Traditional Chinese Woodworking Tools

Curtis Evarts

Carpentry tools were ennobled in Chinese classical literature and often served as metaphorical guides or rules for modeling behavior and living virtuous lives. The square and compass were symbolic means by which order was brought to chaos. Other carpentry tools were used to define the cardinal points of the universe. The creative process in which a series of graduated implements was used by the artisan to transform raw materials into beautiful and useful objects was extended by analogy to the development of inner metaphysical qualities.

Mastery of tools requires practical experience as well as knowledge. Mengzi noted, "A carpenter or a carriage maker may give a man a compass and a square, but cannot make him skillful in the use of them." Initially, the novice is taught to select the correct tool for specific applications and demonstrated basic techniques. After developing his skills, the artisan learns not only to use his tools, but eventually understands their potentiality to the extent of modifying them or even creating new ones for special applications. The evolution of tools from ancient times reflects the ability of craftsmen to respond to new demands.

While a comprehensive history of Chinese woodworking tools has yet to be written, this survey can serve as an introduction to better understand the tools and techniques that allowed the Chinese furniture-maker to create enduring masterpieces.

Historical Background

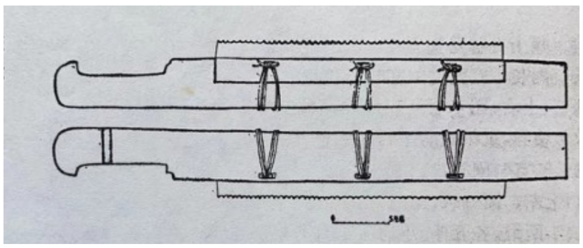
Excavations at the seven-thousand-year-old site at Hemudu have not only provided the earliest evidence of timber frame construction with pinned mortise-and-tenon joinery, but have also yielded some of the earliest tools known—axes, wedges, and chisels made of bone and stone (fig. 2). Primitive woodworkers probably began by using fallen trees, and then graduated to felling trees with stone axes. These fallen giants were delimbed, debarked, and chopped to manageable lengths. Experience taught loggers how to select trees with straight grain that could be split with wedge-shaped stones. The earliest Chinese textual references to board production refer to splitting timbers (*pi* 鈲, *cai* 裁, *lie* 劈, hewing (*zhizhuo* 执斲), and scraping (*gua* 刮, *xue* 削) surfaces, reflecting a basic primitive process common to many early cultures. Design was determined by the available tools and materials, and the measurements of early buildings, as well as the forms of early furniture, were dictated as much by the natural way in which wood could be split or cleaved as they were by aesthetics.

When straight-grained timber is split along the natural cleavage of the wood grain, the resulting exposed surface is undulating and splintered. With a hoe-shaped implement called an adze (*ben* 锛), these surfaces were hewn relatively flat. The earliest adze was simply an ax with a sharp-edged stone rotated ninety degrees to the handle. While standing on the piece to be surfaced, the workman swings his adze in an arc-like motion toward his feet–as if he were using a small garden hoe. By carefully monitoring the arc and radial distance, the sharp adze head can be swung with natural ease to uniformly chip away the highest points to create a level surface. With what is today considered extraordinary labor, relatively uniform planks were commonly hewn from quartered timbers.

Because the adze leaves a scooped surface typical of roughly hewn timber, ancient woodworkers attained a further level of refinement by using a long-handled, spear-like paring knife (*si* 斯). Excavations of ancient sites throughout China indicate that such a tool was in common use over a widespread area. The long, narrow blade is shaped like a willow leaf, and is sharpened on both sides; its flat stem was fitted into a wooden handle and wrapped with split bamboo cane. Sometimes the tip of the blade was curved upward slightly. This knife was worked back and forth over the surface to pare away the ridges left by the adze, a process requiring considerable hand-eye coordination (fig. 3).

With the development of metallurgy during the Shang dynasty, bronze cutting tools appeared that could be sharpened more easily than stone tools, and hold their edge much longer than those of bone. Axes, adzes, chisels, and awls fitted with bronze caps are consistently found in excavations at ancient sites. Nonetheless, stone and bone continued to be used as inexpensive materials for tool manufacture, and are found together with metal tools. A Western Zhou workshop site that had specialized in the production of bone tools and utensils was recently discovered in Shaanxi province, and back saws and knives with bronze blades were also found (Shaanxi 37-33).

The importance of tools in ancient times can be further inferred from numerous finds in tomb excavations, including toolboxes unearthed from two important Chu tombs. One found at Jiangling, Wangshan, in Hubei province contained an adze, paring knives, and whetstones (Zhang Yinwu 55); another, found at the renowned Xinyang site, held a set of small tools, including a saw, an adze with a bronze-capped cutting head (fig. 20) , and various carving and paring knives. The saw was fit with a finely-toothed bronze blade set into a groove in a long wooden handle and secured by a wrapping of fine string (fig. 4). Although it has been suggested that these tools were used for preparing bamboo writing slips, similar tools probably played an important part in the crafting of many of the early pieces of furniture found in the same tomb. A Warring States tomb, perhaps that of the king of Bashu (an ancient kingdom in modern Sichuan province), contained a group of beautifully crafted bronze woodworking tools that included crosscut saws and carving knives, as well as other variously shaped and sized knives and chisels.



A tomb site in Tianchang of Anwei province, thought to have been occupied by an important official of the Western Han (207 B.C.-A.D. 25), contained a toolbox with twenty-eight well-preserved carpentry tools (fig. 5). Interestingly, a modern tradition relates twenty-eight specific carpentry tools to the twenty-eight lunar mansions (Ruitenbeek 21); this new evidence may link this tradition to a very early date. The Anhui discovery is the largest singular group of ancient carpentry tools known, and provides important evidence for the historical development and their cosmological significance.

Iron production began during the technologically innovative Warring States period (476-221 B.C.). By the third or fourth century B.C., it was discovered that cast iron, which is a relatively brittle material, could be treated with heat to form a malleable product that could be folded and welded into caps for tools and agricultural implements. This technology, which resembled bronze production but was much less expensive, spread quickly throughout China. A passage from the late fourth-century B.C. *Guanzi* lists the allotments defined by the iron administrators: “Each woman certainly has a needle and a knife . . . each tiller of the soil certainly has a pointed plough, a forked plough, and a large hoe . . . each cart builder certainly has an ax, a saw, an awl, and a chisel” (Sung 198). Iron technology also quickly developed in the areas of welding and tempering, and, as cast iron was refined into low-carbon steel, laminated steel products appeared that surpassed those of bronze.

Although the materials used for tools developed from stone and bone to bronze and iron, it appears that the basic woodworking process—quartering timbers with wedges, and producing flat, smooth surfaces with the adze and paring knife—remained essentially the same for several thousand years. Traces of this process may be seen in the timbers of temples in Japan constructed during this latter period, when architectural styles, as well as Buddhism, were being transmitted from the fashionable Tang dynasty Chinese culture. As long as supplies of straight-grained timber existed, it was expedient to split timbers and surface them flat with an adze. By the Song dynasty, however, the depletion of timber resources was already placing new demands on carpenters. The shortage of timber that could be split with wedges stimulated the development of tools for joining shorter and smaller pieces, and also for the more economical method of sawing longitudinally thinner planks from timbers with twisted and convoluted grain that does not split naturally. It is presumably during this period that the large frame saw emerged.

More was accomplished with less when additional attention was directed to structural and joinery design, thus improving the rigidity of architectural frameworks. Knowledge of the mechanical properties of various woods also began to be practically applied. Records of such developments are evident in the Song *Yingzao fashi* (Treatise on Architectural Methods), which contains the earliest reference to pieced columns and beams, with illustrated instructions for creating laminated wood columns from two, three, or four smaller pieces joined with internal dovetail keys. Thus begins what can be considered another major stage in the development of architecture as well as carpentry tools.

Carpentry Tools

Now we may more closely examine specific carpentry tools, many of which developed in this later stage to meet the new demands inherent in the changing materials and developing architectural styles of the Tang and Song dynasties. Simultaneously, the trend from the ancient mat-level culture toward seating furniture began.

Carpentry tools in general reflect many different types of woodworking. There were master builders who oversaw both the design and execution of architectural projects, whose tools probably included ruler, square, brush and inkline, and level. Timber frame carpenters used sturdy tools to fashion large structural members, and sawyers cut logs into required lengths and planks. The tools of finish carpenters, who fashioned doors, screens, and windows, were scaled to more refined work. And there were maintenance carpenters whose tool chests would have included a wide variety of tools for the repair and upkeep of wooden structures. Specialized tools were also developed for furniture-making, boat-building, carriage-making, cooperage, wood carving, and so on.

