Early Chinese Lead-Barium Glass

Its Production and Use from the Warring States to Han Periods (475 BCE-220 CE)

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1. INTRODUCTION

Research on early Chinese glassmaking is a relatively recent endeavor only properly begun within the last fifty years. Pioneering studies were conducted in the 1930s but the field lay dormant until the 1950s and 1960s, at which time numerous archaeological excavations in China provided scholars with more material to work with (Brill and Martin 1991:vii).[1] Even then, research on early Chinese glass was primarily led by scientists; in 1982, Robert Brill was only able to locate three Chinese scholars "who had more than a passing interest in early Chinese glass" (Brill and Martin 1991:viii). Since then, however, the field has grown steadily in large part due to further advances in chemical analysis techniques and growing interest on the topic. At present, it is accepted that in China,[2] glassmaking began around the 5th century BCE during the late Spring and Autumn to early Warring States periods (see Fig 1.1 for a timeline of early Chinese history). Chemical analyses of glass samples dating to this time have identified no less than three glass systems: potash-lime, lead-barium, and potash;[3] of these, lead-barium was the most significant in early China, and is therefore the primary focus of the present study.[4]

Despite considerable advances in the study of Chinese glass, a number of critical issues are still unclear and fiercely debated: (1) Many scholars argue that Chinese glassmaking derived directly from Western glassmaking, and so is not an independent innovation, and (2) the comparative lack of glass objects, particularly glass vessels, relative to those of bronze, ceramic,

[1] Especially significant was Beck, Seligman, and Ritchie's 1934 article which first identified early Chinese glass as containing large amounts of lead and barium (Gan 1991:1).

[2] The geographic term China in this paper should not be understood to correspond to the country's modern borders. Rather, I use the term as an abbreviation to refer to Inner China (China proper). Inner China demarks the core region of China as opposed to the frontier. This region comprises the immediate areas in and around the Huang He and Yangtze River valleys. It is also worth noting that Xinjiang, although a Chinese province today, was for most of history a frontier region (called *Xiyu*, or Western Regions, by ancient contemporaries) more often under foreign control than Chinese rule (cf. Fig. 2.3). It is believed that Central Asia, of which Xinjiang was a part, was home to a separate glassmaking tradition of its own, one marked by influence from both East and West.

[3] In this paper, the lead:barium:silica glass system is abbreviated as lead-barium. Likewise, soda:lime:silica is rendered as soda-lime, potash:lime:silica as potash-lime, potash:silica as potash, and so on.

[4] I would like to thank my friend Rui Pei, whose aid in translating a number of difficult Chinese texts greatly facilitated my research for this study.

or precious stones, have led some scholars to suggest that glass was not a valued product in early China. The findings of this study—which examines both textual and archaeological evidence to chart the life cycle of lead-barium glass and assess the manner in which it was made and used in early China—challenge these two positions. I first suggest that Chinese glassmaking has roots that go beyond the currently accepted 5th century BCE start date. While this does not prove that Chinese glassmaking was invented independently, it does question the evidence put forth in support of the alternative theory. I also argue that despite their limited functions, lead-barium glass objects filled a highly significant ritual niche in Chinese society and therefore were more important than their small numbers appear to indicate.

2. ORIGINS

The archaeological evidence presents the following chronology for glass systems in early China: The short-lived alkali-lime glass system of the 5th century BCE (the alkali component is usually potash) was followed by two new glass systems in the Warring States period, lead-barium and potash (see Fig 1.2 for a timeline of glass systems in China). As far as can be inferred, the latter played a largely peripheral role in early Chinese glass history. In the Eastern Han period, soda-lime glass vessels from the West (also called Roman glass) were introduced. Lead-barium glass declined during the course of the Han Dynasty and was virtually non-existent by its fall in 220 CE. In this section, I examine the first segment of this chronology by investigating the shift from potash-lime glass to lead-barium glass.

The oldest glass material culture found in China date to the late Spring and Autumn and early Warring States periods (ca. 500-400 BCE). Most scholars accept this date for the start of glassmaking in China. It has also been argued that polychrome beads from the West entered China during this time and subsequently sparked the beginning of the Chinese glass industry

(Braghin 2002a:xi). The stylistic similarity between these Western beads and locally produced Chinese beads makes this argument compelling, as does the chronology: The Silk Route was active as early as the 2nd millennium BCE and since glassmaking originated in West Asia much earlier, the notion that Western glass entered China in the 5th century BCE is entirely plausible.

