RECONSTRUCTING MANUFACTURING TECHNOLOGY AND TECHNOLOGICAL ORGANISATION AT THE QIJIA *JUE* EARRING WORKSHOP IN WESTERN ZHOU (1046-771 BC) CHINA

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ABSTRACT

This paper discusses the pattern of Qijia jue production in the Western Zhou dynasty at the predynastic capital site of Zhouyuan, from the aspects of manufacturing technology and technological organisation. The Qijia workshop exemplifies the use of natural resources in the local environment, in an operation based on principles of production efficiency, from raw material procurement to final manufacture. The reconstruction of manufacturing technology shows that jue production did not require much technological investment or complicated facilities, and that it could have been carried out under a "holistic" organisation of technology, where each working group was responsible for the full range of manufacturing steps from preforming to final refining.

INTRODUCTION

Degree of technological complexity has long been viewed as connected to the organisation of production. As a result, it is often used as evidence for identifying a particular type of organisation of production or degree of organisational complexity (Costin 2001:288). While some previous studies of craft technology focused narrowly on the reconstruction of manufacturing techniques (e.g. O'Neil 1974; Arnold 1985), many recent studies emphasise the role and meaning of technology in society, the relationship between technological strategies and socio-economic organisation, and the social/political implications of difference in technology. This paper is such an attempt to link technology with the organisation of production, through an analysis of manufacturing debris unearthed from the Qijia *jue* workshop in the site of Zhouyuan, central western China. Issues such as manufacturing technology, tool utilisation and the way production was organised will be studied from an archaeological point of view.

THE PREDYNASTIC CAPITAL SITE OF ZHOUYUAN AND THE QIJIA *JUE*-EARRINGS WORKSHOP

Zhouyuan was the administrative centre of the Zhou during the reigns of Danfu, Jili and King Wen in the time before the Great Conquest of the Shang (ca. 1046 BC). It is located in the western part of Central Shaanxi Plain, ranging 6 km from east to west and 5 km from north to south with an area of over 30 square km (Xu 2002) (Figure 1). Here, the Zhou people built the new capital city of Qiyi, which archaeologists normally refer to as Zhouyuan following the poem of Mian in *Shijing*. Archaeological studies and historical documentation indicate that Zhouyuan remained an important site for aristocratic residences and royal temples, and probably was still used for ritual worship after the capital was moved to Feng-Hao with the establishment of the Western Zhou dynasty (1046-771 BC) (Chen 1979; Zhu 1988; Zhang 2002).

The Qijia workshop is located in the heartland of Zhouyuan, 300 m north of Qijia village and 3 km south of Mount Qi (Figure 2). It measures about 100 m from east to west and 90 m from north to south, covering an area of over 0.9 ha. The data utilised in this paper are derived from the excavation of the Qijia workshop from September 2002 to January 2003 by the Zhouyuan Archaeological Team. A total of 96 pits, 7 house foundations and 40 tombs were excavated, of which 37 pits and 6 house foundations contained lithic debris resulting from the manufacture of *jue* (Fig. 3). The ceramic chronology suggests that the Qijia workshop activity started in the Early Western Zhou, possibly prospered in the Middle Western Zhou and eventually declined in the Late Western Zhou.

The lithic debitage unearthed from the Qijia workshop comprised three major categories: manufacturing wasters (15.3%, total weight over 164 kg); production debris (80.8%, total weight over 870 kg) and stone tools (3.9%, total weight over 42 kg) (Figure 4). These materials clearly demonstrated that the Qijia workshop specialised in the manufacture of *jue* earrings. Five major raw materials were identified, including schist, marlite, limestone, calcite, and quartzite. In addition, small quantities of co-products including stone knives and other decorative lithic ornaments (accounting for 0.2% of the entire weight) were occasionally produced in this workshop, as is evident from their manufacturing failures.

A *jue* is a round flat penannular ring with a narrow opening, in China usually made of jade or other types of stone (Figure 5). This artefact type is believed to have