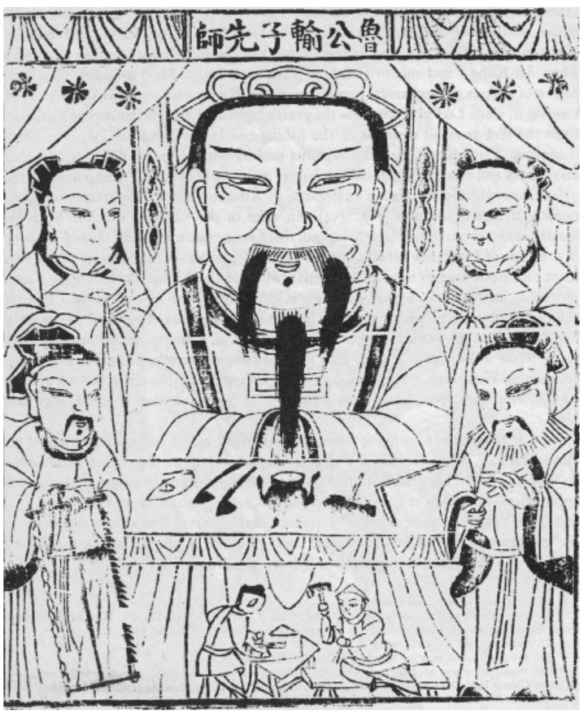
Makers of carpentry tools existed in most major population centers. A painting attributed to Su Hanchen (1101-1125), but generally considered to be a Ming Academy work, illustrates an itinerant peddler and his wheelbarrow cart loaded with hundreds of items, including many common carpentry tools—frame saw, drill, adze, plane, ax, rule, inkline, chisel, drill bit, and scraper. Such roving "middlemen" were still evident in modern times, replacing broken tools or outfitting the graduating apprentice with a set of new tools. Specialized tools were also made or designed by the carpenters themselves. A line from a poem by Pu Songling (1640-1715) entitled "Woodworkers" records that "handles for axes and adzes were made the carpenters themselves, yet for plane blades, chisels and saw [blades], money had to be spent" (*Pu Songling ji* 742)—obviously referring to the acquisition of metal parts from blacksmith tradesmen.

In the following discussion, carpentry tools are categorized according to the normal progression of basic woodworking processes, and in some cases by specific tool groups, and these divisions inevitably overlap. **Design tools** (I) are those which regulate and modulate mental concepts, and include measuring tools, the carpenter's square, marking tools, and so on. **Hammer tools** (II) were probably the first primitive tools, and are often used in beginning the physical process of transforming raw materials. The **adze** (III) is the earliest surfacing tool. Later **surfacing tools** (IV), such as planes and scrapers, are indispensable to the final stages of refinement. **Chisels** (V) are used throughout the basic process, for joinery as well as for surface decoration. Although **saws** (VI) are utilized early in the preparation of raw material, they are treated separately because of the relatively late development of longitudinal sawing. **Boring and piercing tools** (VII) such as awls and drills, are commonly necessary at the assembly stages of construction. **Abrasive finishing tools** (VIII) give the final polish to carved as well as smooth surfaces. And last, but not least, are the **maintenance tools** (IX) such as wetstones and files, which serve to maintain the cutting edges on chisels, planes, and saws that permit woodworkers to excel at their tasks.

I. Design and Measuring Tools

The celebrated patron of carpenters is Lu Ban (fig. 6), a legendary techno-wizard of the Warring States period, who, although earlier archeological evidence indicates otherwise, is credited with the invention of many carpentry tools. The Ming dynasty *Classic of Lu Ban* (*Lu Ban jing*) begins with a short biography, who is said to have spoken the following words:

> Roundness not brought about by the use of compasses, squareness not brought about by use of the square, such is the natural shape of Heaven and Earth. Using compasses to bring about roundness, using the square to bring about squareness, such is truly the faculty of man's senses with regard to these shapes. Furthermore, even if my understanding is sufficient to grasp fully the spirit of construction, how would it be possible that ten thousand generations all over the world would by their own effort have an understanding like mine? If their understanding is not like mine, then my own understanding will die with me, and my skill as well. So having strained the power of my eye to the utmost, I extend it by means of compasses and square, level and ink line so that when I want to build palaces and houses publicly or privately, to construct ships and carriages, to assemble implements and pottery, the methods that were used by people in the past should not surpass my own perfect method and self-tested way.



Because of his god-like abilities, Lu Ban was free from rules and guides. Nevertheless, he created the means that his art be transmitted. He was deified by later generations throughout China and southeast Asia, and became the patron saint of carpenters and other building workers.

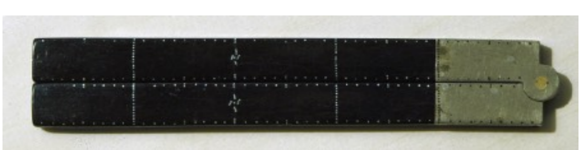
Foot rule 尺

A story that connects Lu Ban to the length of the *chi* concerns the duke of Lu, who wanted to rebuild his palace on a grander scale but feared repercussions because of sumptuary regulations. The problem was solved, however, when Lu Ban simply created a longer foot rule for him. Whether this story is legend or fact, the *chi* unit did lengthen over time, and no small amount of confusion has stemmed from the numerous foot rules associated with Lu Ban. The earliest foot rules (*chi*) found are from the Shang period and are approximately 15.8 cm in length, with decimal divisions of ten *cun* (inch), each of which is divided into ten *fen*. When China was unified under the Qin emperor, weights and measures were standardized, and throughout the Han periods the length of the *chi* seems to have remained stable at around 23 cm. By the Tang dynasty, the *chi* had increased to 30 cm, perhaps reflecting the increased scale of architectural constructions at that time. Each dynasty established anew the length of the official foot (*yingzao chi*), which during both the Ming and the Qing periods was set at 32 cm.

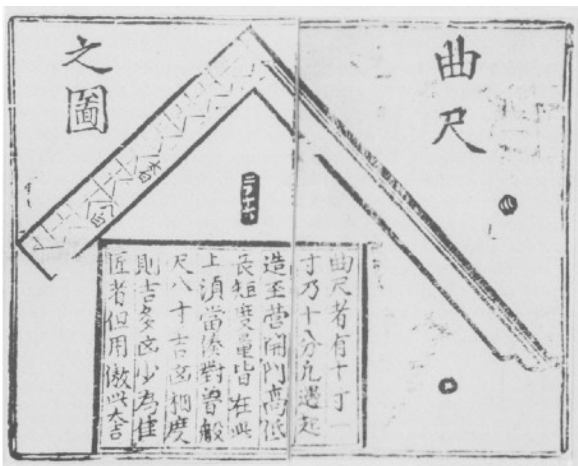
Although many different foot rules used for ritual and geomantic purposes are recorded from the Yuan to the Qing dynasties, the basic carpenter's foot rule is generally considered to have been relatively constant at 30 cm, with each inch assigned a specific color that has favorable or unfavorable characteristics. The first, sixth, eighth, and tenth (white) inches were considered favorable, as was the ninth (purple). All of the others were said to bring harm. It is not understood to what extent auspicious measurements were used in furniture-making. The only reference known to date is found in the *Lu Ban jing* and relates to the screen panels of a canopy bed; it states, "on no account may their width be [exactly] 1 *chi*".

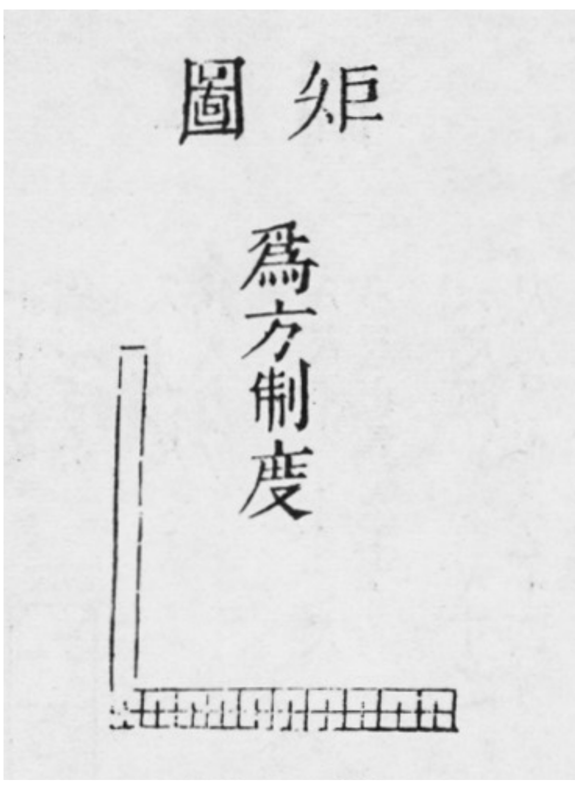
The *Xinbian Lu Ban yingzao zhengshi* (Newly Complied Correct Building Methods of Lu Ban), published c. 1500, explains that carpenters also used another rule called the *Lu Ban chi*. Its length of 1.44 *chi* was subdivided into eight inches, each measuring 1.8 inches on the carpenter's rule (fig. 7). These eight inches correspond in the following sequence to eight lucky and unlucky conditions: Wealth, Illness, Separation, Justice, Office, Plunder, Harm, and Luck. In house construction, this rule was used in conjunction with the *chi* foot rule to select favorable or unfavorable measurements for door openings and important frame members, according to the disposition of the builder toward his client. Its connection with the common carpenter's square will be discussed below.

In the Ming and Qing periods, the length of the *chi* varied among the trades. The most common lengths were the official foot (*yingzao chi*), the carpenter's foot, the cloth cutter's foot (*cai'yi chi*), and the land-surveying foot (*liangdi chi*). The Qing dynasty land-surveying foot was 34.37 cm, while, according to the *Qing Huidian* (Compilation of Records from the Qing dynasty), "The commonly used cloth cutting ruler is one official (*yingzao*) *chi*, one *cun*, one *fen*, one *li*, one *hao* in length," corresponding to 1.1111 *chi* or 35.56 cm. Other than a stretched length, the cloth-cutting foot was probably similar to that used by carpenters. With regard to those used for furniture-making, measurements taken from examples dated to the Ming and early Qing periods with a 30 cm rule generally fall neatly on even divisions, and, after a few tests, the 3 cm/*cun* and 3 mm/*fen* units become as recognizable to the eye as standard modern units like the centimeter or inch.



