and the holes have smooth traces of the holes made by the drilling process. The hole diameter is roughly equal, and the hole diameter is approximately equal to the hole diameter, measuring 9.6 cm in length, 7.7 cm in width, 4 cm in thickness, and 1.6 cm in diameter (Figure 6; The Institute of Archaeology, Chinese Academy of Social Sciences et al., 2003: 231). On this basis, it can be surmised that the perforated weighted stone was likely used as part of a composite drilling tool to provide a counterweight.

**Figure 6.** A perforated stone unearthed in the Zengpiyan site. (The Institute of Archaeology, Chinese Academy of Social Sciences et al., 2003: Figure 42-1).



Composite drilling tools also recorded in written historical sources; the "*Tiangong Kaiwu*" (Song 1637: 193) contained: "梓人转索通眼，引钉合木者用蛇头钻" (carpentry turnstile perforation to drive nails to put together wood pieces, with shetou drills), and in the "*Hegong Qiju Tushuo*" (Wanyan and Li, 1836: 309) on the carpenter used drilling tools have more graphic physical drawings, such as steely screw drill. These drilling tools were used in the modern traditional carpentry industry, Tangshan Fengrun Museum collection of 1 piece of modern traction drill, by the drill handle, drill rod, pull rod, drill rope, chuck, and drill, and its use is mainly for use in the processing of traditional wood products. The drilling tool carpenters in Linhai City, Zhejiang, use a stone drilling screw, a cord, and a pressure rod (Li, 2004: 188).



**Figure7. a.** A steely screw drill recorded by the "*Hegong Qiju Tushuo*" (Wanyan, 1836: 309). **b.** Modern traction drill collected by Fengrun Museum, Tangshan, China. (Photo taken by Author, July 2023). **c.** A steely screw drill. (Li, 2004: Figure 5-4).

From the written historical sources and the modern drilling techniques, perhaps some inspirations for examining how the composite drilling tools in prehistoric China got power conditions are obtained, which can help to understand further the production process of the drilling tools and drilling methods, and from the perspective of experimental archaeology, through the simulation of different types of drilling tools and drilling methods, combined with the archaeological discovery of drilled holes with traces of drilling on perforated shellfish materials, to explore the prehistoric drilling technology, and to consider the relationship between the components of drilling tools and the drilling effect in the actual drilling process.

### **Experimental Method**

The experiment is divided into the preparation of experiment, experiment 1, and experiment 2. Each experiment is not isolated, with a certain degree of progressivity and relevance. The core of the preparation of the experiment is to determine the selection of materials used in the experiment. To reconstruct the process of drilling tools and perforated shells, some of the materials required for the experimental production are selected through fieldwork, which has a specific helpful effect on the pre-preparation process of the experiment so as further to explore the issue of shell selection in prehistoric.

The reconstruction planned for Experiment 1 is a reconstruction of a single drilling tool. In contrast, Experiment 2 is a reconstruction of a composite drilling tool, where certain relationships and evolutionary processes of use exist. Experiment 1 reconstructed the process of making and using stone drill bits further to explore the use of drilling technology in prehistoric China.

Experiment 2 was produced to explore further the findings based on the results of Experiment 1. Experiment 2 focused on the production of composite

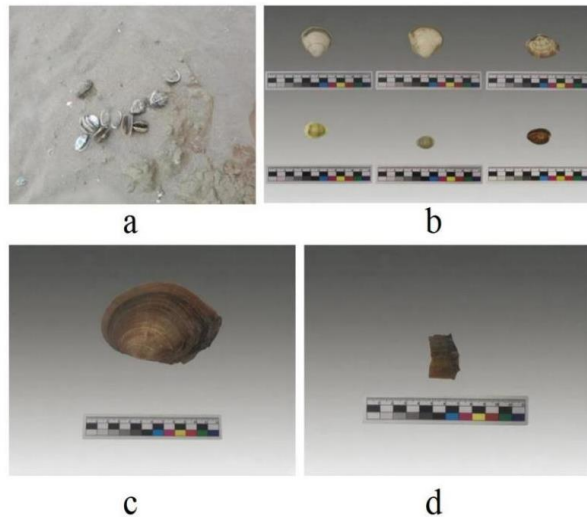
drilling tools A, consisting of a stone bits drill and a wooden pole, Composite Drilling Tool B, consisting of a stone bits drill, perforated weight stones, a wooden pole, and a thick rope, Composite Drilling Tool C consisting of a stone bits drill, perforated weight stones, a wooden pole, and a thin rope, and drilling of seashells and freshwater mussels, to study the relationship of the perforated shell ornaments seen in archaeology to the drilling tools. The experiment explores the changes in drilling tools while analyzing them in the context of archaeological findings and previous scholarly research and contributes to the study of prehistoric drilling techniques.

