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Technological Wears on the Prehistoric Jades in East Asia

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Introduction

In the recent research, the author has always noticed the traces of string-sawing and pecking scars on the Neolithic jade artifacts of East Asia. According to Mou Yongkang, these traces of string-sawing should be the result of soft string-sawing with sand abrasives (Mou 1989a, 2003).[1] He named it as "gritted string sawing technique" 線切割 (Mou 1989b ; Zhou & Zhang 1984) (Fig. 1). This term is taken within the archaeological circle generally and is basically correspondent to the Japanese term "ITOKIRI" derived from *Koujien* 広辭苑 (Shimura 1983)[2] and "string-sawing" in English. Internationally, it is defined as the use of hide or plant fiber made string being embedded with sand abrasive. The hardness and the sharp edges of the sand grains will cause abrasion when the string is moved back and forth on jades, which will then be split eventually. *Zhuo* 琢 is rendered as "kouda" 敲打 in Japanese and "pecking" in English. Pecking was a percussion technique commonly used in jade technology during the Stone Age. It is some way between flaking and grinding, but excels the former in controlling the precision of form and the latter in efficiency. After the initial blank was obtained by flaking, pecking was used to touch up the shape. During the process of pecking, stone percussors of various sizes were used to suit different situations. Usually, the percussor was held in one hand and made to strike down with a force applied to the surface of the jade in a perpendicular direction to form overlapping superimposed cones. Scars of superimposed cones on the pecked surface of artifacts are evidence of the existence of the pecking technique.

However, there is a lack of in-depth analysis of the jade surface done by both techniques in the academic circle. The main problem of this debate is due to the lack of a set of objective scientific principles for the observation of the traces left by both techniques, while a good grasp of an accurate observation of the traces left by both techniques is the key to resolve the mystery of the ancient jade manufacture. Therefore, in the paper, an overview of the string-sawing technique and the experiment results will be provided, followed by an account of the pecking technique.

[1]This paper is the first systematic explanation of the features of the string-sawn surfaces in China.

[2]The Japanese word 糸切 Etokire means string-sawing (糸できること). Therefore it can be seen that Japan also has the tradition of string-sawing in the past. It is known by now that string-sawing had been used to produce jades and pottery implements in ancient Japan.

1. Understanding of string-sawing on jades

According to our observation in recent years, the manufacture of the slits of the early Neolithic slit rings found in East Asia region were commonly done by string-sawing.

There are two main ways of application of the string-sawing technique — the string could either be mounted onto a bow or held by hands. As reflected from the traces left on the jades, hand-held string-sawing was mainly used in the Neolithic China. Different types of jade slices in the Neolithic China were produced in a large number for making jades of predetermined style. Many different types of secondary retouch were also done by string-sawing technique including hole enlarging, groove openings, coring, cutting, relief, etc. It can be seen that the string-sawing technique is essential to the whole procedure from extracting material to processing at the end.

In order to have a better understanding of various features of string-sawing, experiments have been conducted with the following conditions under consideration : the material, the size and length of the string, the grain size of sand, the form of weathering, the amount of water added, the structure of the object being cut, the differences of stabilizing and opening tools, the manipulation of application, the choices of sawing direction and the adjustment of the force applied. Archaeologically, the traces on the jades left by string-sawing can be used to deduce the direction of sawing; the relation between the new/old cutting surfaces and other processing traces, also, the size of string and the functional differences reflected from the cutting position on the jade.

2. Report of the experiments

a. String-sawing and blade-sawing experiments

(1) *Experiment instruments*

(i) Rock material for sawing

According to the past experiments, sawing jade material is very time consuming. Therefore, pyrophyllite was used as the main material in the experiments. Two forms were used here: long strip and square shape (abbreviated as I and II materials below). Sizes are 1.9 x 1 x 5.8 cm and 5.8 x 5.8 x 6.9 cm respectively.

(ii) Sawing instruments

(a) Soft string-sawing

In our experiments, hemp (Cannbis sativa) string

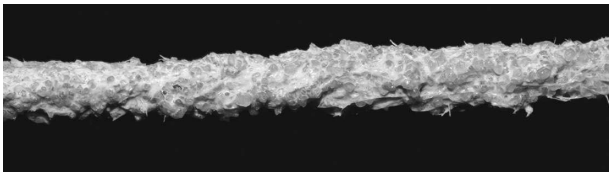

Figure 1. Gritted String
Hemp (Cannbis sativa) string becomes a gritted string when it is entwisted with sand slurry. Relying on the sharp edge of sand grains, jade can be cut by a gritted string.

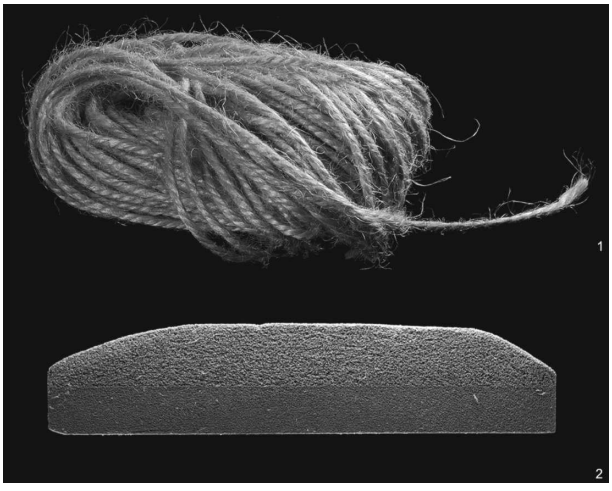

Figure 2. Sawing experiment tools
1. Hemp (Cannbis sativa) string : diameter of each is 0.5 cm **2.** Blade saw : made from a whetstone

(diameter of a single string is 0.15 cm) was used as sawing tool (Fig. 2 : 1). Both single string and multiple strings sewn up into one were used.

(b) Blade-sawing

It is known from the archaeological record that blade-sawing used on jades was very popular. Experiment of this was therefore also conducted for making a comparison with string-sawing. Home used whetstone was used here and was cut up by a steel saw into a long thin blade sized 8 x 2 x 0.5 cm. Its cutting edge was made by grinding (Fig. 2 : 2).

(iii) Abrasive — quartzite sand

Sand used in the experiments is from the beaches in Hong Kong. It is quartzite sand with hardness 7 in Mohs' scale. The minimum diameter of grain is 0.02 cm, the maximum is 0.15 cm.

(iv) Stabilizing tool

How to stabilize the jade during processing is a crucial factor. A modern industrial used pliers was used in the experiments here.