Bone, ivory, bamboo, wood, and bronze rules found at numerous excavation sites from the Shang period onward establish a long tradition of decoration with auspicious motifs. The 34 cm *hongmu* rule (fig. 8) has divisions of *cun* and *fen* marked out with brass wire studs; the former with neat lines of closely spaced studs, and the latter with a single stud. Each half-*cun* (five-*fen*) division is highlighted with an inlaid diamond pattern to facilitate reading the minor divisions. The central point of the rule is decorated with an auspicious, lozenge-shaped amulet, and the two- and eight-*cun* divisions are each set off with double *wan* characters. The folding rule finely crafted from ebony with white brass fittings is also decorated with *wan* motifs (fig. 9).





Square 曲尺

The carpenter's square combines the foot rule with a right-angle leg and is used predominantly to mark out right angles for cutting boards to length or for laying out mortises and tenons. It can also be used to mark out various angles or pitches by positioning the square relative to specific markings along its two legs.

An illustration of the traditional carpenter's square is also found in the *Xinbian Lu Ban yingzao zhengshi* (fig. 10). The short leg is the traditional *chi* rule divided into ten inches, with the sixth and eighth "white" auspicious inches labeled. Although the longer leg is not marked with subdivisions in this illustration, its proportional length to the shorter leg is 1.44:1, precisely that of the *Lu Ban chi*. Moreover, this is an interesting approximation of the Golden Section, that being the relationship equivalent to $\sqrt{2}$:1, or 1.41:1—the length apparently adjusted to be evenly divisible by the eight favorable and unfavorable inches, each measuring 18 *fen* along the *chi* foot rule. In Japan, a nearly identical square (*sashigane*) is based more precisely on the Golden Section. The length of the longer leg is divided into both eight and ten subdivisions; the latter enabled carpenters to make quick calculations to efficiently mark out square timbers from round logs. A method of squaring round timbers is described in the late Ming encyclopedia, *Sancai tuhui* (published 1607) with an illustration (fig. 11), and is based on the less precise relationship of 1.43:1, which is also close to that of the two legs of the Chinese carpenter's square.

The importance of ritualistic and geomantic calculations appears to have compromised geometric precision. Nevertheless, a few simple trigonometric calculations show that commonly used angles could have approximated evenly marked auspicious inches on both rules. For example, a 22.5-degree angle, necessary for an octagonal construction, is closely approximated (22.6°) with the square set on the white sixth inch (60 *fen*) and on the eighth inch corresponding to luck (144 *fen*).

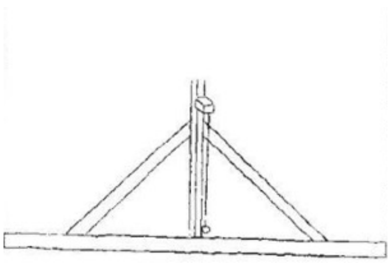
A 30-degree angle, used to construct hexagonal forms, could be approximated (29.1°) by creating a line from the white eighth inch (80 *fen*) to the eighth inch of luck (144 *fen*). And a precise 45-degree angle, commonly used for mitered construction, could be found along the ninth purple inch (90 *fen*) and the fifth auspicious inch corresponding to office (90 *fen*). Extant Chinese carpenter's squares vary considerably in their size, however, and are commonly found with the 30-centimeter *chi* foot rule for the longer right-angle leg and a shorter leg of various lengths.

Compass 圆规

Both compass and square are depicted on a Han tomb brick as traditional emblems of Fuxi and Nugua, mythological gods who brought order to chaos (fig. 12). Because the circle and the square came to respectively symbolize heaven (*tian*) and earth (*di*), the tools used to make these forms also acquired cosmic associations. These associations are clarified in a passage in which Lu Ban explains, "Roundness not brought about by use of compasses, squareness not brought about by use of the square, such is the natural shape of Heaven and Earth…"

The compass carved on the Han tomb pillar is a traditional two-leg compass. The bisection of angles is quickly accomplished with the compass, and equilateral triangles and hexagons are also easily marked with it. Thus many of the repeating hexagonal and coin patterns traditional in lattice decoration were undoubtedly dependent on it. Used in conjunction with the square, the possibilities are manifold.

The *Sancai tuhui* illustrates a beam compass grouped with other measuring tools of the carpenter, including square, inkline, and level (fig. 13). It has a pivot point affixed to one end and a scribing point that can be adjusted to various radii. The beam compass is well suited to marking out variously sized large diameter circles simply by changing beam lengths. With the radii set, the beam is swung around the pivot point to mark the circumference of a circle.



Level 準

The level, termed *zhun* in the *Sancai tuhui* was illustrated four centuries earlier illustrated in the Song *Yingzao fashi* (Treatise on Architectural Methods), where it is termed a *zhenchi* (true rule) (fig. 14). There the T-square-shaped tool with braces is shown with a weighted plumb line hanging from a small bracket attached to the vertical arm, which is attached at a 90-degree angle to the base. When placed on a level surface, the weighted plumb line hangs parallel to the vertical arm.

Inkline 墨斗

Using an inkline, the craftsman could mark long, straight lines onto planks of wood to serve as guides for sawing and planing straight edges. Its inkwell also provided a source of ink for marking brushes. The body of the inkline is carved from a block of wood, with one end hollowed out to form the ink pot and fit with a reel at the center. The inkline is one of the more artistically conceived tools, and many were probably made by artisans for their own use. That illustrated in the *Sancai tuhui* is carved like a bird (fig. 15).

The inkline in figure 16 carved with a *ruyi* cloud-head design and reinforced with metal mounts (fig. 16). The reel is housed within a deep mortise carved into the center of the wood block, and is turned with a long handle bent like a small crank. The shaft turns on blossom-shaped bushings like those often seen as furniture escutcheons, and a small bushing is fit on the end as a to prevent enlargement of the hole from wear at the point where the string enters and exits the inkwell. When in use, the inkwell would be filled with a wadding of silk waste or moxa saturated with black ink. The best type of line was also made from silk, which lightly absorbs the ink as it is pulled through. When the inked line is stretched taut between two points on the flat surface of a board and snapped upwards from the middle, an inked impression of the straight line is marked on the board.

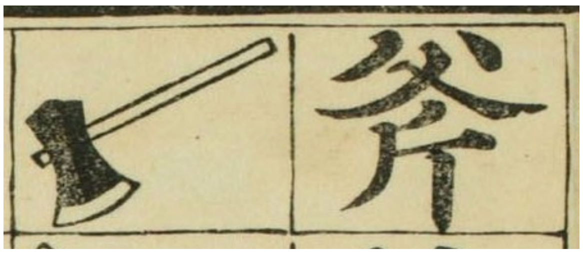
The end of the ink line is attached to a small wooden block with a sharp iron pin that could be pressed into the wood, thereby enabling the line to be snapped by one person. Legend has it that Lu Ban also invented this device, to avoid inconveniencing his wife when he need someone to hold the end of the line—the pin thus acquiring the term "Lu Ban's wife"(*Lu Ban qi*).

Marking brush

Carpenters made their own marking brushes from split bamboo. One end was cut at an angle with many longitudinal cuts to form a coarse, brush-like bristle. The other end was pointed to draw lines. The marking brush was dipped into the inkwell of the inkline, and is very efficient for marking straight lines on boards against a ruler or for writing assembly codes on finished parts (cf. fig. 17); like a pencil, it could also be easily recut from time to time. Scribing brushes were also fashioned from bamboo, and were used like a compass with legs or dividers to trace parallel lines or to transfer an uneven profile onto a board. The width between the two legs of the split brush is adjusted and fixed with a sliding wedge held in place by a wrap of string. To increase or

decrease the distance between them, the string is loosened and the wedge is moved upwards or downwards to the desired distance. The string is then tightened again to keep the wedge in place (Hommel 251).

II. Hammer Tools



Ax 斧

The ax is the most common hammer-like tool used by Chinese carpenters (fig. 18). The *Zhoushu* (History of the Zhou dynasty) credits Shen Nong, the legendary father of husbandry, with the development of the ax for splitting (*po*) wood. The *Tiangong Kaiwu*, a compendium of late Ming technologies published in 1637, explains the process that had probably been used for centuries for making the ax head. "The hollow space in axes and mallets, into which the handle is fitted, is made in the following way: first, a 'bone,' called a 'sheep's head,' is prepared by hammering a piece of cold iron: second, a piece of hot iron is placed around the cold iron bone [and is hammered to form either an ax or mallet]. The cold and hot iron do not adhere to each other, and [when the 'bone' is withdrawn] a hollow space is left [in the ax or mallet that has been made]" (Sung 190).

The cutting edge is generally sharpened with a single bevel, which naturally hews a relatively straight line. Because the blunt end of the carpenter's hatchet is not used for striking nails or metal, it does not become deformed with a rough edges. Therefore the broad, flat side of the carpenter's hatchet can also be slid along a rough surface to cleave off high areas in preparation for finer surfacing. The broad side of the hatchet is also used for impact during assembly and disassembly of tight-fitting parts, in preference to its smaller striking face, which tends to mar surfaces. The broad side of small ax-shaped mallets is also used by carvers to strike their chisel.

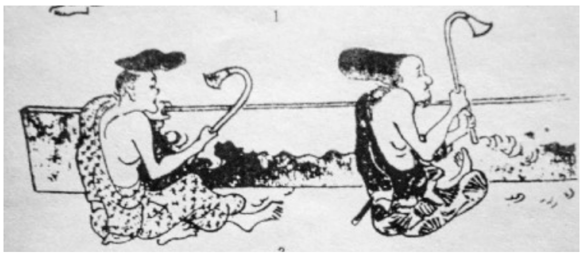
Wooden mallets

Wooden mallets were also used by carvers to impact chisels and gouges. Dense hardwoods were especially appropriate for mallets, and gave the carving chisel a sharp impact that could be easily controlled. Such is the small *zitan* mallet (fig. 19) that was quite possibly used by a woodcarver. It appears to have been shaped from a small branch of *zitan*.