However, the case of an alkali-lime inlay on a bronze *qi* axe in the Freer Gallery of Art, dated to the 12th century BCE, complicates the aforementioned model for the origins of Chinese glassmaking (Cheng 1974:226). The material of this inlay has been classified by the British Museum Laboratory as follows: "The red substance is not lacquer nor the remains of any organic filling, but seems to be a siliceous enamel" (Watson 1962:31). While it is important not to overemphasize the potential significance of this anomaly, the inlay offers some interesting possibilities when placed within the broader context of early Chinese glassmaking. The chemical composition of glass objects from the 5th century BCE, most of which are beads, is also alkali-lime (Gan 2009a:13), which suggests that there may be some connection between these and the inlay. Cheng proposes that the rare inlay is evidence for Chinese glassmaking in the late Shang period, pointing to hard glazes developed by Shang potters as further evidence (Cheng 1982:26). However, most Shang inlays are black lacquer-like material (Watson 1962:32). My own view therefore is that while a glass industry was not established in the Shang period, glasses of the 5th century BCE were ultimately derived from such materials as the Freer *qi* axe inlay.

There is then a considerable gap in from the 12th to 5th centuries BCE to account for. Unfortunately, no relevant archaeological evidence exists for this period of time, perhaps due to problems of preservation. As I will discuss later, even the Chinese glass objects produced after the 5th century BCE were fairly fragile. Any glass produced before—and this may not have been the case—were likely to be experimentations and thus of even lower quality. Nor do textual

sources offer a convincing explanation. The earliest reference to possibly glassmaking occurs in the mythical story of the goddess Nüwa, which survives in several sources. The 4th century BCE text *Liezi* (Master Lie) recounts how the collapse of a pillar supporting Heaven causes damage to the sky, in response to which the goddess Nüwa "smelted stones of all five colors to patch up the flaws" (Liang and Li 1995:96). The same story is related in the 2nd century BCE text *Huainanzi* (Masters of Huainan): "Thereupon, Nüwa smelted together five-colored stones in order to patch up the azure sky" (Major et al. 2010:224). Although glass is not explicitly mentioned in either of these passages, the mention of smelting stone seems to describe glassmaking.[5] Needham also argues, utilizing the story's reference to five colors, that "the legend was a garbled reference to glass… Ancient glass had a strong tendency to iridescence, and its broken edges would be likely to show the spectral colors" (Needham 1962:107).

Neither *Liezi* nor *Huainanzi* provide any concrete dates. However, that glassmaking is associated with one of the oldest characters in Chinese mythology at least on the conceptual level hints that it may have had an earlier start than is possible to prove with archaeology. The most likely scenario is that the establishment of the glass industry in the 5th century BCE was the result of several centuries of experimentation, drawing from existing technology that enabled the production of ceramic glazes, faience, frit, and, as the Freer *qi* axe inlay suggests, enamel. The production of potash-lime glass in the 5th century BCE and its eventual replacement in the 4th century BCE by lead-barium glass was perhaps another phase of this experimentation.

The use of lead instead of alkali fluxing agents was a natural progression in the development of glass technology in early China for two reasons. First, not only was lead (and

[5] In the 1st century CE text *Lunheng* [Critical Essays], the following passage occurs: "The jade made out of melted jade-like stones is as brilliant as real jade" (Liu 1988:60). In this instance, "melted-jade like stones" undoubtedly refers to glass; ancient writers may have used the term "melted stone" as a substitute for the word glass. I will later revisit this passage in the context of the relationship between glass and jade.

barium) readily available,[6] Chinese bronze smiths had worked with lead since the Shang period.[7] Second, the use of lead and barium facilitated production by lowering the melting temperature of glass and also engendered in glass certain properties the Chinese found desirable (Braghin 2002b:13; Needham 1962:103). A passage from the 5th century CE text *Shishuo Xinyu* (New Account of Tales of the World) states, "the beauty of this [glass] cup lies in its transparency. For this reason I consider it highly valuable" (An 2002:57). The same idea is present in *Yen Fan Lu* (1175 CE), which further contrasts Chinese glass with Western glass:

> The *liuli* [glass] which is made in China is rather different from that which comes from abroad. The Chinese variety is bright and sparkling, and the material is light but fragile. If you pour hot wine into it, it will immediately break. That which is brought by sea is rather rough and unrefined, and the colour is also slightly darker. But the strange thing is that even if hot water is poured into it a hundred times, it behaves like porcelain or silver and will never break. (Needham 1962:110)

High lead content increases the reflectivity of glass (Gan 2009a:20), a property Western glass appears not to have exhibited. Western glass, which by the 2nd millennium CE was relatively widespread in China, was therefore aesthetically unattractive to the Chinese. The quoted text also emphasizes the fragility of Chinese glass when in contact with hot liquid, the implications of which I will discuss presently.