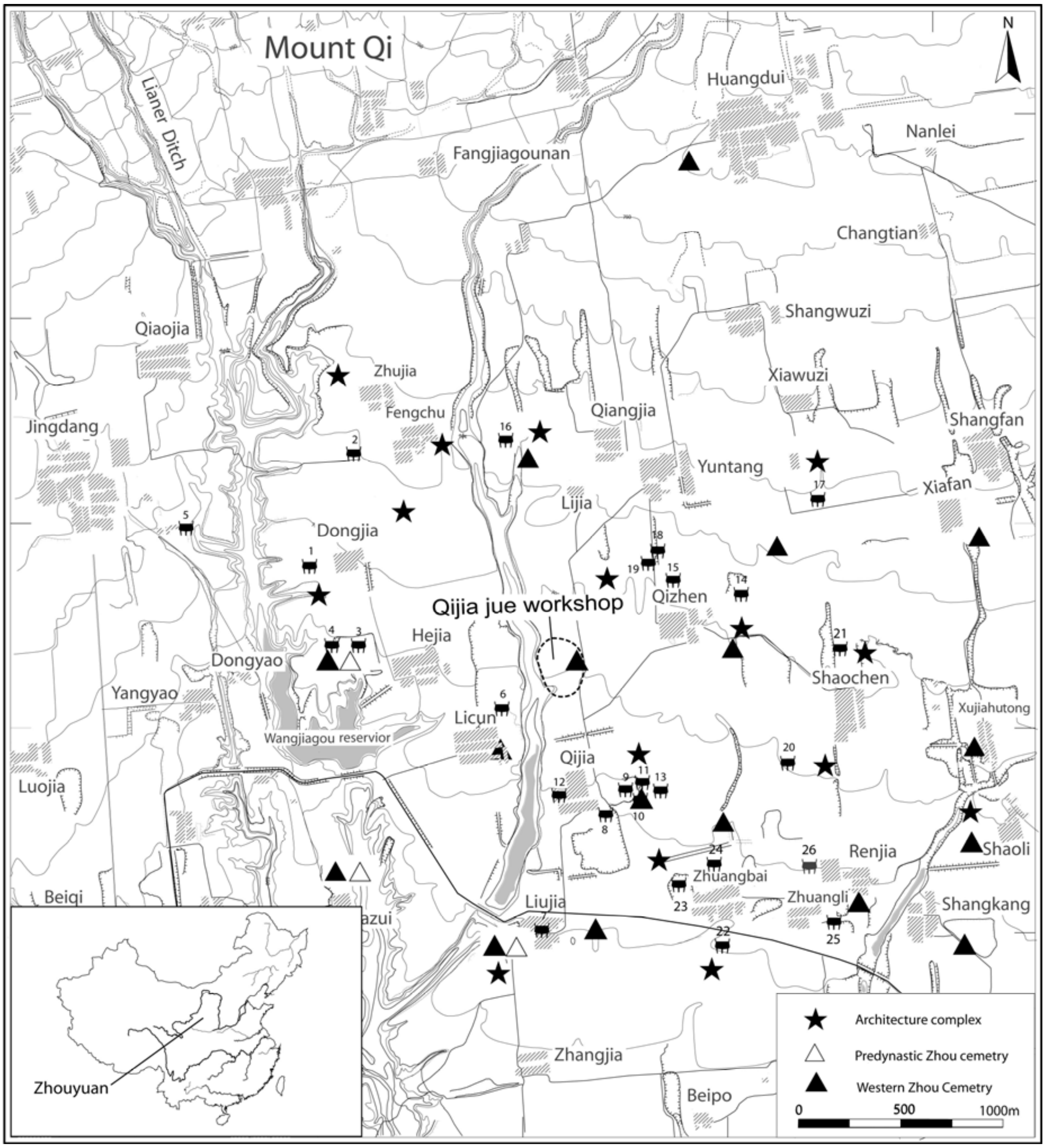

Figure 1. Map of the Zhouyuan archaeological region.

originated in China, and spread from north to south through East and Southeast Asia during the Neolithic period (Tang 2000). As *jue* are sometimes found in burial contexts on both sides of the body near the deceased's ears orclose to the upper shoulders, they are commonly interpreted as earrings, and sometimes as mouth fillers or neck pendants. The use of *jue* as ear ornaments was prevalent during the Shang and Zhou dynasties (An 1984), expanding in the Spring and Autumn period (771-475 BC) but eventually vanishing during the Han dynasty (206 BC-AD 220) (Xia 1983; Sun 2003). *Jue* in the Western Zhou dynasty were used in large numbers by different social groups without reference to socio-economic status (Sun 2003:112; Huang 2004). The Qijia workshop, as the first archaeologically identified *jue* manufacturing site in mainland China dating to the historical period, enables us to reconstruct manufacturing technology and technological organisation from a broader perspective.

JUE MANUFACTURING PROCEDURES

Reconstruction of the various stages of *jue* production is based mainly on manufacturing wasters and the stone tools, in conjunction with my replica experiment (described below). The manufacturing sequence can be divided into four major stages:

Stage I. Preparation: prospecting, quarrying and raw material transportation;

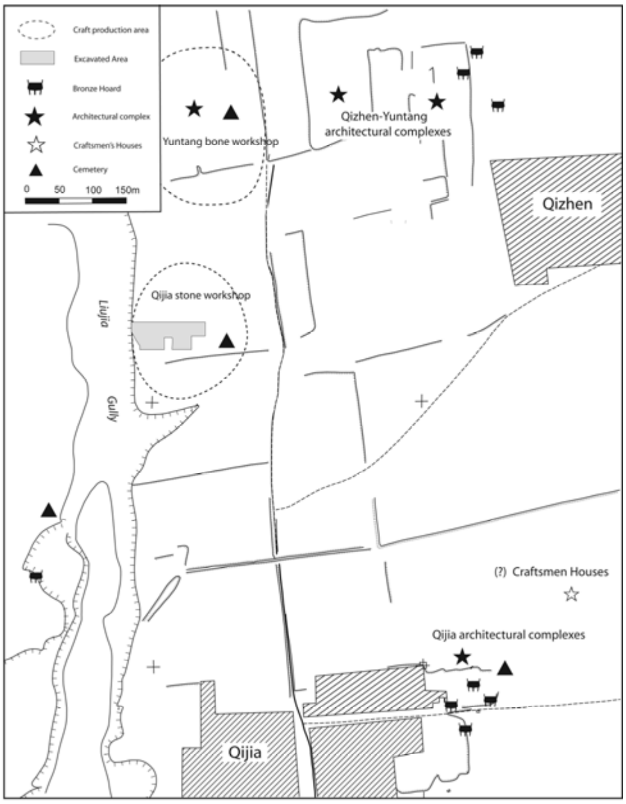

Figure 2. Location of the Qijia workshop and nearby sites.

Stage II. Preforming: chipping, pecking, trimming and grinding;
Stage III. Perforation: chiselling and drilling;
Stage IV. Refining: sawing a radial opening across the annulus, polishing the interior, and decoration.