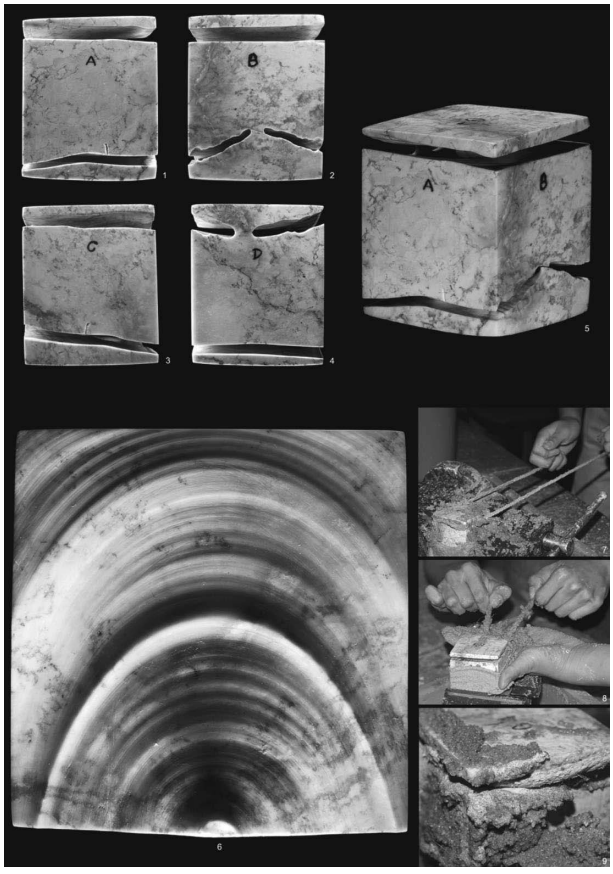

Figure 3. Experiment (Slicing by one-way string-sawing)
1-5. various cutting surfaces after refitting of the slices and the parent rock material : uneven cutting edge is one of the typical features of hand-held string-sawing.
6. morphology of cutting surface.
7. sawing : tightened the string, sawing horizontally.
8. sand adding : putting sand slurry at the mouth where the gritted string is moved along to ensure the sand slurry would not permeate into the cutting surface.
9. sand slurry flows along the gritted string as paste.

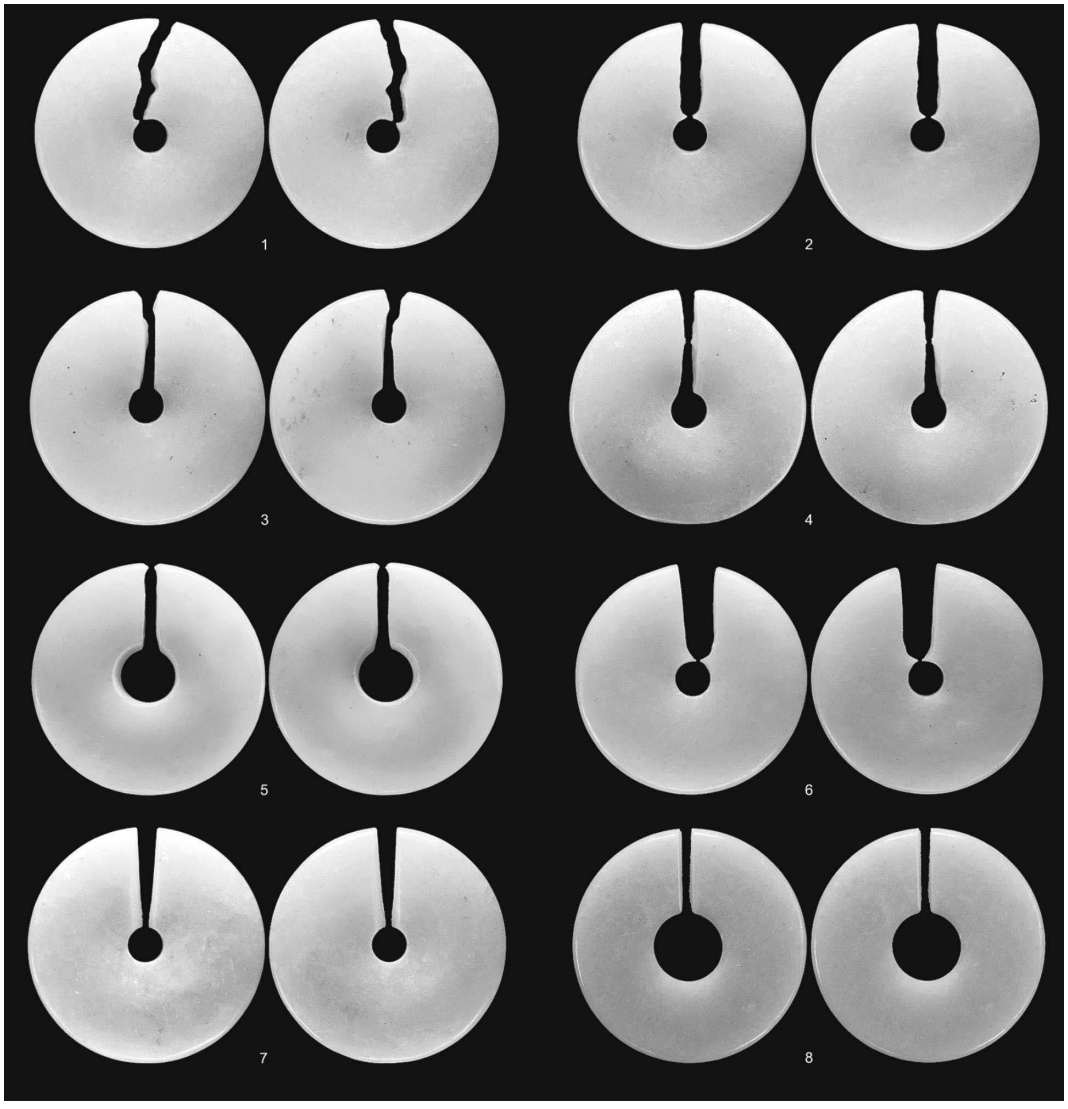

Figure 4. Experiment of slit rings manufacture : slits opened by string-sawing samples from 1-5 and 6-8 by blade- sawing

(2) *Experiments and Results*

Experiment : Slicing by one-way string-sawing

(i) Steps

(a) A II material was stabilized. A coarse hemp (Cannbis sativa) string sewn up by 4 hemp (Cannbis sativa) strings (0.6 cm in diameter) was pulled by one person at an average rate of 5 rounds per second. Two ends of the string always kept close (Fig. 3 : 7). Sand slurry was kept being added during sawing (Fig. 3 : 8). It can be seen that the paste formed by sand slurry and powder from the rock material flows along the string (Fig. 3 : 9).

(b) After sawing for 105 minutes, a slice was separated from the II material. For the convenience of comparison, the sawing rate was decreased to 3 rounds per second to produce a slice under the same conditions. The slice was separated from the II material after 150 minutes.

(ii) Observation of the cutting surface

Slice (Fig. 3 : 6) : The surface is generally cambered like the ventral face of stone flakes. The thickness varies. The thinnest one measures 0.3 cm and the thickness measures 2.2 cm. The middle of the cutting point is slightly recessed and two sides are uneven. The ending point is cambered with two sides being lower but higher in the middle. The cutting surface is full of intensive undulations caused by sawing that the raised ones appear in ridge shape, and the recessed ones appear in groove shape. These ridges and grooves appear interchangeably with different intensity. An obvious raised ridge can be seen clearly in the middle of the cutting surface. It should be due to the

increased use of sand during sawing.

Sawing the parent material (Fig. 3 : 1–5) : It is generally similar to the blade scars on the surfaces of stone core. The edge of the cutting surface is uneven, and the traces of sawing left are similar to those of blade-sawing. The raised ridge on the slice is correspondent to the recessed grooves on the parent material.

b. Experiment on sawing different slit rings

Eight case studies have been done for this experiment. Big white marble rings were used for sawing here. They are of the same size measuring 3.5 cm in diameter. The holes measure 0.5 cm in diameter and 0.5 cm in thickness. Sawing tools (including hemp string, sand and stabilizing tool) and steps followed are the same as those mentioned above. The finished products of the five cases of string-sawing can be seen in Figure 4 : 1–5 respectively.

Cases 1 and 2 : sawing from the edge, but the ring in case 1 was not stabilized, while the one in case 2 was stabilized well.

Case 3 : pulling string between the hole and the edge continuously along the radius of the ring.