During the experiment, the drilling of seashells and mussel shells was microscopically observed at any time using a stereo microscope XTL-165-XTWZ2T to explore the effect of different drilling tools on the drilling effect.

### **Preparation of Experiment**

Prehistoric shellfish material with holes mainly consists of freshwater shellfish and seawater shellfish, freshwater shellfish such as mussels, and seawater shellfish such as clams, conchs, scallops, et cetera. Considering that early drilling techniques were mainly locally sourced, a field collection of wood needed for making drilling tools and mussels and seashells needed for the materials used for drilling is necessary (Figure 8a). Experimentally collected seashells included *Cyclina sinensis*, *Macraa veneriformis*, *Reeve* and *Ruditapes philippinarum*, and prepared seashells included *Monetaria moneta*, *Monetaria annulus*, *Monetaria caputserpentis* (Figure 8b). The collected and prepared seashells were then screened and cleaned based on the size of the perforated shell ornaments from the archaeological excavation process, from which medium-sized and undamaged seashells were selected. The mussel shells collected for the experiment included freshwater mussels (Figure 8c). The screening method was the same as for seashells, and the mussel shells

were intercepted after cleaning to obtain freshwater mussel materials that were flatter and less curved (Figure 8d).



**Figure 8.** *a. Gathering of seashells. (Photo taken by Author, March 2023). b. Gathered and prepared seashell materials. (Photo taken by Author, April 2023). c. Prepared a freshwater mussel shell. (Photo taken by Author, April 2023). d. Intercepted a freshwater mussel material. (Photo taken by Author, April 2023).*

Although wood materials can be affected by environmental factors during burial and are not easily retained, the experiment still included them in consideration of components for the composite drilling tool. At the end of the organization and screening of the shellfish material, branches were picked up from a location closer to the experiment, straighter and more intact branches were selected whenever possible, and selected branches were sorted according to the size of their diameter (Figure 9). Tools were used to peel off the bark from the branches of the trees, making the wooden poles smoother.

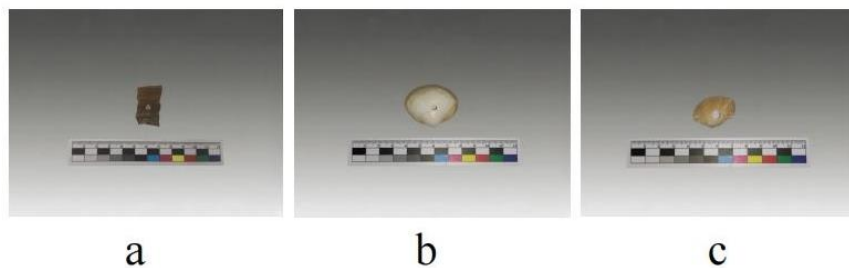
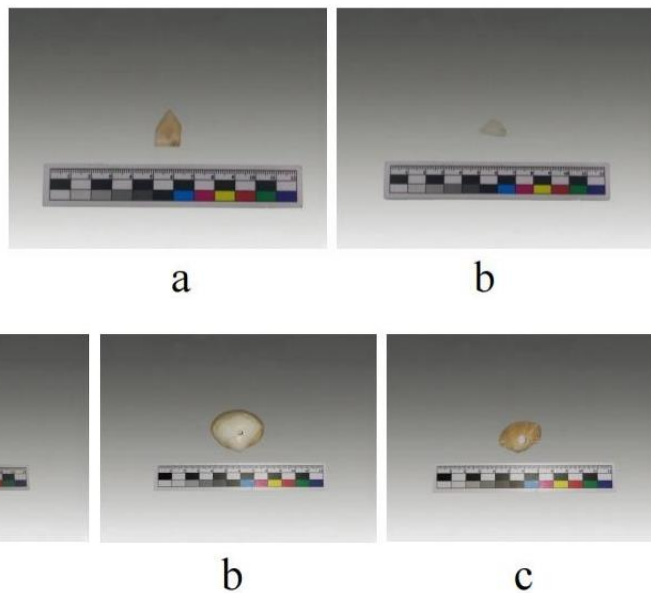
**Figure 9.** *Collection of tree branches. (Photo taken by Author, April 2023).*



## Experiment 1

Stone drill bits of materials selected flint stone, stone colour is yellow, the texture is pure, and impurities. The stone will use a bipolar technique after the formation of stone pieces, after the repair of the two ends to form a more prominent sharp tip, to get stone drill bits a and stone drill bits b. The drilling is done by the bipolar technique where the stone drill bits are first pressed against the top of the seashells and mussels to find a suitable smashing point. Then, the stone drill bits are struck using stones to leave an irregularly shaped hole in the surface of the freshwater mussels and seashells.