Stage I: Preparation

The first step in *jue* production is to obtain a suitable raw material. All materials used in the Qijia workshop were acquired from the immediate vicinity of Zhouyuan, where there are several geological sources located roughly 3-5 km from the workshop and visually identical to those used for the *jue* production. It is likely that primary thinning and outlining were completed before transportation to the workshop area, since our excavation did not yield any large primary flakes. The rocks used at Qijia were not of particularly high quality and are present over a wide area, so access to sources was probably unrestricted.

Stage II: Preforming

Chipping, pecking and trimming

After the raw material was transported into the workshop, the next stage was to manufacture *jue* preforms (Figure 6). The process was divided into two consecutive steps. First, blanks were flaked and pecked by direct percussion in order to approach the intended shape. The second step was to remove any flaking scars and unwanted protuberances by trimming and pecking (Figure 7:1). Normally, trimming was carefully applied from the edges in order to form a circular shape. If unsuitable in dimension or shape, some complete preforms were rejected at this stage in the production process.

Tools associated with *jue* preform manufacture include percussion tools and anvil stones (Figure 8). The percussion tool served as an active tool through which forces were applied by the craftsmen, and the anvil stone served as a pad which allowed the worked material to be stabilised. The elongated large percussion tools were possibly used to detach the preforms from large blanks, whereas the smaller spherical percussion tools are more likely to have been utilised in the finer preforming processes. Anvil stones are usually flatter in shape and larger in size than percussion tools.

Grinding

After the preform was retouched, a formalised outline would have been ready for grinding (Figures 7:2, 7:3). Wasters with manufacturing errors from this stage are called 'ground preforms' (Figure 6). The major tools used in this process are grindstones of various shapes (Figure 9).

Striations left on the ventral surfaces of ground preforms are either parallel or diagonal, indicating that grinding might have been multi-directional. Some have highly regular patterns. Others are more randomly distributed or aligned. Besides the surface smoothing, the sides also needed to be ground. The tools used for this have been classified as having U-shaped or V shaped grooves (Figure. 9:1-3).

Stage III: Perforation

The third stage in *jue* manufacture is to perforate the preform. The basic sequence is divided into three steps:

1. bifacial/unifacial chiselling of a shallow depression in the centre of a ground preform (Figure 10a);
2. bifacial/unifacial enlarging of the depression by further pecking, so as to obtain a desirable hole for facilitating drilling in step 3 (Figure 10b);
3. bifacial/unifacial refining of the previously pecked hole by rotary drilling (Figure 10c).[1]

Chiselling and pecking

In order to achieve a desirable hole size, the Qijia craftsmen did not initially rely on drilling because it was so time-consuming. For the sake of efficiency, chiselling was employed in the initial stage of perforation (Figure 7:4), then a ready-made shallow depression would be continuously worked by further pecking. The tools used for chiselling and further pecking remain unknown. According to traces left on the ventral surfaces of sample products, the depressions might have been started by using a kind of bone chisel or awl, or the pointed end of deer antler. In my replica experiment, I stabilised the worked preforms on a wooden anvil and then used a pointed wood stick to perform the chiselling. In this way I successfully made the depressions, and reduced the frequency of potential incidental breakage. This may be further demonstrated with additional ethnographic and archaeological evidence in the future.

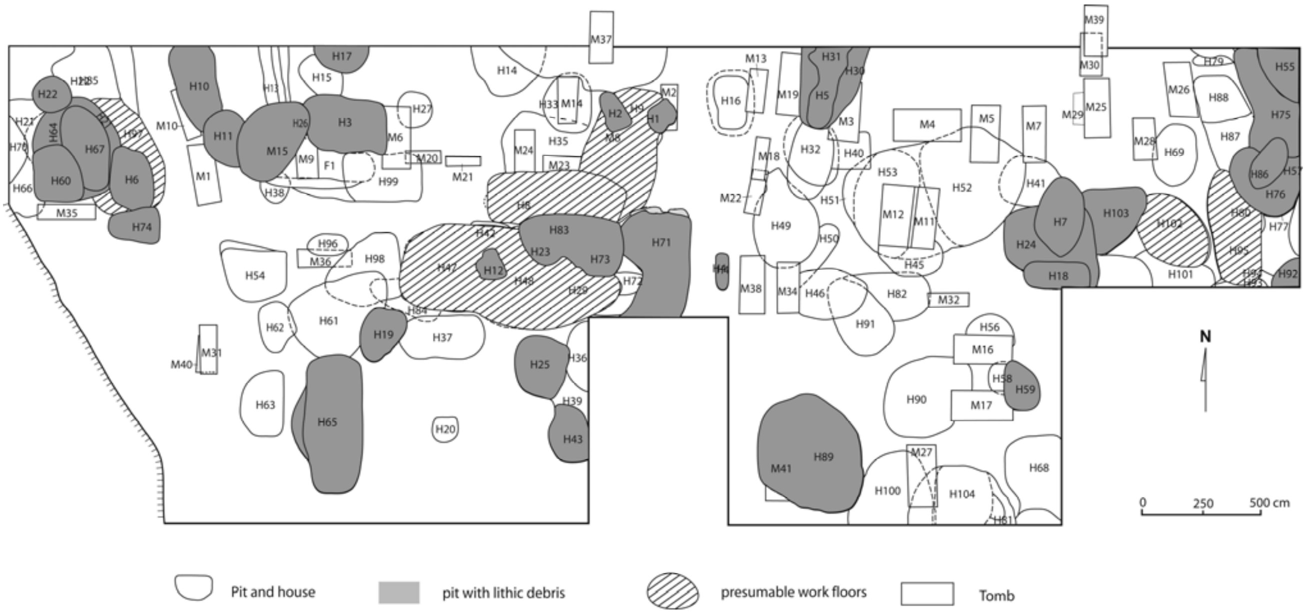

Figure 3. The distribution of archaeological features in the 2002 excavation at Qijia.