Case 4 : sawing from the edge and from the hole in the centre independently on both sides.

Case 5 : sawing from the hole in the centre. It can be seen from the figures that the results were affected by different factors. Same is found in the three cases of blade-sawing as shown in Figure 4 : 6–8 respectively.

Case 6 : sawing from the edge towards the centre.

Case 7 : opposing blade-sawing on both sides.

Case 8 : one-way sawing from the hole on one side.

3. Interpretation of the fracturing surfaces and string-sawing surfaces features

The physical mechanisms of the fracturing surface of rocks formed by percussion and string-sawing are completely different. The former is brittle fracture under force. The latter is splitting by sand grinding. Nevertheless, the morphologies of both kinds of surfaces could be quite similar. Small scale of brittle fracture can often be found at the ending point of sawing under string-sawing technique. Features formed by both techniques like these will be further discussed and compared in the following.

Figures 5 and 6 show the obsidian slice produced by direct percussion with stone hammer and the pyrophylitte slice produced in string-sawing experiment respectively. They both look similar as they all have undulations on their surfaces. The striking point and termination point of string-sawing also look a bit similar. But the physical mechanisms of their formation are completely different. The whole sawing procedures of both techniques will be discussed below in order to give a clearer picture of the characteristics of the traces left by string-sawing.

a. Way of splitting

Regarding the fracturing caused by percussion, striking point is the starting point of fracturing as shown by the eraillure and fissures formed by Hertizian Cone fracturing theory (Cotterell & Kamminga 1987). Traces left by such striking point cannot be found at the cutting point of string-sawing. In the prehistoric time, string-sawing and blade-sawing were always used side by side. Blade-sawing was always used to mark a guiding line for the cutting point of string-sawing. As can be seen in our experiment, the pyrophylitte used have grooves cut on the pre-determined positions on both left and right as the cutting points of string-sawing. Gritted string was then pulled along the grooves which left some traces of curves, but the traces of blade-sawing were worn away.

b. Undulation

The fracturing surface of percussion and the cutting surface of string-sawing are always covered with undulations. They are said to be useful at inferring the direction of fracturing, level of force used and the order of inter-cutting relationship of undulations on different surfaces. Nevertheless, there is a big difference on the mechanism of undulation formation on the fracturing surface of percussion and the cutting surface of string-sawing, so as the morphologies of the ending of undulations. The eraillure around the striking point of a stone flake is nearly in round shape. Those undulations in the surrounding are in slightly bow shape. The morphologies of their contraction at the left and right sides along the edge of the fracturing surface all show consistency. Generally speaking, the direction of percussion is consistent with the dispersing direction of the undulations. The formation of undulations on the cutting surface produced by string-sawing is totally determined by the pulling direction of the gritted string. Because of the contact between the gritted string and the cut object, the abrasion caused by tightly stretched gritted string is in a curve shape. Undulations were formed on the cutting surface. Since the string is pulled up and down by hands, the sawing lines formed would not be parallel. The curved endings of the sawing lines are lack of consistency. The bigger the movement and the more force applied during string-sawing, the richer the undulations are formed on the jade surface, vice versa.

c. The end of splitting

From the striking point extending to the front of the splitting axis is the edge of the termination of fracturing surface, where the undulations are generally rich. For the lithic technology, the termination occurs on the edge of an individual flake can be classified into step, hinge, feather, plunging and axial these few types. Their formations are related to the mechanism of different mechanics applied at the end of splitting. String-sawing can be done in 360° by hand and terminated at any points of the jade. Figure 6 : 4 shows the termination point of string-sawing under the force of the pulling string, where a small fracturing surface is formed. Both sides of the fracturing surface are raised and recessed correspondingly without any traces of striking point. It belongs to the so called bending fracture. One of the characteristics of bending fracture is that the cone shaped fracture under the Hertizian Initiation would not occur. Such kind of bending fracture always exists at the

Figure 5. Obsidian flake produced by percussion **1.** Ventral **2.** Dorsal

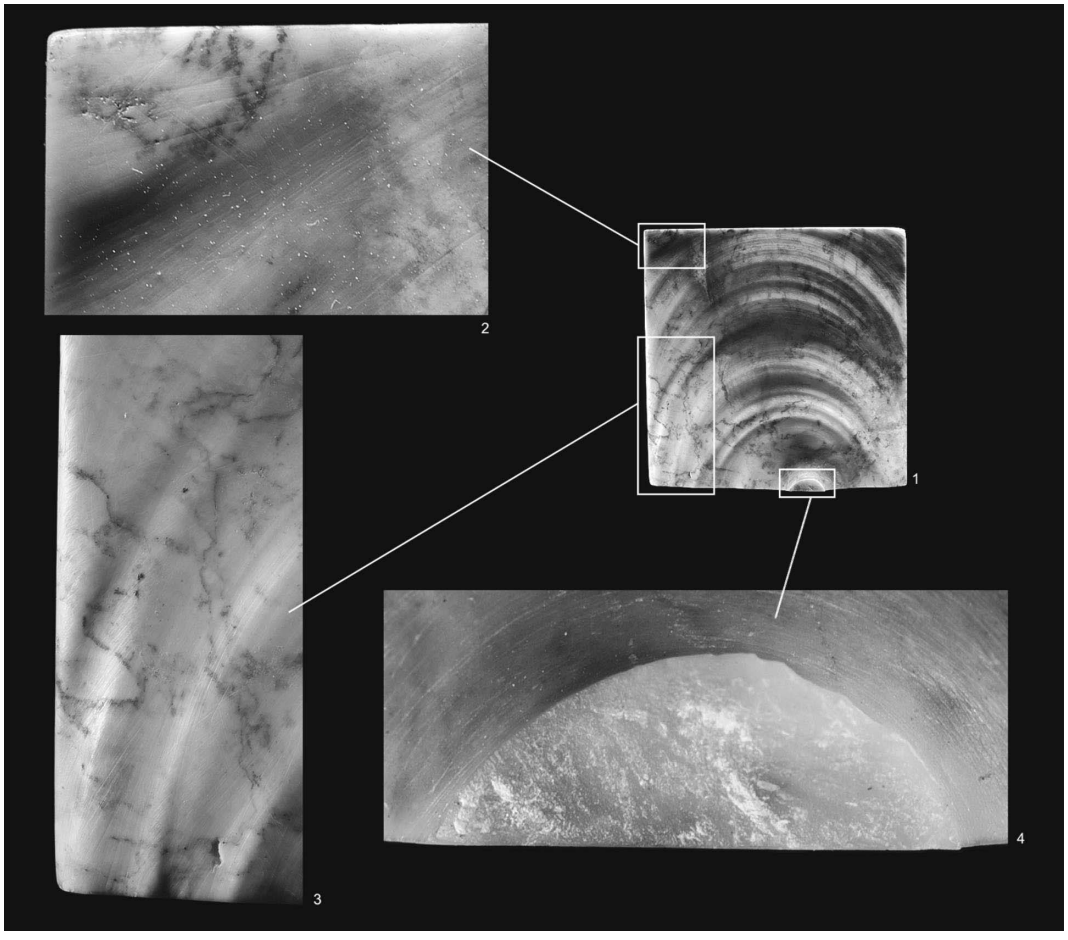

Figure 6. Cutting surfaces and details on the string-sawn pyrophylitte
1. cutting surface **2.** cutting beginning
3. the sides of undulations left by sawing show contraction
4. the line traces left at the termination of sawing and the bending fracture