**Figure 10.** a. Stone drill bit a. (Photo taken by Author, April 2023). b. Stone drill bit b. (Photo taken by Author, April 2023).



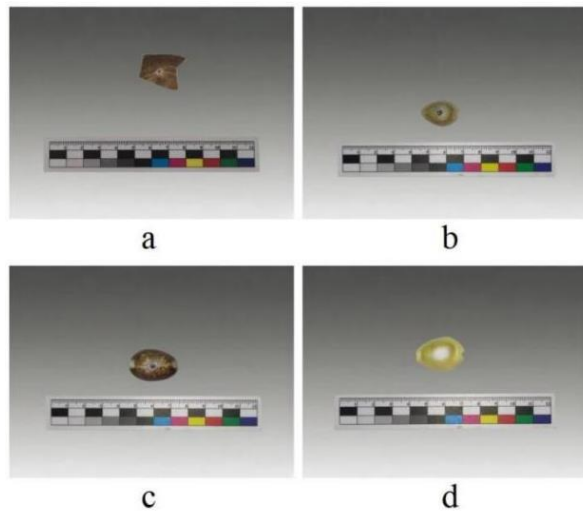
**Figure 11.** a. Perforated freshwater mussel material by bipolar technique. (Photo taken by Author, April 2023). b. Perforated *Macraa veneriformis*, Reeue by bipolar technique. (Photo taken by Author, April 2023). c. Perforated *Ruditapes philippinarum* by bipolar technique. (Photo taken by Author, April 2023).

Considering the phenomenon of freshwater mussel shells and seashells excavated from archaeological sites, the experiment should also make use of the stone drills used in the experiment to grind and drill freshwater mussel shells, select a point on the convex side of the mussel shells, and rotate the

stone drill bit with bare hands at this point, repeat the rotation many times until a small hole is ground out (Figure 12a). A point was selected on the smoother side of the seashells, and the drilling method and process were consistent with using freshwater mussel shells for grinding and drilling, resulting in an oval-shaped hole (Figure 12b-12d).

The drilled mussel shells and seashells were microscopically observed using a stereo microscope at 7x magnification.

**Figure 12.** a. Perforated freshwater mussel material by grinding method. (Photo taken by Author, April 2023). b. Perforated *Monetaria annulus* by grinding method. (Photo taken by Author, April 2023). c. Perforated *Monetaria caputserpentis* by grinding method. (Photo taken by Author, April 2023). d. Perforated *Monetaria moneta* by grinding method. (Photo taken by Author, April 2023).



## Experiment 2

Experiment 2 used the collection of a large amount of material in the course of the preparatory work to reconstruct prehistoric wooden drilling tools. Since it is too old to find the actual object in archaeological excavations, it was still possible to restore the appearance of the wooden composite drilling tool through the traces of the artifacts.

Wooden Composite Drilling Tool A: Choose one end of a long wooden pole to make a groove, embed the stone drill bits made in Experiment 1 into the groove of the wooden pole, use a coarse hemp rope composed of natural plant

fibers to wind the stone drill bits so that fixed in the grooves of the wooden pole (Figure 13), and rotate the wooden pole after the making of the drilling tool to try to drill freshwater mussel shells using this tool.