Nail hammer

Because Chinese carpenters did not use nails to the extent that they are used in the West, the claw hammer that facilitates their removal had little purpose, although it was adopted in coastal regions where foreign nails were more commonly encountered (Hommel 238). A specialized nail hammer existed, however, with a large round face used for driving a nail most of the way. The back of the head, which tapers to a small diameter face, is then used for setting the nail without leaving unsightly hammer marks (fig. 20). Nails were more commonly removed with special nail-pulling pliers.

III. Rough Surfacing Tools



Adze 锛

The adze is rough surfacing tool that is closely related to the ax. It has a sharp cutting edge oriented perpendicular to the handle, and is swung with even radial strokes toward the feet to shape flat the surfaces of rough timber (fig. 21). The earliest adzes were fashioned from a piece of wood that naturally curved back on itself to form a handle with a wooden head that could be fit with stone, and later with bronze metal caps (fig. 22). By the Ming and Qing periods, the adze had long been forged from iron, using a process similar to that described above for the ax. The *Tiangong Kaiwu* also describes the process of quench-hardening, after which such an implement can be given an extremely sharp edge: “The hammer-forged articles of wrought iron and steel are not very hard before the correct balance of water and fire has been achieved, and therefore should be quenched in clear water immediately after being taken from the forge. This is called hardening of steel and iron, meaning that before this the soft properties of the iron and steel were not yet entirely removed” (Sung 190). This latter tempering process produces “tempered steel.”

Traces of adze strokes can be found on the underside of a rather thick (1.2 cm) *huanghuali* tabletop panel of a recessed-leg table in the former Museum of Classical Chinese Furniture collection (fig. 23). The rather deep gouges reveal the use of a sharp blade 3.6 to 3.9 centimeters wide and penetrating at an angle 20 to 30 degrees to the surface. These traces show that the timber surface was worked from one side across to the other in incremental rows moving forward approximately 4 to 5 centimeters at a time. Shallow troughs also remain indicating the subsequent use of a scrub plane, which peeled off thin strips across the grain to even up the roughly gouged surface.

Chan 铲

As mentioned above, spear-like paring knives were skillfully used to further refine roughly hewn surfaces, as was a long, spade-shaped knifing tool called *chan*. The rhyming dictionary *Gujin Yunhui***,** edited during the Yuan dynasty**,** describes the *chan* as “a tool used to flatten wood”, and an illustration is found in the fifteenth-century *Xinbian duixiang siyan*, a pictorial children’s primer for learning common characters (fig. 24). From this depiction, it appears that the *chan*’s cutting head was about the size of an ax head, and was attached to a long handle. The sharp knife edge was presumably held with its long handle at a low angle to a timber or plank and thrust forward to pare away at roughly adzed surfaces. Although evidently still commonly used during the Ming dynasty, these paring tools were eventually replaced by various types of planes, which removed thin layers of wood much more quickly and with considerably more precision.

IV. Surface Refining Tools

Spokeshave 滚刨

An early visual reference to a spokeshave plane occurs in the Song painting *Qingming Shanghe tu* (Scenes Along the River During the Qingming Festival), which depicts a cartwright straddled over a bench working a flat length of wood with a spokeshave (fig. 25). A bench stop (aka "Lu Ban's wife") attached to the end of the bench holds the piece as the cartwright uses both hands to push a two-handled cutting tool down and away from his body. The spokeshave plane was highly effective for shaping curved surfaces. It is literally termed "axle plane" (*zhoubao* 軸刨*)* and must have been a common tool of the cartwright for shaping spokes and axles.

A large drawknife/spokeshave is clearly illustrated in the *Lu Ban jing,* where a craftsman is shaping a round post (fig. 26). In furniture-making, it is an important modeling tool requiring skill and an artist's eye, and is used primarily to pare away at roughly cut pieces to reveal the beautiful shapes within. Two small Chinese spokeshaves in the author's collection have oak handles and wrought-iron blades inlaid with steel (fig. 27). Similar ones were probably used for the final shaping of rounded table legs and fluid, curvilinear elements like the yokes of chairs, curved armrests, gooseneck supports, swept-back hindposts, S-shaped sideposts, footrests, and so on.

Plane 饱，刨

In Chinese, the plane is called *bao*. Its two pictographs are formed from the character *bao* (包), meaning "surround" and "contained," and the metal radical *jin* (金) or the knife radical *dao* (刀), and thus they could be literally interpreted to mean "contained metal [blade]." The earliest references to the character *bao* are found in Tang dictionaries, where it is described as a "'plane-knife' (*baodao* 饱刀), a tool to work wood." That description, however, could also refer to a knife-holding tool such as the spokeshave or drawknife, both of which today are also referred to as various types of *bao* as well as *chan*. In his work on ancient methods of surfacing wood, Sun Zi concludes that the *bao* plane as we know it today only appeared some time before the middle of the Ming period (Sun 75).

The cutting edge of a plane only slightly projects through an opening in its wooden body, and peels away uniform shavings without gouging the surface. The longer bodied jointing planes (cf. fig. 28) allow long, straight surfaces to be matched with relative perfection. It is remarkable to consider the many surviving wooden artifacts, not to mention the complex architectural woodwork illustrated in the Song *Yingzao fashi*, that may have been produced without the use of a plane. Evidence for an earlier date may possibly be found in a section of the scroll painting, "Taiping fenghui tu" (Street Scenes in Times of Peace) attributed to Zhu Yu (1293-1365), which depicts carpenters working with various tools, including a long jointing plane (fig. 29). Although the scroll painting has a number of colophons that tend to corroborate its authenticity, some modern scholars view it as a Ming work, and thus the curators of the Art Institute of Chicago where it is housed have conservatively dated it to the fifteenth/sixteenth century.

Although it would seem likely that the plane was developed during the Song period, there is little direct evidence to support any widespread usage of it before the Ming, other than dated terminology with some etymological inference and an insecurely dated painting. Perhaps it was an esoteric tool kept secret by members of the cult of Lu Ban, for the first firmly dated depictions of planes appear several times in the illustrated Wanli (1573-1619) edition of the *Lu Ban jing*. At least two types of planes are illustrated: the common scrub plane, used to flatten the surfaces of short pieces, and the jointing plane, used to plane longer surfaces straight. All retain the two handles of the spokeshave plane, and woodworkers are shown pushing them forward.

A number of more detailed descriptions of the plane appear in compendiums and dictionaries compiled after the sixteenth century. The earliest source is *Tiangong Kaiwu* (1609), which is unusually specific:

> [The blade of] the common plane is made sharp with one inch steel laminated onto its cutting iron. It protrudes the smallest fraction at an angle from the opening of the [lower] surface, and therefore [is used to] smooth flat the surface of wood. [This process] was called leveling (*zhun*) by the ancients. Long ones can be supported to lay level with the blade exposed. Wood can then be planed by pulling [or pushing over the cutting edge]. This is called a 'push plane (*tui bao*).' Barrel makers often make use of it. The common type has two wing-like wooden handles perpendicular to the body for pushing [the plane] forward. Used for fine woodworking is the molding plane (*qixian bao*), with a plane blade about 2 *fen* in width. Those for scraping wood extremely smooth are called centipede planes (*wugong bao*). Ten or more small knives are clinched within a wooden handle and look like centipede legs. (Trans. after Song 899)

Twenty years later, additional details appear in the *Zheng zi tong*, a dictionary of characters, where it is also linked to its predecessor, the *chan*:

> Plane (*bao*), tool for straightening wood. The iron blade is shaped like a *chan* and is held tightly within a wooden block so that it cannot move. The wooden block has an opening, and at the sides are two small handles with which the hands can repeatedly push it. Wood shavings come out through the opening. It is faster to use than the *chan*.
> (Trans. after Sun 74)

The Japanese *Wakan sansaizu-e* (Chinese and Japanese Universal Encyclopedia), published in 1712, also compares this relatively new tool to the handheld paring knives.

> The ancients used a spear-like planing knife (Chinese *qiangsi* 枪鏩), but commonly used for more than one hundred years is the *tsuki-ganna* [push-plane]. Although the two forms are different, they achieved similar results. Compared to the planing knife, it is much faster to use and more precise, however, and today is commonly written [Chinese *bao*] .
> (Trans. after Coaldrake 147)

These references indicate that the quick and accurate plane evolved from the early planing knives and spokeshave tools, and was not known in Japan before the sixteenth century, when the push-plane was introduced from China.

The common plane with crossbar grip (*cu bao* 粗刨) was used for a multitude of purposes, and was especially well suited to the quick removal of kerf marks left by a saw. An often published illustration from the *Lu Ban jing* illustrates the common plane being used on a table that has just been assembled, bringing the rough, uneven surfaces of its tabletop frame members and panel together into one smooth, clean surface (fig. 30).

The *Tiangong Kaiwu* also records the basic variations of the plane, including the long plane (*zhangbao* 長刨). "Long ones," like the Western jointing plane, as opposed to the shorter and more common jack or scrub plane, were used to surface long, straight edges that could be well matched, and were thus indispensable for making water-tight barrel staves (cf. fig. 31). Using the plane in a fixed and inverted position was an innovation that foretells the modern jointer. Split timbers are relatively free from warping. However, timbers that are sawn longitudinally along a straight line will often release hidden internal tensions and and the planks find equilibrium along a new, yet, curvilinear axis. The long body of the jointing plane maintains the cutting edge on an even plane, and with successive passes thin shavings are removed to produce a long, straight edge. Builders found them indispensable for the manufacture of laminated beams and columns, and furniture-makers also found them instrumental in producing panels with seamless joints for hardwood tables and cabinets, as well as in truing the edges of long frame members such as those found on *chuang*s and beds, racks and stands, and tall folding screens.