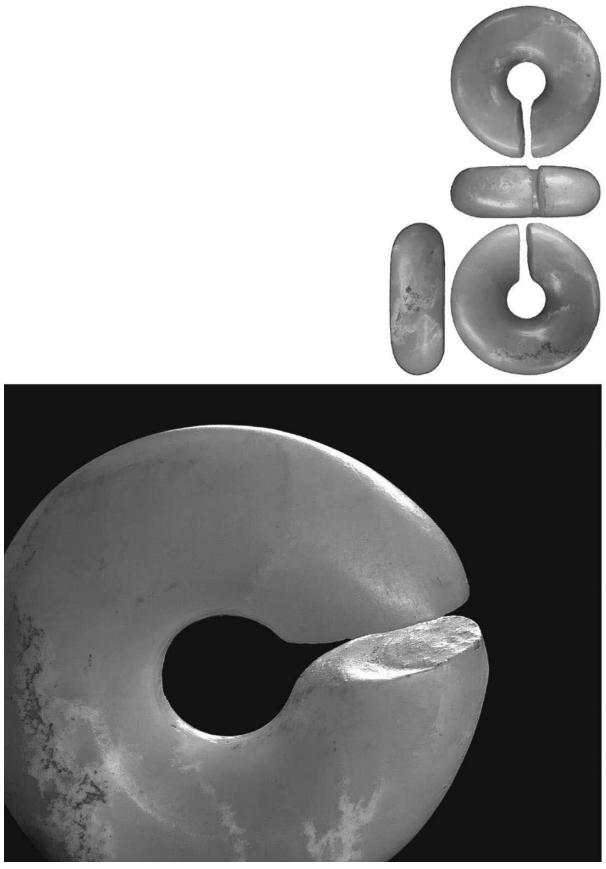

Figure 7. Traces of string-sawing technique left on a slit ring from Wangjia from Wangjiayingzi-shuiquan, Xinglongwa Culture (王家營子水泉遺址, 興隆窪文化).

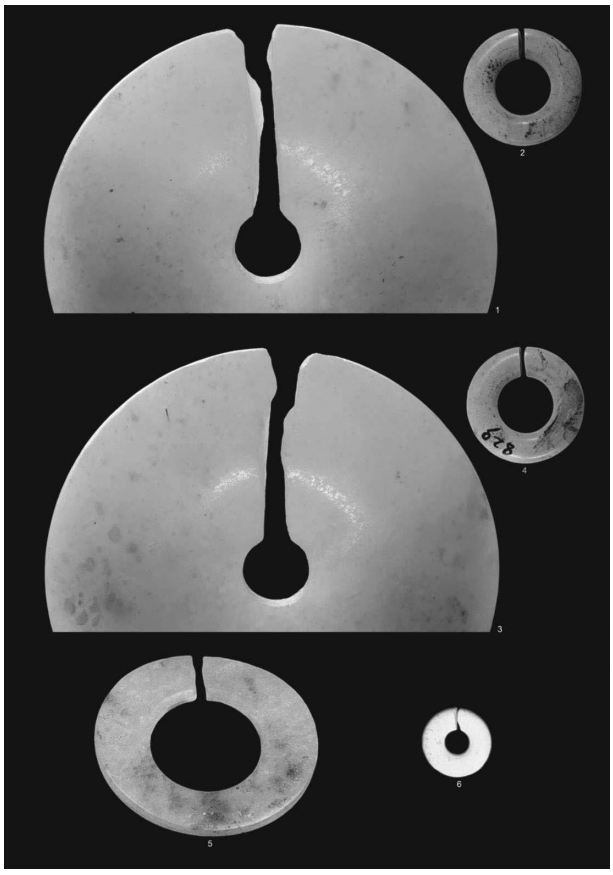

Figure 8. Comparison of slits produced by string-sawing
1, 3. string-sawing experiment : opening side, ending side
2, 4. opening side and ending side of slit rings of Hongshan Culture (after Yu Jianshe, 2004, p. 51) : String-sawn slit, flat and straight opening side, raised and bending ending side
5. Wiedun jade slit ring (after Chen Lihua etc, 2004, p. 145)
6. slit ring from Kuwano site, Japan (after Harunari, Hideji Hideki, 1997, plate 158)

termination point of string-sawing, but it might be also caused by the percussion on the other areas of the cut object.

d. Morphology of two sides of the split object

Percussions under the splitting mechanism of Hertizian, Bending and Wedging all belong to brittle fracture. The parts split can be refitted again. String-sawing is the use of a gritted string to split an object by abrasion. There is a gap between the split parts, which is the movement trail of the gritted string. The width of the gap is proportional to the size of the string, but the parts split up by string-sawing cannot be refitted again.

The above interpretation of the features shown on the jades has provided the standard for differentiating brittle fracturing and the cutting surface of string-sawing. It is also helpful at understanding the change of morphology from the beginning of sawing till the end.

4. An Overview of the String-Sawing Technique in East Asia

String-sawing is one of the very important features of Neolithic jade technology in China. This paper has already given a preliminary analysis based on the characteristics of string-sawing cutting surface and slit manufacturing experiments. In the following, an attempt will be made to explore the unearthed jades of various times and regions in East Asia.

The Xinglongwa Culture of northeast China yielded the earliest string-sawn jades known in the East Asia region. Nevertheless, other than slit rings, traces of string-sawing technique are rarely found on other jades of the Xinglongwa Culture (Fig. 7). There is no way we can judge whether string-sawing had been used on slicing or not at that time (Liu 2004). The book *Hongshan* Jade (Yu Jianshe (ed.), Huhehaote: Yuan Fang Press, 2004) published recently has provided a large amount of information of the jade slit ring of

the Xinglongwa Culture. It enables us to observe the slits of some slit rings. From the jade slit ring from *Baiyinchanghan* (白音長汗) shown on page 47 of the book, it can be seen that the surfaces of both sides of its slits are uneven, which is a common feature of string-sawing technique. A jade slit ring of the Hongshan Culture unearthed from the Bayantalasumutabentaolegai (巴彥塔拉蘇木本套勒蓋) site, Aluke'erqin Qi (阿魯科爾沁旗) can be found on page 51 of the same book. The cutting of its slit is consistent to the one shown in the experiment. Both are produced by one-way string-sawing. Figure 8 : 1 and 8 : 2 show one side of its cutting point by string-sawing. They appear to be wider and flatter than the ending point shown in Figure 8 : 3 and 8 : 4. Examples of this kind of slit produced by one-way string-sawing are very common. Sites at Xudun (圩墩), Jiangsu Province (江蘇省), Yaoshan (瑤山), Zhejiang Province (浙江省), China (Fig. 8 : 5) and Kuwano (桑野) in Awarashi, Japan (Karetsumachi 1995; Harunari 1997) (Fig. 8 : 6), all yielded the same kind of slit ring.