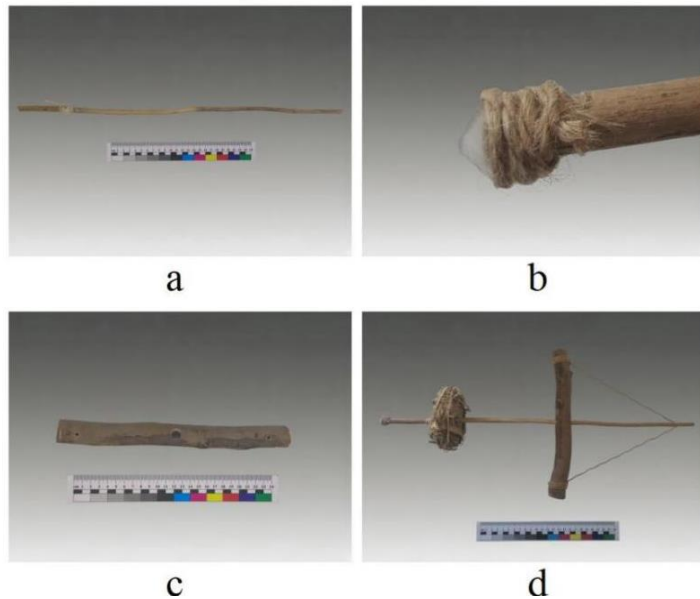


**Figure 13.** *Wooden Composite Drilling Tool A. (Photo taken by Author, April 2023).*

Wooden Composite Drilling Tool B: The same pre-production process was used for the wooden drilling tool A. A hole was pierced through the top end of the long wooden pole (Figure 14a), a groove was made in the lower end of the selected wooden pole, and the stone drill bits made in experiment 1 were embedded in the groove of the wooden pole and wrapped using thin twine (Figure 14b) Choose a short length of wood to act as a short shank, and pierce a giant diameter hole in the centre of the shank, slightly larger than the width of the long shank, and then pierce a smaller diameter hole in each of the left and right sides of the short shank. Subsequently, the short-shanked wooden pole (Figure 14c) was inserted into the long-shanked pole. The two holes of the smaller diameter of the short-shanked pole and the one located at the upper end of the long-shanked pole were threaded using coarse sisal twine to form a triangular structure. The remaining coarse sisal twine was wrapped around the left and right ends of the short-shanked pole. The perforated heavy stone with

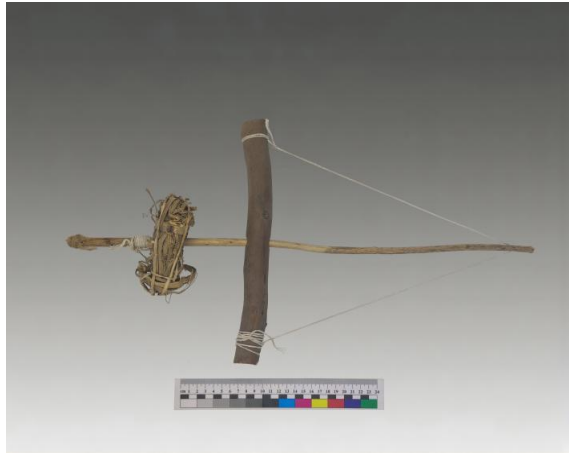
the cornstalks wrapped around it was placed above the stone drill bits at the end of the wooden pole. Once the drilling tool was made, attempts were made to drill freshwater mussel shells using the already-made wooden drilling tool B (Figure 14d).

**Figure 14.** *a. The long wooden. (Photo taken by Author, April 2023). b. Stone drill bits and wooden poles wrapped in thin twine. (Photo taken by Author, April 2023). c. Short shank. (Photo taken by Author, April 2023). d. Wooden Composite Drilling Tool B. (Photo taken by Author, April 2023).*

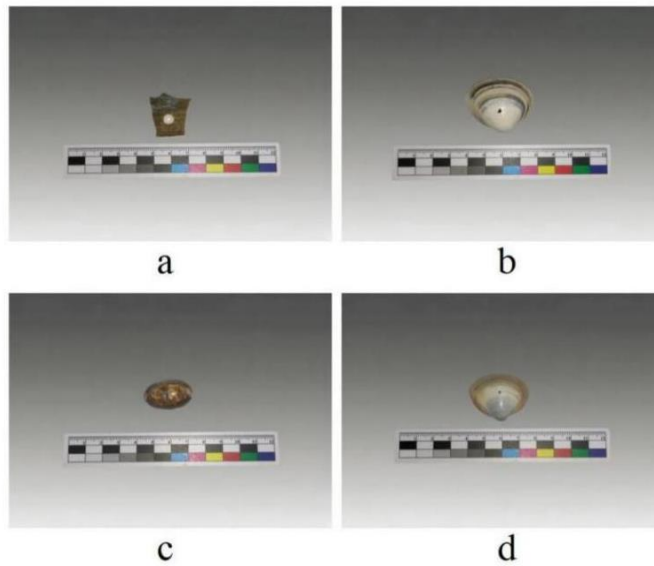


Wooden Composite Drilling Tool C: Wooden Drilling Tool C (Fig. 32) is reworked based on Wooden Drilling Tool B. Unlike Wooden Drilling Tool B, the rope used in Tool C is a fine rope, and the perforated weight stone used is first wrapped around with cornstalks, as much as possible, on one side of the outer edge of the perforated weight stone, and then placed at the end position of the long wooden pole.

**Figure 15.** *Wooden Composite Drilling Tool C. (Photo taken by Author, April 2023).*



Once the drilling tool was made, it was used to drill holes in the freshwater mussel shells and selected seashells. During the drilling process, a drilling point was first found on the drilled material, and then the stone drill bits of the drilling tool were aimed at this point. Then, the short-handled wooden pole was pressed downward by hand until several winding circles appeared on the top of the long wooden pole. Then, the short-handled wooden pole was pushed upward by the effect of inertia. The cycle was repeated until the freshwater mussel shells and seashells were perforated entirely, and then it stopped running to get perforated materials (Figure 16). In jamming, it is necessary to manually rotate the long wooden rod to restore the dynamics of the drilling tool, enabling it to operate again.