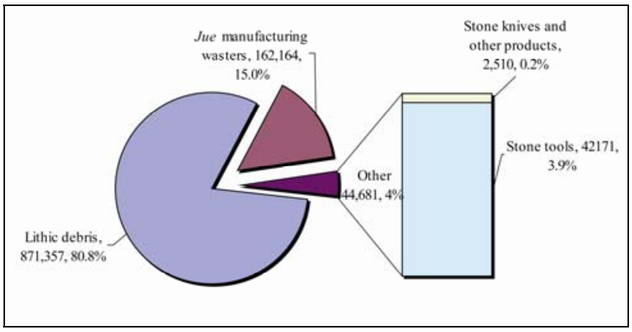

Figure 4. Pie-chart showing the proportion by weight (gm) of lithic remains recovered from the Qijia workshop.

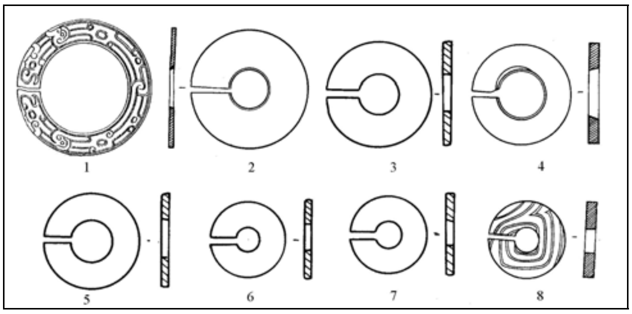

Figure 5. Jue *unearthed from the Western Zhou tombs.*

Drilling with a hand held sandstone drill bit

Drilling was employed as a refining motion to smooth the coarse surfaces of the central perforation of *jue*. The implements used in drilling were various drill bits which have been morphologically classified into three subsets:cylindrical, conical, and prismatic (Figure 11). From the way they were used, these three categories have been further divided into two groups: hand held drill bits (cylindrical and conical, perhaps with the same shape initially and diversified through wear) and compound shaft drill bits (the prismatic drill-head, either used as a bow drill or a pump drill). The large quantity of cylindrical and conical drill bits indicates that these less sophisticated, non-mechanised hand held sandstone drill bits were the predominant perforation tools used in the Qijia workshop.

In this step, the ground preform, with a depression previously applied, was held in one hand, and the drill bit in the other (Fig. 7:5). The drill bit was placed vertically into the shallow-depressed hole and then twirled by hand. After drilling half way, the preform was then turned over and drilled from the opposite side. By means of this bifacial drilling, a biconical hole was made through the centre of the preform, with clearly observable rotary marks.

Drilling with a bow drill or pump drill

Another method of drilling was probably to use a bow drill or pump drill, as suggested by the presence of prismatic drill bits (Figure 11:11-13). The prismatic bit, made of fine sandstone and characterised by a prismatic working end and a cylindrical tang, is presumed to have been used as the functional head of a compound drilling instrument. The methods of mounting such a bit are poorly understood from present archaeological data, but by comparison with drilling instruments used in other regions of the world and in traditional crafts (carpentry and glass repairing) in modern Zhouyuan, I suggest use of either a bow drill (Figure 12a) or a pump drill (Figure 12b).

The bow drill is a simple mechanical implement that was widely used, among other places, in ancient Egypt, Mesopotamia (Moorey 1994:57) and New Zealand (by Maori) (Riley 1987). A bow drill was still utilised by carpenters in Zhouyuan twenty years ago (Figure 12a). Although the prismatic drill bits found in the Qijia workshop do not have a figure-of-eight shaped drill head as seen in modern Zhouyuan carpentry, their general shapes suggest