The string-sawing technique had existed for a few thousand years after its first appearance in the northeast China. On those jades unearthed from the Xiaonanshan (小南山) site at Heilongjiang Province (黑龍江省), traces of string-sawing can always be found on their surfaces (Yin et al 2001). The jades of the Hongshan Culture in the northeast were beautifully made which are supposed to be processed by string-sawing. The renowned jade hoop of Hongshan Culture was made use of string-sawing for coring. Traces can be found along its edge of the inner hole and on the surface of the corresponding core. The tradition of string-sawing of the northeastern region spread slowly towards the south. The *China Cultural Relics News* recently reported the news about jades including slit ring and scoop shaped ornament dated 7000 years ago being unearthed from the Beifudi (北福地) site in Yi county (易縣) of Hebei Province (河北省) in north China. They can be understood as the important evidence of the southern dispersion of the Xinglongwa Culture. They have filled up the gap of the jade tradition between the northeast and the lower reach of the Yangtze River, which is of great significance. In 7000 — 6000 bp, both Hemudu Culture and Majiabang Culture of the lower reach of Yangtze River had inherited the string-sawing tradition from the northeast. The recent published slit ring in tub and ring shapes unearthed from the Xudun site in Changzhou city (常州), Jiangsu Province show very similar morphology and technology to those of the Xinglongwa Culture. The sample of slit ring T234(4B) : 301 (Fig. 9 : 1, 9 : 2) in the report *Hemudu* is said to have "a slit had not been completed". This slit is done by string-sawing in 360°, leaving a cylindrical feature in the middle of the slit surrounded by the traces of raising angles along the perimeter (Fig. 9 : 3). Some of the slit rings from Majiabang were also produced by string-sawing technique. The Pengzudun (彭祖墩) site at Wuxi (無錫) excavated by the Nanjing Museum (南京博物院) in the beginning of the 21st century yielded tubular slit rings of the Majiabang Culture. Their string-sawn slits show exaggerated twisting (Fig. 10 : 1, 10 : 2). It is suspected to be the result of the slit rings not being well stabilized during production which led to a big twisting (Chen et al 2004 ; Zhejiang 2003 ; Sun 2004 ; Nanjing et al 2004).

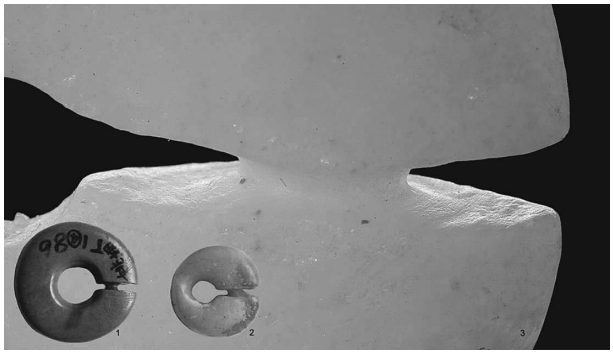

Figure 9. Comparison of slits produced by string-sawing 2
1, 2. Hemudu slit ring (after Sun Guopin, 2004, Colour plates 3 : 2, 3 : 1) : A cylindrical form in the middle of the slit
3. string-sawing experiment, cylindrical form and raised angle in the middle of the slit

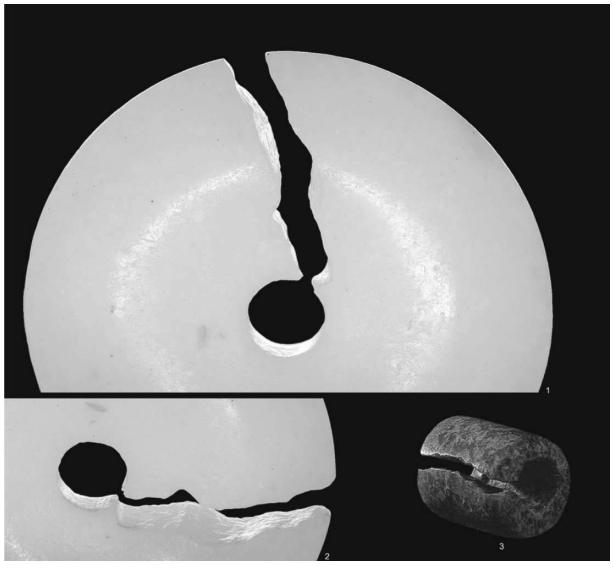

Figure 10. Comparison of slits produced by string-sawing
1, 2. the slit ring was not stabilized during the string-sawing process, forming a strongly twisted slit
3. a strongly twisted slit is also found on the slit ring unearthed from Peng Zudun (after Nanjiang Museum, etc, 2004, p.216)

String-sawing technique used on jades was prevalent in the Yangtze River region 6000 years ago. The arc shaped pendants (*Huang* 璜) of the Songze Culture always show traces of deep cutting by string-sawing. It reflects that the force used on sawing jade was very strong (Zhang 1998). The production of Lingjiatan (凌家灘) jades shows that the use of string-sawing technique on cutting out material and processing had reached the climax. The jades ranging from

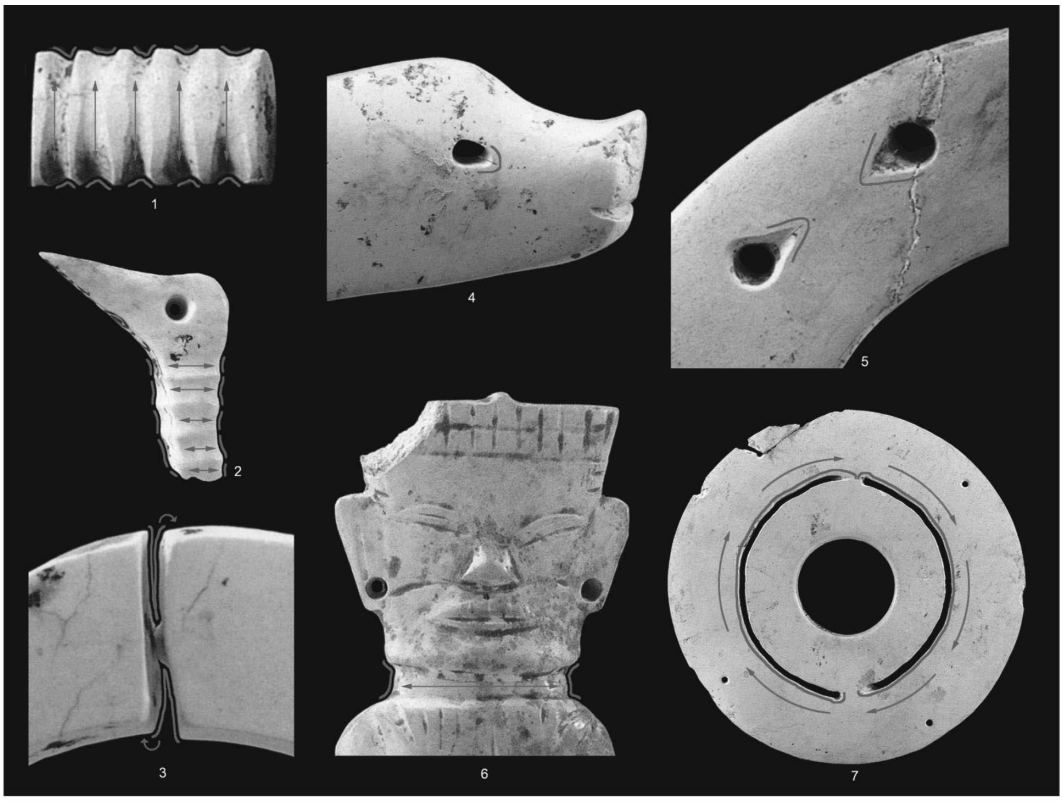

Figure 11. Secondary retouch by string-sawing on Liagnjiatan jade implements (after Anhui province Cultural Relics Archaeology Centre, 2000).
Red lines and arrows show the cutting area and cutting direction respectively.