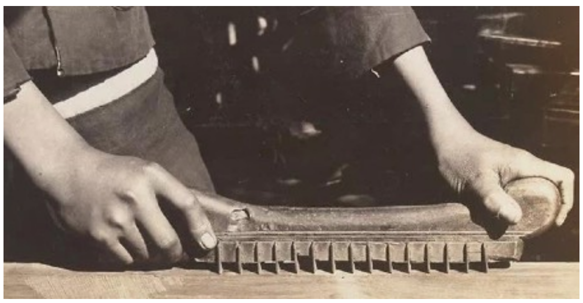
Molding plane 起线饱

The molding plane (*qixian bao*) in the *Tiangong Kaiwu* is described as having a blade width of two *fen* (six mm) in width. The knife blades of molding planes are cut with a profile of the desired molding section, to which the sole of the wooden body is also shaped to match. Two small Chinese molding planes with oak bodies in the author's collection have blade widths of three *fen* and five *fen*, and both are shaped to cut convex molding profiles (fig. 32). The plane blade seat and throat for the shavings to exit are cut at approximately 45 degrees. A small iron pin is driven through the sides, under which the capping iron and plane blade of wrought iron with laminated steel tip are securely wedged. Besides this wedging function, the capping iron, also called a "chip breaker," directs the exiting shavings away from the blade and out the throat.

Surviving examples of furniture from the late Ming and early Qing periods display a variety of molded profiles, as we see on the frames of table tops and seating furniture, and the legs of tables. The earliest profiles seem to be relatively simple, with ogival curves (also called "ice-plate moldings" by modern Beijing craftsmen), found repeatedly on table tops and beds, and large concave moldings, often with a step, on chair and stool seat frames. As plane technology developed throughout the early Qing period, moldings became more intricate and refined.

Rebate and grooving planes

The frame-and-panel construction typical of Chinese furniture was usually assembled with a tongue-and-groove joint produced with rebate and grooving planes. The rebate or shoulder plane is configured to shave a notch along the edge of a board or panel, the width of which is held constant by the integrated guiding edge of the sole plate. Most panels have a notched shoulder on the front side; however, because panels were not generally of uniform thickness, they were beveled on the back side with a jack or common plane along a scribed line to leave a tongue of uniform width. Grooving or plough planes (*gou bao)*, as the name suggests, were used to cut narrow grooves into frame members, and wider versions were also used to clean out the mortises for transverse braces cut across the grain. The sloped sides of these grooves were probably first cut with a small backsaw.



Scraper plane 蜈蚣刨

The passage cited above from the *Tiangong Kaiwu* recorded the use of a "centipede" plane to produce a highly polished surface. This is of particular interest relative to the production of furniture from tropical hardwoods like *huanghuali* and *zitan,* which have interlocked grain and are prone to tearing out regardless of the direction from which they are planed. A scraper is able to finish the wood surface more finely than is a plane, and without tearing out the contrary grain. These planes are still used by modern furniture-makers and restorers in China (fig. 33). Although termed *bao* (plane), they are actually a sophisticated "scraper". Two Americans who made a woodworking tour through China during the late 1980s took special note of this uniquely Chinese tool, which was previously unknown to them. In an article in *Fine Woodworking*, they reported that scraper planes were available in Shanghai marketplaces, but the best ones were made by the workmen themselves utilizing short pieces of old saw blades:

> The blades are held in place on the tool by compression alone. The stock is kerfed using a handsaw with all the set removed, which makes the kerf an exact match for the thickness of the steel. The extended projections of the short grain between the kerfs are flexible enough to allow all the blades to slip into place, except for the last one. This one must be forced in, and this process tightens up the entire row. After mounting, the blades are filed into perfect alignment, and the back side of each cutting edge is beveled to about 60 degrees.
> (Kreigshauser 83)

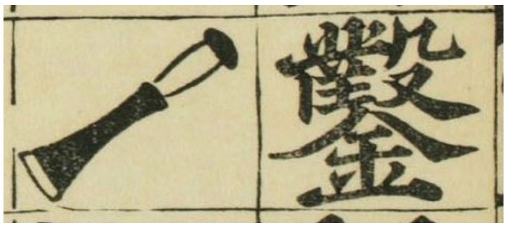
Today in Hong Kong these scraper planes, known locally as *pang bao* 耪刨, have twelve to fourteen steel blades which are one to two millimeters in thickness set vertically into a wooden handle. Because they must all be exactly the same length, the scraper is pushed over the surface of a flat whetstone until the edge of each blade is ground into the same plane. Afterwards, a steel file is used to shape the back edge of each blade to the desired angle. Only then is it ready to scrape the surface of the wooden panel smooth and flat, with each knife removing fine shavings. A skilled workman can quickly shape beading with the scraping tool by using an extended finger as a guide to define its inner edge and then gently rolling it over. One shop in Hong Kong specializing in *huanghuali* furniture restoration utilizes several *bang*s of different sizes, as well as those with convex and concave profiles to accurately shape and smooth large curved surfaces (fig. 34).

Scrapers 刮板

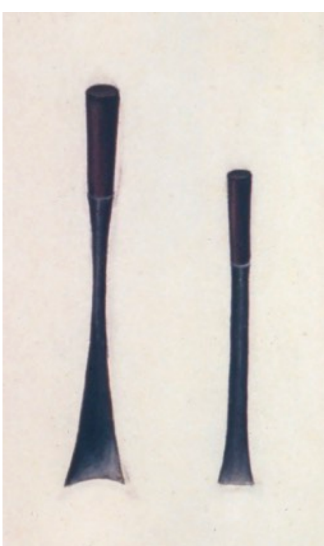
Single scraper blades (*guali*) were probably also used. Modern ones are simply a thin sheet of steel approximately 15 centimeters by 6 centimeters. Once the edge is ground square and flat, the corner is rolled back with a burnishing tool to create a sharp, hooked edge. When scraped across the surface it removes extremely fine shavings (figs. 35-36). Scrapers were also used to flatten recessed areas as well as the background areas behind relief carvings. Curved scrapers were also used to realize smooth thumb moldings.

V. Chisels 凿

Five sets of bronze chisels were discovered in the Warring States tomb from the ancient kingdom of Bashu, each set ranging in blade width from 1.6 to 2.6 centimeters and in length from 15 to 24 centimeters (Sichuan 10). These early chisels are beveled on both edges. A single bevel is much more precise and easily controlled, and probably emerged during the Tang and Song periods, when shortages of timber led to new developments in architecture requiring more accurate joinery.

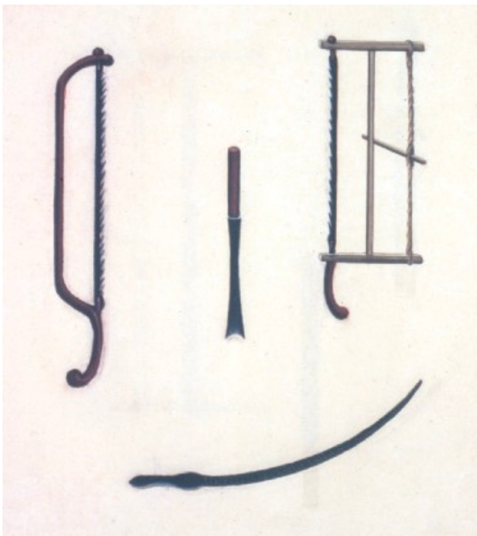


Carpentry chisels (fig. 37) fall into two broad categories of striking or forming chisels and paring chisels, excluding those for woodcarving. The striking chisel is used to cut deep mortises (fig. 38). It has a much heavier blade shank and a less acutely ground knife bevel than other chisels, allowing it to withstand the sharp hammer blows needed to penetrate across the grain when cutting deep mortises. Paring chisels have long, slender blades that are ground with more acute blade angles. Guided by hand, they are often used to finish work begun with striking chisels. According to the *Tiangong Kaiwu*, flat chisel and curved gouge (*wanzao*) blades were forged out of wrought iron in various widths from three *fen* to one *cun* (9 mm to 30 mm) and inlaid with steel along the cutting edge. Like the ax, the shank was hammer-forged around a cold iron plug to form the hollow cylinder into which a wooden handle was fit (Song 900). The butt end of the wooden handles of striking chisels are banded with iron to prevent splintering.

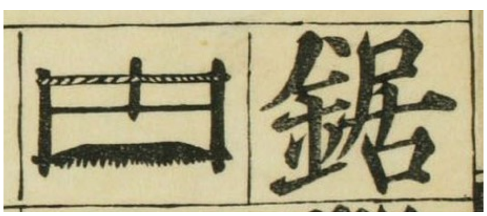


Contemporary with the semi-legendary Lu Ban is the master of woodcarving, Wang'er (王爾), who is credited with the invention of curved chisels and engraving tools (cf. fig. 36). Considering the Chinese fondness for carved wood decoration, it is curious that so little is recorded about carving tools other than the standard chisels, gouges, and knives. Our only evidence is thus the traces of tools found on early work. A modern carver in China has as many as fifty different carving chisels, including various widths of flat chisels, variously radiused curved chisels (cf. fig. 39), various sizes of V-shaped grooving chisels, and various L-shaped background smoothing chisels (Cooper 28), as well as a number of carving knives. A close examination of incised, low relief, high relief, and open carving found on furniture and architectural woodwork of the late Ming period reveals that many of these same specialized chisels and knives must have been used.