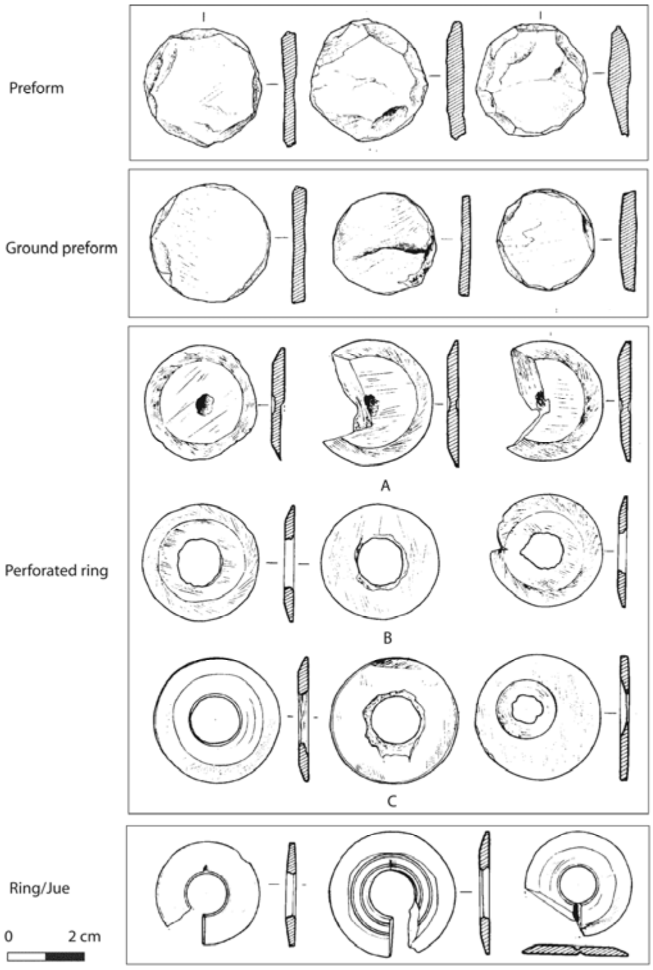

Figure 6. Jue *wasters in various stages of production.*

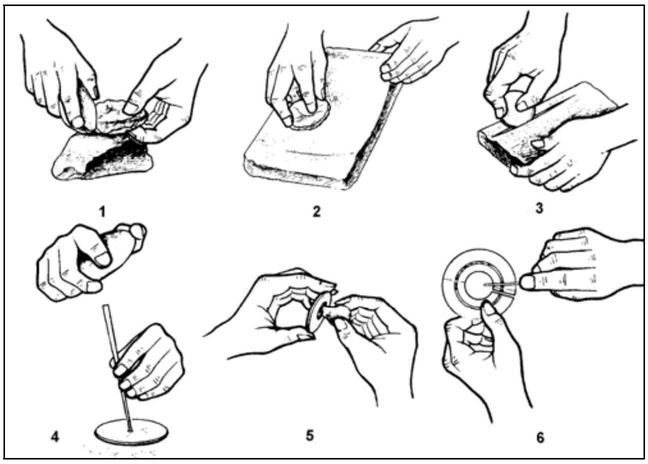

Figure 7. The jue *manufacturing sequence.*

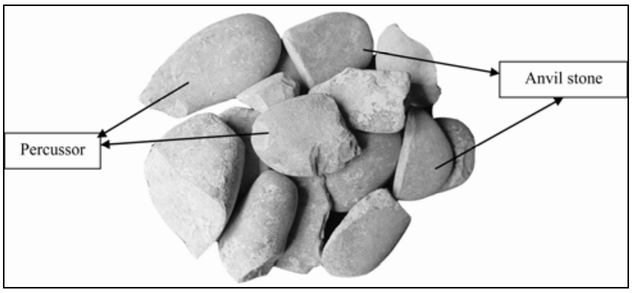

Figure 8. Percussion tools and anvil stones from H21 in the Qijia workshop.

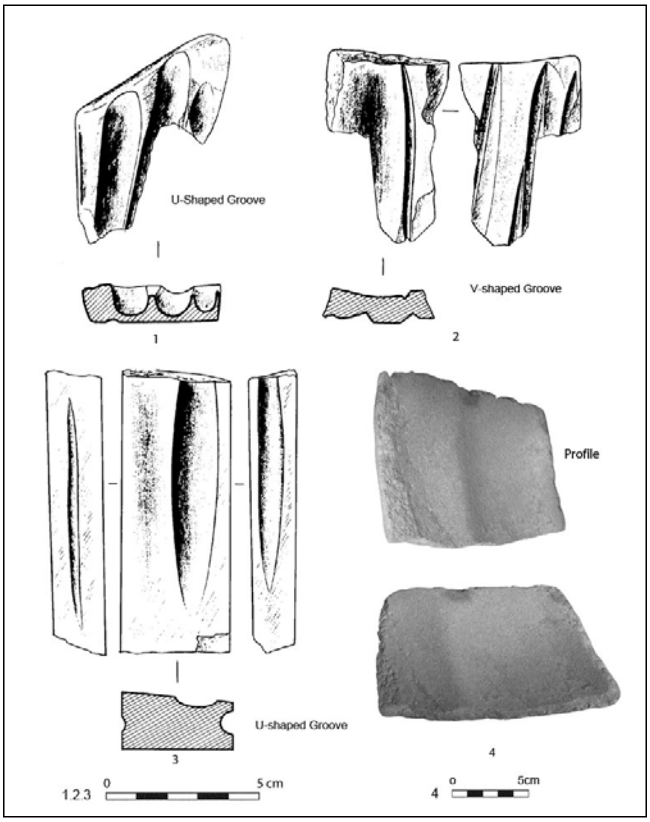

Figure 9. Abraders found in the Qijia workshop.

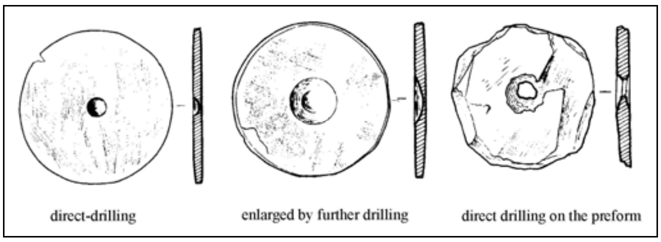

Figure 10. Drilled manufacturing wasters.