**Figure 16. a.** Perforated freshwater mussel material by wooden Composite Drilling Tool C. (Photo taken by Author, April 2023). **b.** Perforated *Cyclina sinensis* by wooden Composite Drilling Tool C. (Photo taken by Author, April 2023). **c.** Perforated *Monetaria caputserpentis* by wooden Composite Drilling Tool C. (Photo taken by Author, April 2023). **d.** Perforated *Mactra veneriformis*, Reeue by wooden Composite Drilling Tool C. (Photo taken by Author, April 2023).

## Results & Analysis

Drilling effectiveness is closely linked to the type of drilling tool, as the hardness of the drilling material chosen for the drilling process is different, for example, the drilling method and the making of the drilling tool may be customized to suit the characteristics of the drilling material. In addition, drilling efficiency may be related to the dynamics of the drilling tool when using the same texture of the drilling material, with the use of a composite drilling tool resulting in more efficient drilling than the use of stone drill bits.

In terms of a single drilling tool, the results of Experiment 1 show that the use of stone drill bits can be used to drill freshwater mussel shells and seashells, and there is a close relationship between the use of drilling tools and the characteristics of the drilling material, the drilling process use of grinding for drilling. Due to the fragile texture of freshwater mussel shells and their roughness, it is easier to find the drilling point, increasing the drilling process's efficiency. Under the same conditions, the drilling of seashells, due to its more complicated and smoother texture characteristics, makes it challenging to find the drilling point, and the phenomenon of slippage often occurs, resulting in a reduction in drilling efficiency.

In the case of freshwater mussel shells, due to the fragile nature of the freshwater mussel shells, the drilling material may be easily damaged during the initial stage of drilling and may break. Similarly, although the texture of seashells is relatively complicated compared to freshwater mussel shells, if a person who is not skilled in drilling is allowed to drill the holes, the drilling material will be subjected to too much impact due to over-exertion of force, and it will also be fractured. The drilling method used in excavating freshwater mussels and seashells is a choice made by the ancients through the accumulation of long-term practice and according to the hardness and smoothness of the drilling material.

Concerning the composite drilling tool, the experimental results show that the drilling effect is related to the dynamic conditions of the drilling tool. Composite Drilling Tool A and Composite Drilling Tool B consume too much manual pulling force and fail to achieve the effect of saving labour. Although Composite Drilling Tool B forms a triangular rod bearing, which can stabilise the axis of the drilling tool and play a balancing role, because the use of the rope is too rough, the friction between the rope and the rod is too large, which

hinders the inertia produced by the drilling tool in the process of operation and fails to achieve the effect of the dynamics of the Composite Drilling Tool C. Therefore, there is likely an operational process of component commissioning before drilling with the composite drilling tool.

The experiment shows that the drilling effect is also related to the bending degree of the long wooden pole. Using a straighter wooden pole as the long wooden pole can keep the centre of gravity of the drilling tool on the stone drill bits, increasing the number of winding loops of the rope and increasing the rotational speed of the drilling tool, and the dynamics have been maintained. The use of bent wooden poles as long poles will easily cause the centre of gravity of the drilling tool to deviate, resulting in the stone drill bits not being able to stay stably at the drilling point of gravity, leading to a reduction in the number of wrapped turns of the rope, a reduction in the rotational speed of the drilling tool, and a loss of dynamics. In conjunction with the results of the experiments, if flat, straight wooden poles that can be shanked are found at archaeological sites, it may be possible to speculate that they may have had the ability to drill holes based on the selection of material for the drilling tools.

The perforated weight stone of Composite Drilling Tool B and Composite Drilling Tool C is of significance to improving drilling efficiency. In the drilling process, the perforated weight stone can increase the overall weight of the drilling tools so that the stone drill bits have been kept on the relatively stable drilling holes without deviation and play a balancing and stabilizing role for the centre of gravity, resulting in the dynamics of the drilling tools being guaranteed. In conjunction with the experimental results, it may be possible to decipher the function of perforated weight stones excavated from

archaeological sites, suggesting that they could have acted as a counterweight as part of a composite drilling tool.