VI. Saws 锯



Legend records that Lu Ban was inspired to invent the saw after he cut himself on a blade of grass and noticed the fine serrations along its edge. The *Sancai tuhui* also credits two contemporary philosophers, Mengzi and Zhuangzi, with roles in its development; the latter described its newly unleashed potential as the external manifestation of eternal principles (*li*). Extant saws excavated from this ancient period are rather diminutive, however (cf. figs. 3, 4), and we are left to wonder what other sorts of saws might have been wielded by masters of that time. A clue may be found in the seventh-century, knife-shaped crosscut saw excavated at Nara (fig. 40), which is thought to have originally measured fifty centimeters in length and is presumed to have been used in the construction of the Horyu-ji temple at Nara during a period of extensive transmission of architectural knowledge from China. Although these early saws were relatively inefficient, knife saws (*liju*) with developed tooth patterns and of various configurations continued to be used, and would have been suitable for cutting cross grain as well as openings in thin panels.



Frame saw 架锯

The deep throat of the frame saw (*jiaju*) has the capacity of cutting much thicker material. It has been used in the West since Roman times, and was possibly introduced to China from the West along the Silk Road. It is only after the Tang dynasty, when trade was flourishing along this route, that traces of its use in China begin to appear. The blade of a frame saw is held in tension at the bottom of a H-shaped frame with twine twisted like a tourniquet (figs. 41-42). Using a thin metal blade held in tension was not a new idea for the Chinese, as wire saw blades strung within a bow-like frame were used for cutting jade as early as the Bronze Age (see wire saw below). Nevertheless, the Chinese frame saw seems to have emerged as a result of several factors, including contact with the West, continuing developments in iron technology, and shortages of straight-grained timber that could be easily quartered.

The earliest traces of the frame saw coincide with its use as a plank-cutting saw. A group of iron tools placed in the tomb of a high official from the Beiyan state during the Five dynasties period (A.D. 907-959) included two frame saw blades with the remnants of their wooden handles attached. The actual length of the original blades could not be determined because the blades had deteriorated into eight pieces; however, the width ranged from 2.6 to 3 centimeters and the thickness was 2 millimeters (Li Yaobo 7). From photographs in the archeological report, it appears that the teeth are oriented in opposite directions from the middle of the blade. This evolved configuration is found on two-man frame saws and developed to equalize their exertion;

the bi-directional teeth cut both pushing and pulling as the saw was stroked back and forth to slice planks longitudinally from a timber (fig. 41). It can be reasonably assumed that the standard frame saw with one-directional blade was already well established at this period.

Textual evidence of the frame saw being used for slicing wood longitudinally follows shortly thereafter in the Song *Yingzao fashi,* compiled in 1097, where equivalent merit is stipulated for sawing different lengths of timber according to their relative density:

> [1] Oak or sandalwood wood, fifty feet (*chi*); [2] miscellaneous hardwoods like elm (*jumu*) or locust (*huaimu*), fifty-five feet; [3] white pine (*baisong mu*), seventy feet; [3] soft woods like *nanmu* and cypress (*bomu*), seventy-five feet; [4] *jumu* [a softer variety?], yellow pine (*huangsong*), water pine (*shuisong mu*), and yellow-heart wood (*huangxin mu*), 80 feet; [5] fir (*shan mu*) or *wutong*, one hundred feet. A ten percent adjustment is made for sawing single lengths over twenty feet (2 *zhang*) or old inferior material full of nails.
> (Trans. after Li Mingzhong, *juan* 24, 8)

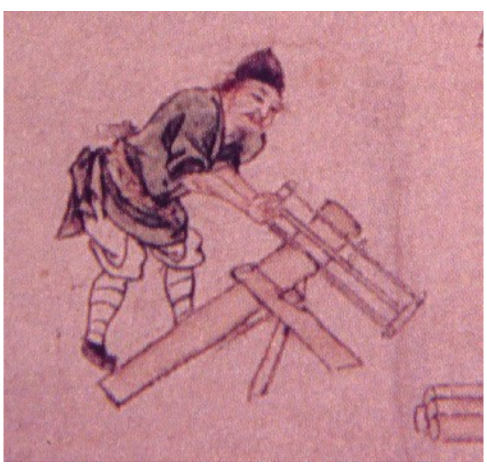
Tooth patterns specific to the varying densities of these woods may have been experimented with at this time. However, the “ten percent adjustment” for material full of nails would have hardly compensated a frustrated sawyer, who would have had to spend a good deal of time removing every nail he could find, well knowing that if the saw blade struck an overlooked nail, all work would stop while the entire blade was resharpened.

Many illustrations from the Ming period depict what must have been a common technique for sawing planks from timber, and records of foreigners from the early part of this century indicate little change. The timber is usually set upon a crossed brace located near the midpoint, with one end secured to the ground, and is marked with the inkline as illustrated in the carpentry scene in “Street Scenes in Times of Peace” (fig. 43). A plank is arranged for the top sawyer to stand upon at the upper end of the log where sawing along the line begins. With slow but steady progress, the sawyers arrive at the midpoint, during which period the platform plank is moved back in increments. A wedge is inserted into the saw kerf at the end to prevent the blade from binding. All the cuts were made in one end of the timber before it was necessary to turn it around (fig. 44). A horizontal sawing technique for cutting very long planks was also developed, using iron “dogs” to attach the timber over weighted supports, and allowing sawyers to work face to face on opposite sides of the log (Hommel 227; Needham 54). Although the largest frame saw Hommel recorded was five feet in length, much longer saws would have been required to cut the hardwood planks of many extant tabletops that are well over two feet wide. Hommel also noted that the saw blades were connected to the outer frame members with iron loops, which allowed the distance from the central support to be adjusted and thus also served as a guide for cutting planks of uniform thickness (Hommel 225). Sawing planks with the two-man saw, sometimes called a "dragon saw," was intensely laborious, and did not necessarily require the expertise of skilled carpenters. Although the task may have formed part of a carpenter's rigorous apprenticeship, sawyers were more likely a specialized group of laborers. Each newly sawn board, however, rewarded their labor with the impression of fantastic natural patterns arising from the freshly revealed wood grain.

The quality of the saw blade, as well as the configuration and sharpness of the teeth, are all crucial in its ability to efficiently slice through wood, and all the more so for longitudinal cutting. The Ming *Tiangong Kaiwu* records:

> Sawblades are commonly hammered with wrought iron into thin strips; no steel is added nor is it tempered. Afterwards, it is cold-hammered to increase its strength. A file is used to shape the teeth. [The frame is] a wooden cross member which is fit to two end pieces [around which] silk cord is wrapped and twisted to open [the other side in order to] tension [the blade]. Long ones are used for splitting timber lengthwise. Short ones cut wood across [the grain], and the finely toothed ones are used for cutting bamboo. When the teeth become dull, a quick touch with the file will resharpen them and the saw can be used again.
> (Trans. after Song 898)

It is obvious from this passage that the Chinese of the Ming period were familiar with the process of cold-hammering, which increases the hardness of wrought iron. (A change in the sound produced by the hammering signaled the smith of the change in hardness.) Interestingly, an analysis of a small iron chisel from a Han tomb revealed that its cutting edge had been hardened with cold hammering (Wagner 280). This hardening technique is also applicable to bronze and may date from the Bronze Age.



The shorter frame saw was a utility saw for woodworkers, and is most often seen in use cutting boards to length across the grain. Thus the blade is patterned with finer teeth all oriented in one direction. The earliest visual reference occurs in "Scenes Along the River during the Qingming Festival"; a handsaw in use can be seen in the painting, "Street Scenes in Times of Peace" (fig. 45). Hommel noted that the early twentieth-century saw frames were made of hardwood, in a variety of sizes, and that the saw blade was usually set at a slight angle to the plane of the frame, so that the carpenter could watch the saw blade cutting along the desired line (Hommel 228).

Backsaws

The earliest backsaws had a thin, finely toothed bronze blade set into the groove of its long wooden handle and secured with lacquered caning (see fig. 3). These saws relate closely to the modern Chinese *jiabei ju*, "clinched backsaw," but were only useful in cutting relatively thin material across the grain. With the development of better quality blades, however, backsaws became instrumental in the accurate cutting of complex tenons and dovetail joinery.

Thus, in more recent times Hommel recorded another type of saw whose short, wide, sturdy blade with fine teeth was “indispensable to the making of high quality furniture”. The reversed direction of the last few teeth permits the woodworker to initiate cuts at both ends to prevent the splintering that otherwise occurs as the saw exits when cutting across the grain. Such saws would have been well suited to initiate the long, shallow bevel cuts for transverse dovetail mortises, as well as to make the successive fine cuts through an open miter that eventually produces a seamless joint. Three similar saws illustrated by Hommel all have the teeth oriented to cut on the pull stroke rather than the push stroke, and may have been influenced by the Japanese (cf. Hommel 238-9).

Japanese saw

It is interesting to note that much more has been written about Japanese carpentry tools than about Chinese tools, yet when the histories of both are examined, it seems clear that most fundamental Japanese technologies were imported from China until the Ming and early Qing periods. At that late point in a relatively long history, there are divergent developments, most notably with the Japanese plane and saw. Pulling, rather than pushing, the plane has been noted above. By the fourteenth century, the Japanese were employing a saw that also cut on the pull stroke. Because a thin steel blade naturally has much greater tensile than compressive strength, pulling one in tension against the cutting edges of its teeth as opposed to the compression resulting from pushing against the teeth is more harmonious with the blade’s material essence. A blade that cuts on the pull stroke can also be thinner than the stiff Western saw that is pushed, and therefore accomplishes the same result with less effort and moreover with less wastage of material because of the smaller kerf. A minor disadvantage of the pull stroke is that sawdust is discharged over the line that the sawyer is attempting to follow. Although Hommel recorded a range of Japanese saws in China during the 1920s, most were of relatively late date, with machine-rolled steel blades, and were used by Japanese carpenters with a preference for their own familiar tools. The motion of pulling into the body offered more control for the Japanese, just as it did for Turkish craftsmen, who also customarily worked on the floor or ground and also independently developed a saw that cuts on the pull stroke (Hommel 231-4).