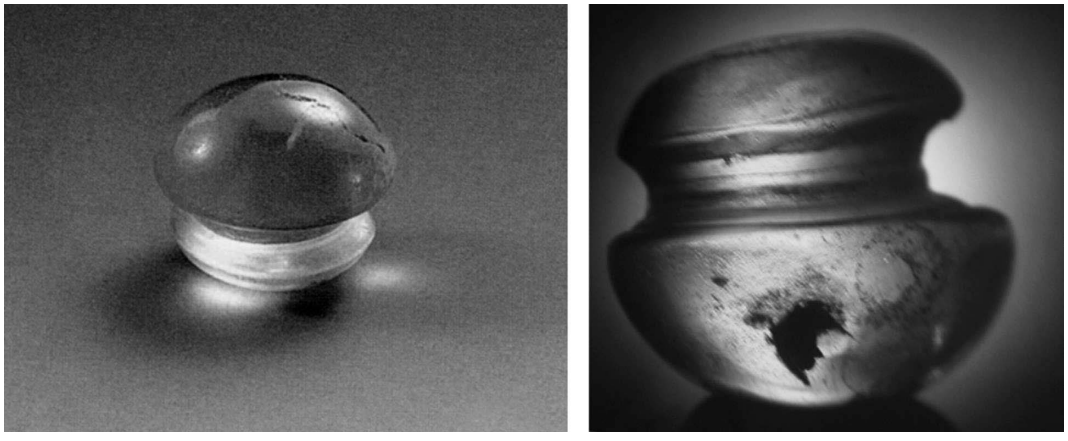

Figure 12. Close shot at the circumferential groove on the Liangjiatan crystal ear plug after secondary retouch (Photos provided by Zhang Jingguo).

large battle axe (*Yue* 鉞), medium sized ring and human-shaped jade ornament all have examples of using string-sawn jade slices as preform. The Lingjiatan site yielded a jade battle axe (*Yue*) 98M20 : 30 in grayish white with some green. It measures 28.3 cm in length, 12.4 cm in width and 0.6 cm in thickness (Anhui 2000). Its surface shows traces of inter-cutting string-sawing curves which had basically been worn away by the later grinding. According to our knowledge gained from the string-sawing experiments, the gritted string used on sawing this implement should be much

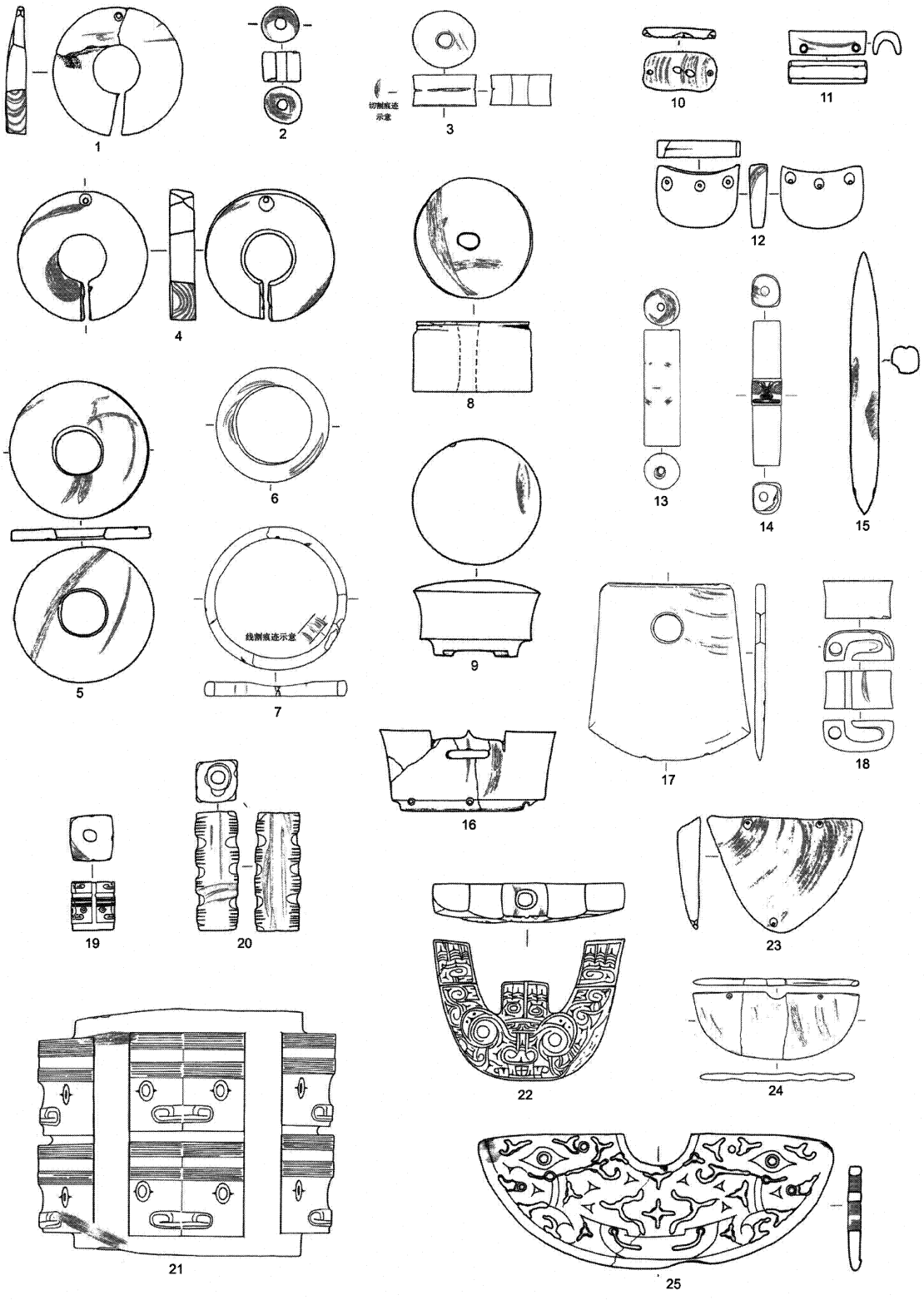

Figure 13. Examples of the application of string-sawing technique on the jades unearthed from Yaoshan site. (After Zhejiang Province Cultural Heritage Archaeology Research Centre, 2003)
Red lines represent the traces of string-sawing.

Figure 14. Metal string-sawing experiment and the so called 'string saw'
1, 2. metal string-sawing on pyrophylitte and a close shot at the it
3. the sample of the Eastern Han dynasty showing the so-called 'string-sawing' (after Fu Xinian, 1995, p. 183) : the traces of the straight cutting lines on which are similar to those produced in our experiment
4, 5. cutting surface of metal string-sawing : cutting traces left on the surfaces are straight lines, the cutting bent left and right.

longer than the length of cutting surface. Say, if the gritted string is five times longer in length, its true length would be 1.5 meters long. We should notice that the radian of the curves left on 98M20 : 30 is very big, and the bending of the destroyed surface at the end of string-sawing no longer exists. It is suspected that the actual size of the preform should be much larger. Base on this, we can imagine that possibly in the workshop at Lingjiatan in Anhui Province (安徽省) 5000 years ago ; two people were pulling an almost 2 meters long gritted string to slice a 1 or 2 cm thick preform from a 30 or 40 cm long big jade material. They must have had worked so hard that the traces of their excellent craftsmanship raises our hope of meeting them even after a few thousand years.

The processing done by string-sawing on those jades from Lingjiatan is also impressive as shown from the following features.