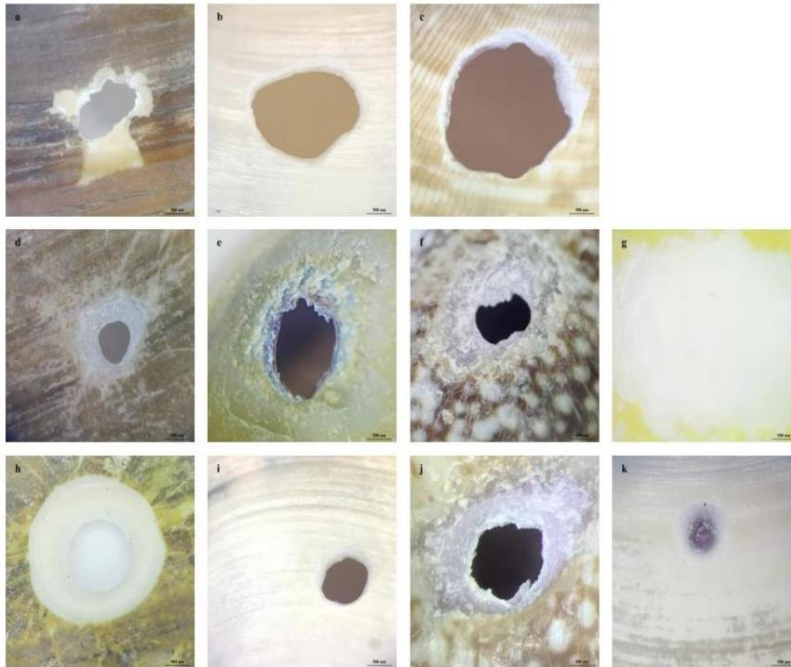
Cornstalks are used to prevent and protect against accidents during the drilling process. During the making of Composite Drilling Tool B and Composite Drilling Tool C, the cornstalks are wrapped around the perforated weight stone on one side of the outer edge. If the perforated weight stone is not wrapped, it is likely to accidentally injure the hand due to the sharpness and roughness of the outer edge of the perforated weight stone when the tool is running at high speeds. Therefore, wrapping the perforated weight stone with cornstalks protects the hand.

The effect of the drilling tool on the drilling effect was significant, as shown by stereomicroscopic observation (Figure 17). the shape of the holes obtained from drilling the material with holes using stone drill bits is round mainly or nearly oval irregular shape. The edges of the holes are primarily jagged, while the shape of the holes obtained from the material with holes using the composite drilling tool is primarily round, and the edges are Un-jagged. The ability to drill holes is also related to the drilling tool's hardness, smoothness, and wear. The use of lower hardness or thinner stone drill bits was unable to drill holes in harder and smoother seashells, leaving only traces of wear and tear on the surface, as shown in Figure 12d and Figure 17g. The drill bits of the composite drilling tools need to be polished in the process of use to increase the sharpness of the drill bits. If not polished, it will make the stone drill bits blunt, resulting in the appearance of jagged material with holes, as shown in Figure 16c and Figure 17j. In addition, the drill bits need to be replaced on time in the case of long-term use to ensure the drilling efficiency of the drilling tools. The microscopic observation of these perforated materials is similar to the actual visual observation. Suppose the perforated materials are

found in the archaeological sites. In that case, the drilling tools and methods can be deduced based on the perforated materials' traces, experimental results, and microscopic observation.

No.	Perforated Materials	Drilling Tools	Drilling Methods	Photo No.	Stereomicroscopic Observation			Hardness Degree	Smoothness Degree
					Hole Formation Situation	Drilled Holes Shape	Drilled Holes Edge		
1	Freshwater mussel shell	Stone drill bit	Bipolar technique	17a	√	Irregular shape, nearly oval	Jagged	General	General
2	<i>Mactra veneriformis</i> , Reeue	Stone drill bit	Bipolar technique	17b	√	Irregular shape, nearly oval	Jagged	Hard	Smooth
3	<i>Ruditapes philippinarum</i>	Stone drill bit	Bipolar technique	17c	√	Irregular shape, nearly oval	Jagged	Hard	Smooth
4	Freshwater mussel shell	Stone drill bit	Grind method	17d	√	Oval	Un-jagged	General	General
5	<i>Monetaria annulus</i>	Stone drill bit	Grind method	17e	√	Oval	Un-jagged	Hard	Smooother
6	<i>Monetaria caputserpentis</i>	Stone drill bit	Grind method	17f	√	Irregular shape, nearly oval	Smooth, partly jagged	General	Smooother
7	<i>Monetaria moneta</i>	Stone drill bit	Drill with stone drill bit	17g	×	/	/	Harder	Smooother
8	Freshwater mussel shell	Composite Drilling Tool C	Drill with tool C	17h	√	Round	Un-jagged	General	General
9	<i>Cyclina sinensis</i>	Composite Drilling Tool C	Drill with tool C	17i	√	Nearly round	Un-jagged	Hard	Smooth
10	<i>Monetaria caputserpentis</i>	Composite Drilling Tool C	Drill with tool C	17j	√	Nearly round	Jagged	Hard	Smooth
11	<i>Mactra veneriformis</i> , Reeue	Composite Drilling Tool C	Drill with tool C	17k	×	Round	smooth	Hard	Smooth

**Table 1.** List of information on perforated freshwater mussel materials and perforated seashell materials produced in Experiment 1 and Experiment 2.