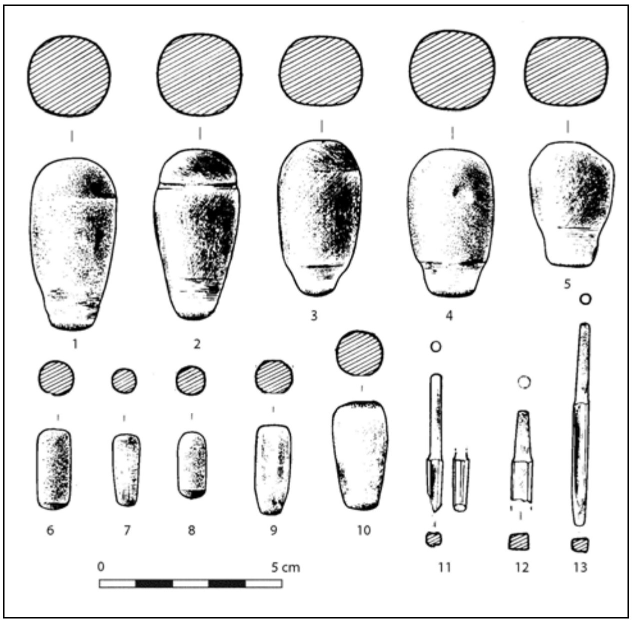

Figure 11. Drill-bits from the Qijia workshop. 1-5 conical;. 6-10 cylindrical; 11-13 prismatic.

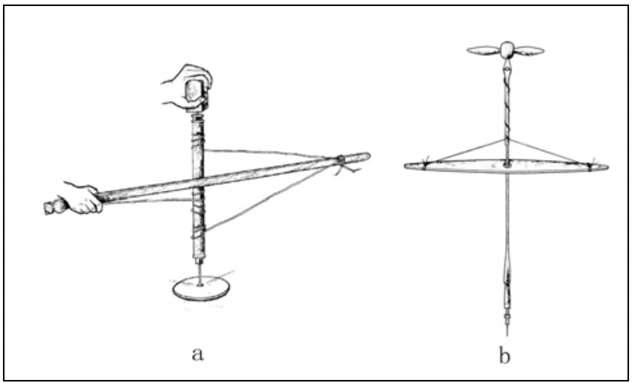

Figure 12. a. Bow-drill used in wood working in the Zhouyuan region; b. Pump-drill used by mica spectacle makers.

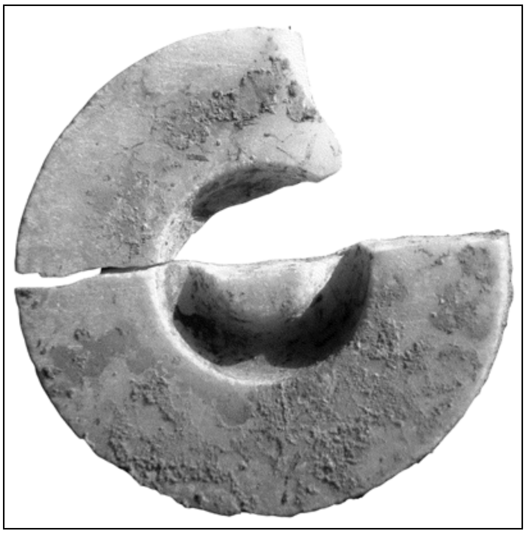

Figure 13. Tubular drilling with an undetached core (limestone waster from H29:36).

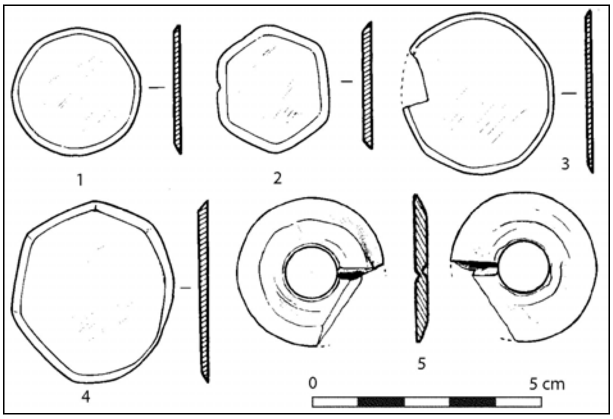

Figure 14. Markers and notches.

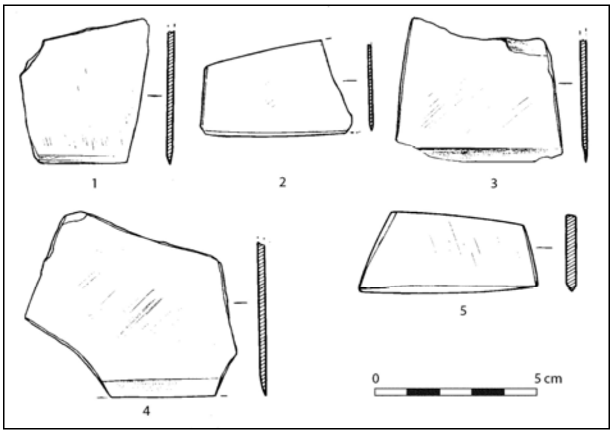

Figure 15. Lithic saws from the Qijia workshop.

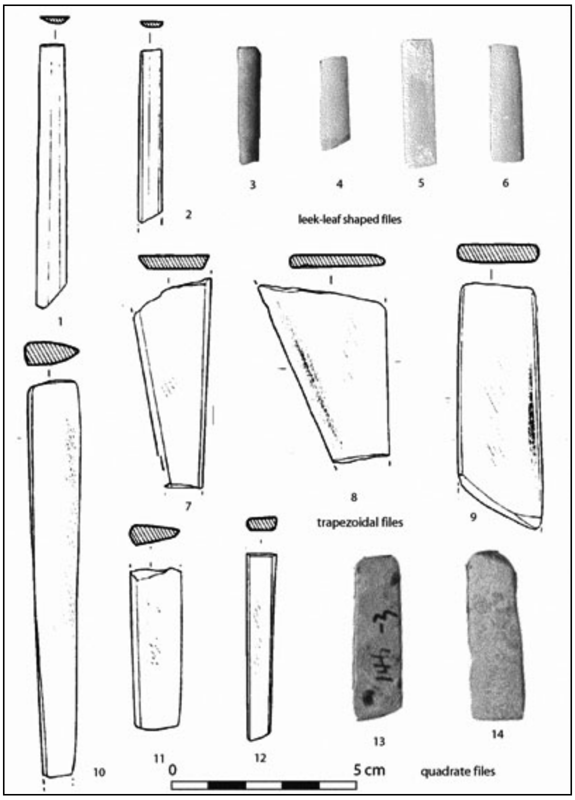

Figure 16. Files from the Qijia workshop.

that they were possibly mounted in a bow drill.