1. groove opening : necklace (87M15 : 52-63) (Fig. 11 : 1), slit ring (87M8 : 16) (Fig. 11 : 3), circular groove of a crystal ear plug (87M4 : 34) (Fig. 12), circular groove at the neck of a god-human figure (87M1 : 1) (Fig. 11 : 6), line groove at the joint of battle axe (*Yue*) (87M9 : 18)
2. openwork: the splitting of all god-human's legs
3. hole enlarging: the eye corners of jade dragon on an arc shaped pendant (*Huang*) (87M : 918) (Fig. 11 : 4), a pair or pierced holes on arc shaped pendant (*Huang*) (87N11 : 4) (Fig. 11 : 5)
4. relief: both sides of the lozenge shaped lines around the neck of a bird shaped headdress (87T3(4) : 2) (Fig. 11 : 2)
5. splitting of perimeter : double connected disc (87T1(2) : 22) (Fig. 11 : 7).

String-sawing had reached the climax in the Liangzhu (良渚) Culture. The C shaped jade pieces inlaid on the lacquer implements in the recently published detailed report, *Haochuan Cemetery* (好川墓地) (Zhejiang Province Cultural Heritage Archaeology Research Centre et. al., Beijing: Cultural Relics Publishing House, 2001) are the representatives of gritted string opposite sawing technique used on slicing. The discovery of Liangzhu jade workshop sites at Tangshan (塘山) and Dingshadi (丁沙地) in recent years had uncovered many semi-finished jade products. Many of them are string- sawn slices which enable us to get closer to the truth of string-sawing on jade (Lu et al 2001 ; Wang et al 2002). The recent publication of the report *Yaoshan* (瑤山) shows the highest achievement of the Liangzhu Culture (Zhejiang Province Cultural Heritage Archaeology Research Centre, Beijing : Cultural Heritage Publication, 2003). As shown by the jades unearthed from the Yaoshan cemetery, string-sawing was frequently used on jade production including slicing of preforms, cutting both ends of tubes, sawing slits, coring the ring-shaped bracelets, producing the forks of three-forks implements, arc shaped pendants (*Huang*) (Fig.

13), etc. String-sawing was so widely used that it was one of the best of Liangzhu jade techniques.

Although the string-sawing technique used on the jades of Liangzhu Culture had once reached its climax, it finally disappeared along with the decline of the culture. During the late Neolithic in the Yellow River region, a new slicing technology arose around the Central Plain area which can split large jade pieces of some ten centimetres in length and a few centimetres in width. It was an unprecedented breakthrough of slicing technique (Tang 2004). The disc (*Bi* 璧) and ritual tube (*Cong* 琮) of the Qijia (齊家) Culture at the upper reach of Yellow River region is said to be originated from the Liangzhu Culture, but there is no report of the use of string-sawing technique on the jades of the Qijia Culture (Huang 1998). Similarly, The Taosi (陶寺) Culture at the middle reach of Yellow River also yielded ritual implements like ritual tube (*Cong*), disc (*Bi*) and battle axe (*Yue*). Jade disc like M1423 : 1 measures 0.2 cm only in thickness, which is the product of slicing technique. However, there is no report of the use of string-sawing in the Taosi Culture. The representative of the Longshan (龍山) Culture in Shangdong, the tomb in Zhufeng (朱封) in Linqu county (臨朐縣), yielded a jade crown. The openwork on which is very likely to be made by string-sawing. Traces of such technique are not found being used on other jade rings and battle axes (*Yue*), nor could it play a significant role at the end of Neolithic in the Yellow River region. The jade tradition after the Erlitou (二里頭) Culture was closely related to the Longshan Culture in the Central Plain region. The jade culture of Sanxingdui (三星堆), Sichuan Province (四川省) inherited the tradition of Xia and Shang dynasties. The author noticed that some jade sceptre (*Yazhang* 牙璋) finished products from Jinsha (金沙) site were horizontally sawn into thin slices by string-sawing. They can be seen as the survivors of the Liangzhu string-sawing technique, as well as the later representatives of the continuous use of this technique we know so far (Gao 1998; Han 1998; Zhu et al 2004). Limited to our knowledge, this would be temporarily regarded as the lower time limit of this technique here. Fu Xinian (傅熹年) once mentioned the use of "string saw" (線鋸) in the Eastern Han Dynasty (Fu 1995). The "string saw" used in the modern lapidary generally refers to the use of metal string. The author noticed the traces of the even and flat cut on a jade scabbard slide (Fig. 14 : 3). We have tried to use bow saw with iron string to cut pyrophyllite with the addition of sand and water. A similarly even and flat cut was formed (Fig. 14 : 1, 14 : 2, 14 : 4, 14 : 5). We therefore propose that the sawing done by metal "string-sawing" is not equivalent to the string-sawing discussed in this paper.

The dispersion of *homo sapiens* from Africa and the spread of culture is the focus of archaeology in the 21st century that the space concerned covers the whole world (Wells 2002). Now the study being restricted to one country or even one Province will surely make further research more difficult. As shown by the string-sawing technique, the area covered should be starting from the whole East Asia region at least. When we talked about the cultural exchange in the past, emphasis was always put on the comparison of the same type of implements. However, research on lapidary has to surpass the morphological limit of implements and take the characteristics of the common techniques in order to connect the prehistoric cultures. The string-sawing technique mentioned in this paper is the genetic code of the jade culture of the Neolithic period in China as the route of its spread is also that of the jade culture. From the present archaeological evidence, it can be seen that string-sawing technique should be originated in the northeast and then spread in all directions. Traces of string-sawing can be found from the northeast plain at the south of Heilongjiang (Amur in Russia side), to the Shangdong (山東) area at the lower reach of the Yellow River; as far as middle and lower reach of the Yangtze River and the vast area of the Beijiang water system in the north of Guangdong (粵北北江水系). Preliminary knowledge of the southern limit of the string-sawing technique during the Neolithic has been gained but not much is known about the northern limit. According to the author's recent international communication with scholars and on-the-spot investigations, definite evidence of string-sawing applied on the prehistoric jades can be found from the Chertovy Vorota cave at the maritime region of Russia and the Kuwano site at the Fukui Prefecture (福井縣) of Japan (Fig. 15) (Kawasaki 2003; Karetsumachi 1995; Kinoshita 2002 ; Fujita 2003). From now on, further exploration and research regarding the northern limit of string-sawing technique distribution is awaiting for an international cooperation.

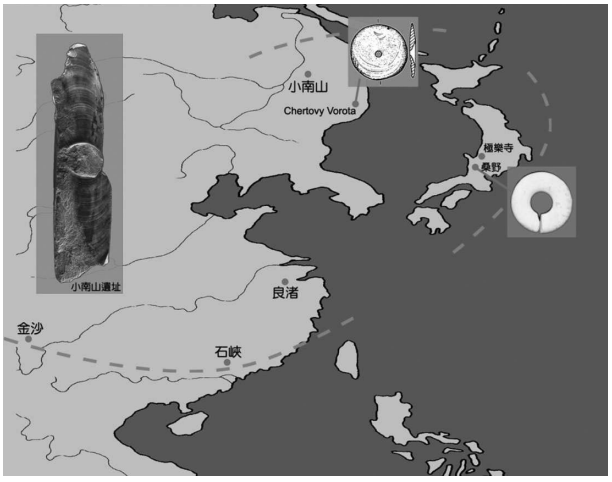

Figure 15. Distribution of the string-sawing technique in East Asia.
The prehistoric string-sawing was originated in the northeast China and then spread in all directions. The northern limit of distribution of the string-sawing technique on jade implement remains obscure now, but it should have included the Amur River region extending to the northeast parts of Honshu in Japan at least. The southern limitof this technique, on the other hand, is relatively obvious. It stretches from around the Yangtze River to northern Lingnan. However, Indo-China, the Philippines and Taiwan are not included in the area of string-sawing technique.