**Figure 17.** Perforated freshwater mussel materials and perforated seashell materials at 7x magnification of the stereo microscope. (Photo taken by Author, April, 2023.)

## Discussion

Multiple drilling, it was found that the drilling effect of the composite drilling tool was better than that of the single drilling tool, and the operation of the composite drilling tool existed in a rotational process, with the stone drill bits as the point of focus, which presented a rounded shape of the drilled holes during the rotation. It was found that the drilling marks on the material with holes were different using different drilling methods, the shape of the drilled holes using the bipolar technique were mostly irregular shapes close to an ellipse with noticeable jagged edges of the holes, the shape of the drilled holes using the grinding method were mostly oval shapes with partially Un-jagged edges of the holes, and the shapes of the holes using the composite drilling tool were mostly round with smoother edges of the holes. As the direction of

drilling involved in the experiments was mostly unidirectional, the perforated shellfish materials were mainly characterized by the equal size of the inner and outer holes.

Perhaps accordingly, it is possible to interpret further the traces on perforated shellfish materials found at archaeological sites. Some perforated shellfish materials found at archaeological sites present drilling traces similar to those observed experimentally (Figure 16a and Figure 17h), such as a freshwater mussel ornament No. S12A: 025 excavated from the Shizitan site in Shanxi (Figure 1c; Song and Shi, 2013), which retains the lip of the mussel body as a whole, with the rest of the mussel piece edges slightly oval, and which the researchers believe should have been drilled in a The researchers believe that the drilling method should be unidirectional, and the drilling traces are characterized by the juxtaposition of two holes and the exact size of the two holes. Similar drilling traces have been found in many prehistoric sites in China. Combined with experiments, the shape, edges, and hole diameters of the drilling traces can be used to speculate on the drilling tools and methods used by people at that time.

In addition to the drilling effect, the technology applied in the production process of drilling tools is also worthy of attention, such as in the production process of composite drilling tools used in the shanking technology, which is a kind of technology that can be assembled into a composite tool of stone tools and handles, which can improve the utilization rate of the stone tools and the use of tools, and at the same time, the producers are required to have a pre-design and include a series of processes such as production, assembly, and maintenance ( Lombard, 2005), and the materials and methods used for bundling has a certain complexity that reflects the more advanced cognitive and behavioral capabilities of humans (Zhang et al., 2010).

The drilling process also faces various challenges and choices; in this case, the experimenter acts as an ancient craftsman, relying on the drilling material and properties to find a good drilling solution to solve the difficulties faced in the drilling process. Combined with the experimental results mentioned in the previous section, in the drilling process of the composite drilling tool, the experimenter made changes in the drilling program for the characteristics of the sea shell material and adopted the direct drilling method at the initial stage. However, after a few attempts, slipping the drill bit appeared, making it difficult for the drilling tool to find a stress point to pierce the holes. It also forced the experimenter to change the way of thinking and make adjustments and improvement measures for the drilling process, considering the smooth characteristics of the sea shell material. At the same time, the experimenter had to change his thinking and make adjustments and improvements by combining the smoothness of the sea shell material with the characteristics of the stone drill bits, firstly, using the stone drill bits to rotate on the surface of the sea shells in a small degree to form a small concave point, and secondly, drilling the holes on the small concave point, in which way the drilling effect was significantly improved. The reason that the drilling effect improved may be linked to the subjective judgment and proficiency of the experimenter. Therefore, combining the subjective feelings of the experimenter in the drilling process, it can be speculated that the ancient artisans were strategic in the drilling process

## **Conclusion**

As far as the experimental reconstruction of Chinese drilling tools is concerned, since there are few archaeological discoveries of drilling tools from prehistoric China, we can only rely on the traces left on finished or semi-finished products of perforated materials found at archaeological sites, as well

as artifacts that may be related to drilling tools found at archaeological sites, to speculate on the drilling tools and methods of drilling at that time. Experimental archaeology is like a bridge between the past and the present. Through the systematic understanding and analysis of excavated hole-carrying materials and drilling tools, experiments on drilling tools are designed and carried out, transforming static archaeological remains into dynamic experimental processes. It is an analytical method transformed into a dynamic process and product through simulated reconstruction.