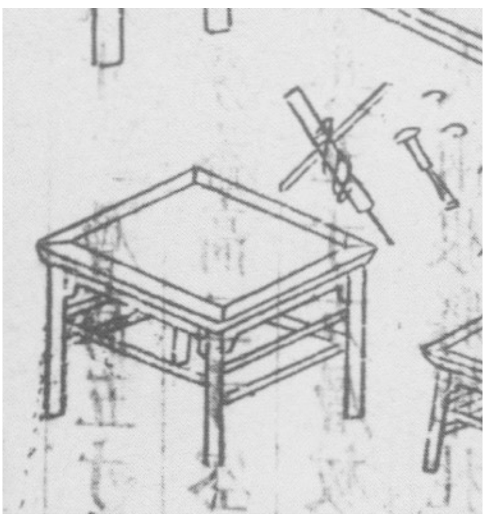
Wire saw 铜线锯

The frame saw is related to and was perhaps inspired by the wire saw, which was strung like a bow with a notched wire blade. A very early wire saw was reportedly found at the Xia level of excavations at Erlitou, and was thought to have been used for cutting jade (Yee 29). The bamboo-and-wire saw is still used by woodcarvers to initially cut out the designs of open-carved panels (fig. 46). After designs are drawn onto blank panels, the bow-like wire saw, like a Western coping or fret saw, is restrung through small holes bored into each space to be removed and then, one by one, each becomes articulated as the wire saw traces its outline. The taut wire blade is delicately prepared utilizing a chisel to raise several rows of fine teeth along its length. Cooper recalled the cautious workshop environment when his master prepared the wire saw: “A poorly executed nick could have caused the wire to pop and the bamboo to whip the wire about in a dangerous fashion. My master’s fellow workers took no chances and made a show of it” (Cooper 38-9). If he survives the preparation, the skilled wire saw sawyer has a multi-directional tool suitable for sharp changes in direction, and is therefore able to quickly rough out difficult designs with laser-like precision.

VII. Boring and Piercing Tools

Awl 锥

The awl is a somewhat primitive tool used to puncture holes in materials. Although the awl bears little relationship to the drill in terms of its mechanics, they remain grouped together in Chinese terminology. Needles are essentially awls, and the *Tiangong Kaiwu* also records various other configurations under the general heading "awl" (*zhui*), such as awls used for leather work and bookbinding, square striking awls (*da zuan* 大钻), and twisting awls (*xuan zuan* 轩钻). The striking awl has a tapered body of square section and a sharply pointed end, and was used by carpenters to prepare holes for iron nails or dowel pins. The three-sided twisting awl also has a long, tapered body, but, unlike the striking awl, it removes some material from the hole when it is twisted.



Drill 钻

Early processes of reciprocal drilling motion were probably used to slowly grind holes in jade for the production of ritual objects. Even earlier, however, primitive man probably learned to start fires with the heat generated from similar motion. Thus, the reciprocating drill remained associated with the ancient Chinese ceremony of obtaining New Fire. Each year, during the Qingming festival, a specially selected wood was ignited with a fire drill (*zuan sui* 钻岁). With this virgin flame, torches were lit and handed to the participating court officials, who returned home with the virtuous New Fire (Needham 56; Gernet 192).

Early reciprocating drills were simply dowel-shaped pieces of wood that were rolled quickly back and forth between the hands; later, metal awl-shaped bits were inserted in one end. Two developed forms of the reciprocating drill appear in the *Lu Ban jing*; it is unclear how much earlier they came into use. One is the bow drill, which is illustrated in a scene depicting a carpenter making stools and benches (fig. 47). Here the carpenter may be drilling holes for webbing and caning in the inside perimeter of the seat frame, or perhaps drilling holes in mortise-and-tenon joints so that they can be pinned with dowels. The bow drill is still commonly used by carvers to make the initial penetration for open-carved work.

The bow has a length of cord is attached from end to end. The slack cord is wrapped around the drill shaft several times, and when the bow is drawn tightly back and forth the cord grabs the shaft and spins it (fig. 48). A set of drills in the authors collection are made of *hongmu* (fig. 49). One end is specially shaped to fit a hollowed and split wooden handle, which allows the shaft to spin freely while being firmly held. The two halves are rejoined with a ring of braided cane. The other end is tapered and sawn lengthwise along the central axis. Into this kerf the metal bit is fit. A small iron hoop is then pounded onto the taper to firmly clamp the bit. The three wrought-iron bits are each of different configurations. The largest is a two-*fen* (6 mm) flat bit with a tip filed

with a centering point and acutely angled cutting faces. The one-*fen* bit has a three-sided point, and a spiral groove is hand filed up its entire length to facilitate chip removal. Although made of hand-wrought iron, both of these bits are patterned after modern bits that spin in only one direction. The smallest bit of the three has three flat sides that come sharply to a point, and is patterned after the "twisting awl."

The section devoted to "awls" in the *Tiangong Kaiwu* also describes a more developed technique of drilling in which "carpenters made small holes for the passage of cord, nails, and dowels, with a wrought iron 'snakehead drill' (*shetou zuan*). About two *fen* above the sharp end, this drill assumes a shape that is round on one side and concave on the other side, with two protruding edges to facilitate drilling." This description can can be fairly well visualized (cf. Clunas 74); the "'chicken-heart drill' (*jixin zuan*), used to penetrate sheet copper," may have been more teardrop-shaped with less of a sharp point (Song 898). Nevertheless, the shapes of these bits were more likely patterned to cut or grind their way through material with reciprocal rotation in either direction.

The second drill found in the *Lu Ban jing* illustrations is the pump drill, also called a "spinning top drill" (*tuoluo zuan*) (fig. 50). Although it is probably both a more efficient and precise drill, it is only suitable for drilling holes vertically. The handle has a hole at the center, and both ends are attached with cord to the top of the drill shaft just below a weighted flywheel. After the handle cords are wound around the shaft, a downward thrust on the handle sets the shaft spinning and the centrifugal force of the weighted flywheel continues the rotation to rewind the cords in the opposite direction. Thus, spinning back and forth, the drill bit bores a hole aided by the rhythmical downward pumping motions as well as the weight of the flywheel. The gyroscopic nature of the spinning flywheel also helps to maintain a true perpendicular line while drilling.

VII. Abrasive Finishing Tools

Various abrasive tools were used to shape and finish surfaces. The round wooden rasp is appropriately termed "incense [stick] file" (*xiang cuo* 香锉) in the *Tiangong Kaiwu,* where it is also differentiated from the metal file by its separate, raised, round teeth (as opposed to the crosshatched, chiseled lines of the metal file). Wooden rasps are particularly useful in shaping troublesome end grain; those with round bodies are commonly used to shape curvilinear profiles. Also recorded was the "sword-face file" (*jianmian cuo* 剑面錯), which was used to refine open-carved work and remove traces of the wire saw (Song 897).

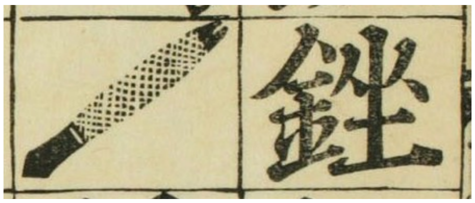
Pu Songling's seventeenth-century "Woodworkers" poem records the use of shark skin to polish wood furniture (Pu 743). The abrasiveness of shark skin (*shapi* 鯊皮) is recorded within its pictograph, , which combines sand (沙) and fish (魚), and is comparable to a modern medium-grit sandpaper. Although it is not known to be used in China today, it is still used to polish wood in the Hawaiian Islands.

A hollow-stemmed, rush-like plant called *muzei* 木賊, which grows along the riverside, provided a somewhat finer abrasive. The fine hairs covering the outside of the stalk stiffen after drying, and it is well suited for polishing wood. Charles Wong, a prominent furniture dealer and restorer in Hong Kong, recalls that the flattened abrasive stalks were mounted on a flat piece of wood or around bamboo and were used as polishing sticks, and that it also worked well by itself to polish open carving. Today, brushes made from coir palm (*zongshua* 棕刷) are commonly used for polishing (fig. 51).

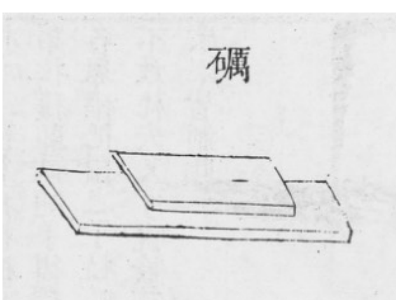
IX. Maintenance Tools

Files 錯

Files were more than simply maintenance tools, and a variety of patterns existed for specified uses. Long, square files as well as flat ones were used by brass smiths for making furniture hardware and locks. In the section on files in the *Tiangong Kaiwu* it is recorded that a steel "grass blade file" (*maoye cuo*), presumably with a thin profile, was used for the initial shaping of saw teeth, after which a "sharp arched [-shaped] file" (*kuaixian cuo*) is used (Song 897). Although the interpretation of *kuaixian cuo* is uncertain, an arched-shaped file illustrated in the fifteenth-century children's primer *Xinbian duixiang siyan* is certainly suggestive (fig. 49), and could have been used to maintain sharp saw teeth.