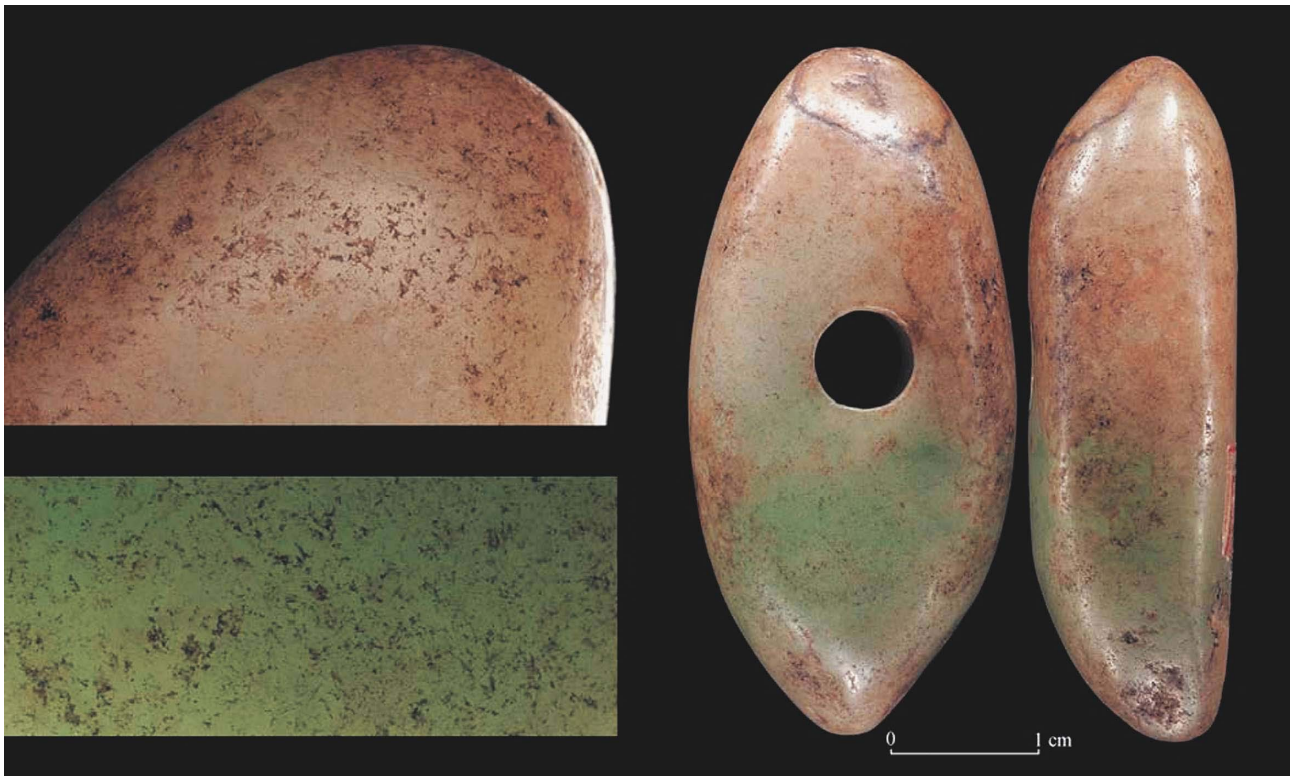

Figure 16. Jadeite pendants from Sasamori-cho, Aomori Prefecture, Jomon period. Tohoku University Collection, Japan
Pendants were made by pecking. Pecks were left along the edges of the pendant.

5. An Overview of the Pecking Technique

Concerning another technique-pecking, we might start by examining how did jade pecking come to exist. The petroglyhs found in the Upper Palaeolithic site at Foz Coa in Portugal was done by pecking. Large numbers of finely pecked stone artifacts have also been unearthed from sites of Upper Paleolithic period in East Asia. Pecking scars are shown on the eyes, nose, mouth and body of the stone human figure dating to around 23,000 BP excavated by Professor Chosuke Serizawa at the Iwato site in Oita Prefecture in Japan. In August 2004, the author had the honor of examining in a laboratory of a honorary Professor Serizawa of Tohoku University, the human figure and the roughouts unearthed from Iwato. The full figure measuring 9.5 cm in length and 3 cm in width was carved on chrolite schist. Moreover, during the Incipient Jomon period (13,600-9,200 bc), some stone axes uncovered from the Mikoshiba stone assemblage in Japan have a highly polished edge and pecking scars all over their surface. The large jadeite pendants like those from Sasamori-cho, Aomori Prefecture in the Tohoku University Collection are extremely exquisite too (Fig. 16). This kind of large jadeite pendants is distributed across the Archipelago of Japan, in particular to the east of Honshu. They have undergone various processes and pecking was definitely an important one among them. This technique found its way into the Early Neolithic period. Some scholars believe that the assemblage of stone tools from Mikoshiba culture was originated from the Osinovka culture in the lower reaches of Amur in Russia. Among the most significant recent archaeological discoveries are some very exquisite stone querns and pestles yielded from an area extending from the coastal region of Russian Far East to North China, from the sites such as the third stage of Ustinovka (12,000 bp) and Shizitan (柿子灘) in Shanxi (山西). That these querns and pestles were largely worked out by pecking has suggested the reliance on tools in the processing of cereal food and the flourishing of the pecking technique.

The jade and stone artifacts of the Xinglongwa culture including slit rings, scoop-shaped implements, arc shaped pendants, adzes and axes have pecking scars and even flaky white marks on their surface, suggesting the important role of pecking technique in the manufacturing process.

As said, an in-depth analysis of the jade surface done by the technique is crucial to our understanding of the ancient jade manufacture. It is therefore necessary to have an accurate observation of the pecking scars. On those Xinglongwa jades, at least three ways in relation to the application of pecking technique have been found :

1. Smoothening the rough surface of roughouts worked out by flaking-as often suggested by the pecking marks on the edge of jade adzes.
2. Working out grooves-as suggested by pecking marks on

the concave surface of the scoop-shaped implements.
3. Working out perforations by two-way pecking—as with the centre perforation and the opening of slit rings.

6. Conclusion

String-sawing and pecking these two techniques undoubtedly played an important role in the true jade culture of East Asia. The traces left on the jades have vividly revealed the extraordinary craftsmanship in the period of human history as early as 8,000 years ago. A further exploration of the dispersion of both techniques would be definitely an interesting topic, which can also give us more insights into the cultural exchange of different areas at that time.

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〈要　訳〉

この論文は糸切り挽きの技術とその実験結果について検討したものである。糸切り挽きの技術は，中国新石器時代の玉

文化の起源をなすものとおもわれる。実験結果から，各遺跡から発見された資料等を比較し，その起源と拡散情報について言及した。宝石細工術に関する研究は，単にその形態学的な研究では方法論的に限界あるので，それを越えた何かを見つけだす方法がなければならない。筆者は，その有効な手段として実験的方法があると考える。先史文化の技術に近づくためには共通した技術の特徴をそれによって把握し，比較することが良い方法の一つと考える。この論文ではそのことを言及した。現在の考古学的な証拠から糸切り挽きの技術は北東のアジアの本土中に起源を持ち，次にあらゆる地域に拡散したものと考えた。筆者の最近の研究によると，それはロシアの Maritime 領域の Chertovy Vorota 洞窟や日本の福井県桑野遺跡から先史時代のひすいに適用された糸切り挽きの技術の明確な証拠を見ることができたからである。