Many experimental factors are involved in the reconstruction process, such as type of perforated materials, smoothness, hardness, method of drilling, composition of drilling tool components, and proficiency level to discuss the relationship between drilling materials and drilling tools and methods of drilling. The experiment's stone drill bits and wooden composite drilling tools can drill holes in seashells and freshwater mussels. The dynamics of the composite drilling tool and the addition of critical components affect the drilling effect. The composite drilling tool performs better than stone drill bits in the drilling process, and the drilling traces tend to be smooth and round. The key components are evident in the drilling effect of the composite drilling tools, which will indirectly affect the dynamics of the drilling tools, such as perforated weight stone and the smoothness of the wood poles. The features of the shellfish materials will also indirectly affect the drilling results, such as the roughness and hardness of the shellfish materials. Furthermore, due to the high dynamics and timeliness of the composite drilling tool and its possible use in the processing of shellfish products, it is likely to be applied to jade and stone processing and bone processing to improve the drilling efficiency.

Since the experimental process contains many experimental factors containing various small details, it is challenging to fully reproduce the ancient people's

drilling tools and drilling techniques by relying on more than one reconstruction. The reconstruction of the drilling tools involved in the experiment mainly focuses on the strategies and choices of the drilling tools and shellfish drilling techniques from the perspective of the ancient artisans concerning the drilling materials, in the hope of contributing to the understanding of the drilling traces on the perforated shellfish materials found at the archaeological sites.

## References

Chen C and Zhang ZF (1986) Mopandun shizuan yanjiu. *Southeast Culture* 01: 140-141 (in Chinese).

Chen W and Kuang HB and Zhang Q (eds) (2020) Brief investigation report of Pre-Qin Sites in the Bailong River Basin (Zoige Section). *Sichuan Cultural Relics* 06: 6-7 (in Chinese).

Chen YB (2009) Shiqian yizhi qiwu chuankong tanyuan. *Prehistory*: 221, 224 (in Chinese).

Gai P and Wei Q (1977) Discovery of the Late Palaeolithic Site at Hutouliang, Hebei. *Vertebrata Palasiatica* 15(4): 297 (in Chinese).

Gu YC (1995) An experimental study on drill tools from Xianrendong Site. *Acta Anthropologica Sinica* 14 (03): 220-221, 225 (in Chinese).

Huang WW and Zhang ZH and Fu RY (eds) (1986) Bone artifacts, ornaments from Xiaogushan Site of Haicheng, Liaoning Province. *Acta Anthropologica Sinica* 5(03): 262-263 (in Chinese).

Institute of Archaeology, Chinese Academy of Social Science and Archaeological Team of the Guangxi Zhuang Autonomous Region and

Zengpiyan Site Museum (eds) (2003) *Guilin Zengpiyan*. Beijing: Cultural Relics Press, 107, 231 (in Chinese).

Ji P and Zheng JF (2017) The excavation of the locality D of the Nan Baoligaotu Site in Jarud Banner, Inner Mongolia. *Kaogu* 12: 36 (in Chinese).

Jia LP (1951) *Shandong Ren (Shandong Man)*. Beijing: Longmen Lianhe Shuju, 70 (in Chinese).

Li Z (2004) *Zhongguo Chuantong Jianzhu Muzuo Gongju*. Shanghai: Tongji University Press, 188 (in Chinese).

Lombard M (2005) Evidence of hunting and hafting during the Middle Stone Age at Sibidu Cave, KwaZulu-Natal, South Africa: a multianalytical approach. *Journal of Human Evolution* 48(03): 279-300.

Pei WC (1935) On a Mesolithic (?) industry of the caves of Kwangsi. *Bulletin of the Geological Society of China* 14(3): 3.

Song YH and Shi JM (2013) Research on the ornaments unearthed from the Shizitan Site of the Paleolithic Age in Jixian County, Shanxi. *Kaogu* 08: 50, 53 (in Chinese).

Song YX (written in 1637) and Pan JX (translated in 2016) *Tiangong Kaiwu Yizhu*. Shanghai: Shanghai Guji Chubanshe, 193 (in Chinese).

Tang BC (2023) Discrimination and analysis of the difference between experimental archaeology and laboratory archaeology. *Journal of Baoding University* 36(01): 42-43 (in Chinese).

Wang Q (2009) Discussion on Prehistory Perforation. *Sichuan Cultural Relics* 06: 46-48, 52 (in Chinese).

Wanyan LQ and Li FY (written in 1836) (published in 2015) Hegong Qiju Tushuo. Hangzhou: Zhejiang People's Fine Arts Publishing House, 309 (in Chinese).

Zhang XL and Chen C and Gao X (eds) (2010) Weihe fenxi queren wannian qian de fuhe gongju yu qi gongneng. *Chinese Science Bulletin* 55(03): 234 (in Chinese).

Zhang ZF and Zhou XL and Yan F (1985) Jiangsu dantu mopandun yizhi fajue baogao. *Prehistory* 02:74-76 (in Chinese).

Zhou GX (2007) Shiqi shidai de "wanneng gongju": chuankong lishi huo chuankong shi (zhongshi). *Nongyekaogu* 01: 143, 147 (in Chinese).