Another possible way to mount the prismatic drill bit is in a pump drill, around which twisted cords were wrapped, providing two cords to be tied at the ends of a cross-bar (Figure13b). A pump drill was used by the makers of mica spectacles in modern Zhouyuan.

Drilling with a hollow tubular drill

Although the majority of *jue* wasters were drilled by handheld sandstone drills and bow/pump drills, a third method was also used, involving drilling with a tubular bit. This technique removes a cylindrical rod from the worked material, and was occasionally used on calcite and limestone *jue*, but never on marlite or schist.

A drilled preform from pit H29 (specimen H29:36) is a limestone *jue* waster that has an unfinished annular drill mark with a central protuberance (Figure 13). The transverse section of the bored protuberance is slightly tapered, measuring 7.5 mm in inner diameter and 16.5 mm in outer diameter. It was possibly formed by severe wear of the inner edge of the drill. Deep rotary marks indicate that some sort of abrasive agent (possibly sand) was used, while water may have been employed as a lubricant.

The technique of tubular drilling is believed to have appeared in Neolithic China and was widely used in jade making in the Liangzhu culture in eastern China. Unfortunately, archaeological specimens of such tubular drills have never been found. The presumption that they were made of some kind of perishable material, perhaps bamboo.

Stage IV: Sawing and refining

After perforation, the next step was to make the slit through the ring in order to attach it to the earlobe. During the process of sawing, the ring was presumably secured in a wooden anvil. The craftsmen first made a short linear groove, using a fine sandstone saw (Figure 14). After sawing half way through, the ring was turned over and sawn from the opposite side. The resulting groove usually has a width of 2 to 3 mm, varying according to rock type. A number of lithic saws and files have been identified (Figures 15 and 16). After the slit was successfully made, the final step was to polish the finished *jue*.

ASSESSING BREAKAGE IN *JUE* PRODUCTION

Analysis of 35,563 diagnostic manufacturing wasters demonstrates that over 50% of them were rejected in the initial step of preforming. Limestone has the highest breakage rate (78%), whereas schist and calcite have comparatively lower rates (ca. 50%). The lowest rate of breakage occurred during the second grinding stage, when only 0.3% to 11.3% of preforms were discarded, according to materials. In the perforation stage, the ratio of failure increased sharply, with an average percentage of 26.5. The final action of making the slit had a failure rate of 14.6%, varying from 8.2% for limestone to 32.9% for marlite.

Without reference to raw material, the highest breakage rates therefore occurred during preforming (51.9%), and the lowest during grinding (0.3%) (Table 1). More detailed estimates of the breakage frequency and the time investment at each manufacturing step are provided by my experimental *jue* replication (Table 2).

My replica experiment also provides an estimate of time investment in each manufacturing step. Although all steps in *jue* replication are important, they do not require the same amount of time. In the first step, the average time expended on preforming was around 7 minutes on schist and 12 minutes on limestone. Comparatively speaking, schist took less time than limestone because schist has a laminated structure that produces smooth surfaces naturally. It took me nearly one hour to create a complete limestone preform, after three incidental breakages. The second step, grinding, seemed easier but consumed much more time. On average it took me 13 to 14 minutes to achieve a well-ground preform by grinding. Of all the activities, drilling consumed the most time (nearly 50%). The drilling in my experimental replication was performed using hand held sandstone drill bits. Depending on the variety of worked materials, it took 30 minutes on average to drill one centimetre in depth. Unfortunately, I could not perform tubular or bow drilling in my replication studies. Presumably, they would take less time than the hand powered drill bit, as they would be aided by dynamic devices. Sawing may be the most risky action in the entire process because any vibration from the saw would make the ring split. A range of 14 to 34 minutes on average was spent on slitting and refining (Table 2).

In summary, one to one and half hours were required to replicate a *jue*, from the initial step of flaking to the final polishing. It is worth noting that the time investment in each step of *jue* working in my replication study does not necessarily represent the actual time investment by the Qijia craftsmen during the Western Zhou dynasty. The Qijia craftsmen probably spent less time than me owing to their greater familiarity with the tasks.

TECHNOLOGY AND THE ORGANISATION OF *JUE* PRODUCTION

This section focuses on the relation between technology and technological organisation in *jue* production by adapting the holistic/prescriptive model proposed by Franklin in the 1980s (Franklin 1983a; b). It aims to connect the production debris with the organisation of production, within an organisational context.