Various tooth patterns evolved for crosscutting and longitudinal (rip) sawing, as well as to suit varying densities of material and direction. Without a sharp sawblade, it is difficult to cut a straight line, and a great amount of energy is wasted. Supplemental tools for the saw included a "saw set" to reset the teeth, and files of triangular section for sharpening its cutting edges. A saw set is a small, forked tool that fits over individual teeth and is twisted with the fingers to bend each successive tooth alternately right or left (cf. Hommel, fig. 325). Sometimes every other tooth was set, leaving a straight one in between. The "set" or "kerf" of the saw is thus slightly wider than the blade thickness. This reduces friction and allows room for the wasted material to be carried away. To further reduce friction, oil was applied to the sides of the blade as required with an oiler made from a section of bamboo stuffed with cotton wadding (Hommel 226); oil was also used to keep blades from rusting.



Whetstones 礪，磨刀石

Before he aspires to create beautiful objects,
The artisan must first sharpen his tools.
~Confucius

This ancient Chinese saying reflects the care and discipline that a master craftsman must take with those intermediary instruments that transform his conceptualizations and raw materials into tangible realities. Files were used to maintain sharply pointed teeth on saw blades, and whetstones were used to hone the cutting edges of planes and chisels razor sharp.

Quality whetstones have been highly prized for their sharpening potential as early as the Bronze Age. Potential quarry sites were noted in the ancient geographical treatise, *Shanhaijing* (Classic of the Mountains and Sea), and ancient states were said to have paid tribute with them. The fourth-century *Guangzhi* (Extensive Records of Remarkable Things) recorded that the "whetstones from Shouyang Mountain are purple, white and pink; however, the best stones come from Nanzhang [Nanjing]" (Wang Ji 1299) (fig. 50).

One coarse and one fine whetstone were found together with other tools in the toolbox excavated from the Chu tomb in Jiangling, Wangshan (Zhang Yinwu 55). A coarse whetstone grinds quickly to remove nicks from the edge of the blade. Also like an inkstone, a small amount of water placed on the stone's flat surface acts as a lubricant and suspends the fine filings to prevent them from choking the abrasive surface. Metal cutting edges are worked back and forth over the abrasive surface of the stone until they are ground to the desired profile. A finely textured whetstone is then substituted to hone the edge razor-sharp. Carvers also required variously shaped stones to fit the profiles of their specialized chisels.

Two Americans who toured Chinese woodworking facilities in the late 1980s found fully equipped automated factories, not unlike those in the United States, for the manufacturing of modern furniture. Looking for shops that still produced handcrafted furniture, they found one in which workmen were economizing by using efficient power planers to size lumber and bandsaws to rough out shapes (Kreigshauser 81-82). This is also the case in antique furniture restoration workshops in China and Hong Kong, where a great variety of electric tools can be found. Mortise-and-tenon joints as well as decorative carving are, however, still being skillfully executed by hand.

Much of what is known about the history of carpentry tools is gathered from the traces left by the tools themselves. An understanding of period tools and the ability to distinguish old tool marks from modern ones is crucial in the attempt to differentiate authentic period Chinese furniture from the heavily restored or fraudulent pieces so common in today's antique furniture market. Using the above knowledge of traditional woodworking tools, a few points have been derived that apply to Chinese furniture from the Ming and Qing periods:

- Measurements of early pieces should correspond to the even divisions of the *chi* unit rather than to centimeters or inches.
- Traditional panels are not usually of uniform thickness, and have been beveled from the back outside edges to create a tongue of equal thickness. Panels of uniform thickness are suspect and should be closely checked for marks left by a modern thickness planer. These uniformly spaced ripple marks found across the grain are left by the knives held in the rotating cylinder head of thickness planers as well as modern jointers; the inside edges of all frame members should also be checked for ripple marks.
- Both the bandsaw and the circular saw are modern tools in China, and their relatively uniform kerf marks can be distinguished from those of the handheld frame saw.
- Traces of the modern router's variously shaped radial bits, used to quickly shape tongues and grooves, as well as moldings, can also be readily distinguished from the linear cutting rabbet, plough and molding planes.
- Holes drilled with an electric drill are straighter, cleaner, and of more uniformly round diameter than those bored with the traditional Chinese hand drill.
- Marks left by a circular electric grinder should be scrutinized to determine at what stage of the process that tool was used.

The study of woodworking tools renews our respect and admiration for the early master furniture-makers, who painstakingly handcrafted from the raw material each element of chair, table, or cabinet. We can imagine the artisan's state of mind when his labor of love is finally assembled into a whole. Standing among scattered remnants and tools, his conception has been actualized, and is now independent of his hands. He tidies his workshop, and lays his tools carefully away for another day, when the process begins anew.

WORKS CITED

Clunas, Craig. *Chinese Furniture*. London: Bamboo Publishing Ltd, 1988.

Coaldrake, William H. The Way of the Carpenter: Tools and Japanese Architecture. New York: Weatherhill, 1990.

Cooper, Eugene. The Wood-carvers of Hong Kong: Craft Production in the World Capitalist Periphery. Cambridge: Cambridge University Press, 1980.

Gernet, Jacques. *Daily Life in China on the Eve of the Mongol Invasion 1250-1276*. Translated by H. M. Wright. Stanford: Stanford University Press, 1962.

Goodrich, L. Carrington. 15th Century Illustrated Chinese Primer *Hsin-pien tui-xiang szu-yen*: Facsimile Reproduction with Introduction and Notes. Hong Kong: Hong Kong University Press, 1967.

Hemadu yizhi kaogudui. "Zhejiang Hemedu yizhi di'erqi fajue de zhongyao shouhou" (Important Finds from the Second Period of Excavations of the Hemadu Ruins in Zhejiang Province). *Wenwu* 1980:5, 1-15.

Hommel, Rudolf P. *China at Work*. Cambridge and London: The M.I.T. Press, 1969.

Huang Shilin and Zhu Naicheng. *Zhongguo zhongyao kaogu faxian* (Important Archeological Discoveries in China) Taiwan: Taiwan shangwu yinshuguan gufen youxian gongsi, 1994.

Institute of the History of Natural Sciences, Chinese Academy of Sciences. *History and Development of Ancient Chinese Architecture.* Beijing: Science Press, 1986.

Kreigshauser, John, and Nancy Lindquist. "Woodworkers' Tour of China: Ancient ways persist in the age of automation." *Fine Woodworking*, no. 74 (January-February 1989), 81-83.

Li Mingzhong. *Yingzo fashi* (Architectural Methods). Beijing: Zhongguo shudian, 1989.

Li Yaobo. "Liaoning Beipiao xian Xiguanyingzi Beiyan Feng Sufu mu" (The Beiyan Gravesite of Feng Sufu at Xiguan Yingzi, Beipiao County, Liaoning). *Wenwu* 1973:3, 2-28.

Lou Yudong, ed. *Xinyang Chumu.* Beijing: Wenwu Press, 1986.

Needham, Joseph. Science and Civilisation in China. Volume IV: Physics and Physical Technology, Part 2: Mechanical Engineering. Taipei: Caves Books, Ltd., 1986.

Pu Songling ji (Collected Works of Pu Songling). Beijing: Zhonghua shuju chuban, 1962.

Ruitenbeek, Klaas. Carpentry and Building in Late Imperial China: A Study of the Fifteenth-Century Carpenters Manual Lu Ban jing. Leiden: E. J Brill, 1993.

Shaanxi Zhouyuan kagudui. "Fufeng Yuntang Xizhou beiqi zhizao zuofang yizhi shijue jianbao" (Excavation Report on Relics Found at a Western Zhou Workshop for the Manufacture of Bone Implements Near Yuntang in Fufeng County, Shaanxi). *Wenwu* 1980:4, 27-38.

Sichuan sheng bowuguan/Xindu xian wenwu guanlisuo (Sichuan Museum, Xindu Cultural Administration Office). "Sichuan Xindu Zhanguo muguomu" (A Warring States Wooden Coffin excavated in Xindu, Sichuan). *Wenwu* 1981:6, 1-16.

Sun Zi. "Woguo gudai de pingmu gongju" (Ancient Chinese Wood Surfacing Tools). *Wenwu* 1987:10, 70-76.

Sung, Ying-Hsing. *T'ien-Kung K'ai-Wu: Chinese Technology in the Seventeenth Century*. Trans. by E-tu Sun and Shiou-chuan. University Park and London: The Pennsylvania State University Press, 1966.

Song Yingxing. *Tiangong Kaiwu* (The Exploitation of the Works of Nature). Zhongguo gudai banhua congkan (*Collection of Ancient Chinese Woodblock Print Publications*). Volume 3 of 4. Shanghai: Shanghai guji chubanshe, 1988.

Tan Junping. *Mudiao Gongyi* (The Art of Wood Carving). Beijing: Zhongguo linye chubanshe, 1992.

Wagner, Donald B. Iron and Steel in Ancient China. Leiden: E. J. Brill, 1993.

Wang Ji. *Sancai Tuhui* (Pictorial Encyclopedia of Heaven, Earth and Man), 1609. 3 vols. Shanghai: Shanghai guji chubanshe, 1985.

Zhang Shengfu, ed. *Zhongguo gudai duliangheng tuji* (Weights and Measures in China through the Ages). Beijing: Wenwu Press, 1984.

Zhang Yinwu. "A Survey of Chu-Style Furniture." *Journal of the Classical Chinese Furniture Society* 3:4 (Summer 1992), 48-59.

Illustrations