In order to analyse the technological processes of Shang bronze making and the organisation of production, Franklin (1983b:96-97) proposed two ways in which production procedures could be organised: holistic and prescriptive. A holistic process is defined as a sequential, linear development, involving a single, stepwise progression toward the final object. In this process, the craftsman is supposed to be in charge of the manufactured objects and all the manufacturing procedures (Franklin 1983b; Li 2003:20). A prescriptive process occurs if production is divided into predetermined production units, or groups of workers, wherein each production stage is carried out by individuals with independent skills. In a prescriptive

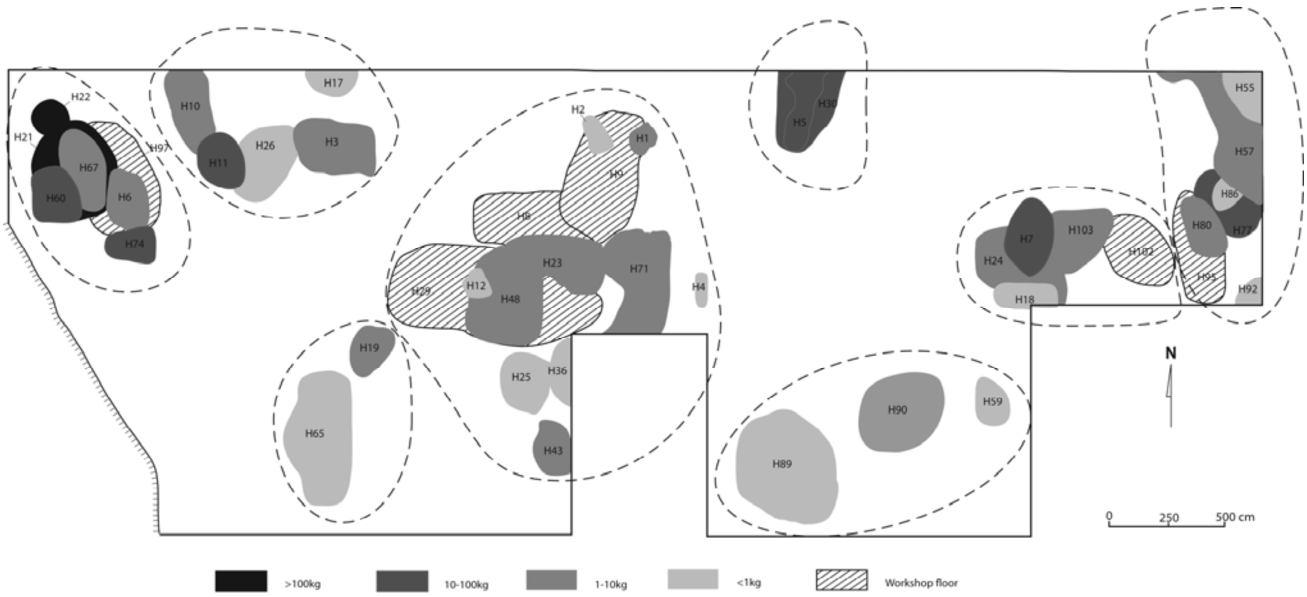

Figure 17. Possible production subgroups in the Qijia site.

technology, individual workers do not necessarily possess a complete knowledge of the whole production process, but rather are confined to a limited range of tasks (Franklin 1983b). These concepts of holistic and prescriptive technology have long been the only models for the evaluation of craft production and production organisation in Bronze Age China (Franklin 1983a, 1983b, 1990; see comments in Li 2003).

For reconstructing the organisation of production in the Qijia workshop, we can only derive information directly from the mass of trash pits and a few scattered work floors. I assume that each lithic pit found in the Qijia workshop represents a production unit where the lithic debris and manufacturing wasters were created and disposed of within a short time span, possibly during an independent production event. The 37 identified lithic pits and six work floors can be further subdivided into at least eight groups, without considering temporal differences (Figure 17). From these pits and floors, a large amount of lithic debitage including sets of tools, manufacturing wasters and lithic debris has been recovered, along with domestic trash. Each dates from the Early to the Late Western Zhou. The analysis of the materials taken from each pit shows that the *jue* wasters recovered were not concentrated on one single manufacturing stage. Rather, a complete range covering the various stages of *jue* manufacture (preforms, ground preforms, perforated rings and virtually complete *jue*) was recovered from each context. The lithic materials from each group of facilities closely resembles those from the others in terms of raw materials and manufacturing stages represented. More importantly, each group produced similar, if not identical, sets of manufacturing tools used to process the *jue* from initial flaking to finishing. Batches of similar *jue* wasters rejected in the same manufacturing stage had been simultaneously processed by different production groups, implying that all such groups performed the entire range of manufacturing procedures with no clear division of labour in production tasks. This, the process of *jue* manufacture in the Qijia workshop was not broken down into separate prescriptive steps. The Qijia workshop did not have a flow-line of production organisation, and the *jue* were manufactured throughout by separate groups or artisans. These characteristics strongly support a 'holistic technology' form of organisation.

CONCLUSION

The manufacturing sequence for *jue* earrings has been reconstructed from excavated debitage in combination with my experimental replication. *Jue* production was basically broken down into four operational stages: preparation of raw material, preforming, perforation, and sawing/refining. Although the first stage of raw material quarrying is not yet actually attested, the manufacturing procedures themselves were reconstructed from the various unfinished *jue* wasters and their associated manufacturing tools. If we return to the technological models proposed by Franklin (1983a, b), we may tentatively offer an interpretation of the technological organisation of the Qijia workshop. The production groups based there produced discrete clusters of lithic discard pits and work floors. The findings from these individual production groups, including a full range of *jue* manufacturing debitage and sets of stone tools, indicate that each group followed the same full range of production procedures. Thus, a holistic model of production best describes technological management at the level of the craft community.

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NOTE

1. Not all perforations were processed strictly following the above proposed manufacturing order. The application of a different order of actions seems to have been driven by the need for efficiency, according to which techniques capable of maximising human power and reducing time spent were preferentially considered during the process of accomplishing the task of *jue* manufacture.

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