Investigating the origins of both lead-barium glass and more generally of Chinese glass, it has been found that the development of the lead-barium glass system in China was possibly the result of centuries of experimentation by Chinese craftsmen, who may have discovered glass earlier than the archaeological evidence indicates. While this does not debunk the theory that Chinese glassmaking was not an independent invention, it calls into question the extent to which

[6] Lead, in the form of galena (PbS), and barium, in barite ($BaSO_2$), are plentiful along the Yangtze River valley (principally in Hunan, Anhui, and Jiangxi). In Hunan, lead and barium occur in conjunction (Gan 1991:2). These regions, which in the Warring States period were part of the Chu state (1030–223 BCE) (see Fig 2.2 for a map of 4th century BCE China), are therefore the probable home of the earliest glassmaking centers in early China (Gan 2009a:20). In fact, the ritual use of Warring States glass probably originates from the ideology of the Chu state (see Braghin 2002b).

[7] Chinese bronze was often a copper:tin:lead alloy (Cheng 1974).

Western glassmaking technology influenced that of China. Currently, the lack of additional evidence renders us unable to trace the development of glassmaking technology prior to the 5th century BCE. More can be said, however, on glass of the Warring States and Han periods.

3. PRODUCTION AND USE

From its inception in the 4th century BCE to its decline during the early 1st millennium CE, lead-barium was the predominant glass system in China. Produced in the Yangtze River valley region, lead-barium glass circulated throughout all of Inner China.[8] I will now discuss how the various types of lead-barium glass objects were produced and how they were used, in order to show that they filled an important niche in Chinese material culture during the Warring States period.

The most common types of objects made from lead-barium glass that date to the Warring States and Han periods are beads, jewelry pieces, sword parts, and ritual *bi* disks. Beads are by far the most plentiful, comprising some 80% of the approximately one thousand objects found.[9] Anyone familiar with Western glass typology will have noticed some interesting discrepancies from this catalog. Two widespread uses for glass in the West—as vessels and windows—are conspicuously absent from early Chinese glass typology, which instead indicates more ornamental and symbolic than practical usage. At the same time, however, Chinese glass and Western glass were similar in a fashion, as both served as cheaper imitations of precious gems and stones. I first explain the absence of glass vessels and windows in early China, and then discuss the particular role of lead-barium glass as imitation gemstone.

[8] Modern provinces in which lead-barium glass objects dating to the Warring States to Han periods were found: Guangdong, Guangxi, Sichuan, Guizhou, Qinghai, Gansu, Xinjiang, Liaoning, Inner Mongolia (Gan 2009a:21).
[9] Although the present study does not investigate Chinese glass beads in depth, the evidence is clearly vast and closer scrutiny will doubtless yield many new insights. For more on the subject, see Braghin 2002b.

3.1. LIMITATIONS OF LEAD-BARIUM GLASS

The fragile nature of lead-barium glass, as previously quoted in *Yen Fan Lu*, accounts for the absence of glass vessels and windows in early China. Lead has the property of softening glass and because lead-barium glass in early China consisted of as much as 10-45% lead, it was not particularly strong nor durable (Gan 2009a:21). More specifically, lead-barium glass turns brittle and cracks easily when exposed to sudden changes in temperature (Lu 2010:269). Therefore, lead-barium glass vessels could not hold hot beverages the same way Western soda-lime glasses did. Consequently, lead-barium glass vessels were not mass produced in the early stages of the Chinese glass industry. The only surviving lead-barium glass vessels to date belong to the Western Han period. In the tomb of Liu Sheng (154-113 BCE) in Hebei,[10] three vessels were found (Fig 3.1). In the tomb of King Liu Dao (d. 128 BCE) in Jiangsu,[11] sixteen lead-barium glass cups (Fig 3.2) of various sizes were uncovered (Braghin 2002b:31).

In both examples, the presence of numerous air bubbles on the surface of the cups was noted by archaeologists (Kwon 2001:45-6). From this we can infer that lead-barium glass vessels were of a lower quality relative to the soda-lime glass vessels of the West. Glass vessels, however, were not particularly in demand in China. Generally, civilizations with advanced ceramic industries, such as China, appear not to have had a need for glass vessels (Francis 2002:54). Possibly the first reference specifically to glass bowls and cups occurs in the 7th century CE text *Jinshu* (Book of Jin), which implies that the aforementioned Western Han lead-barium glass vessels were truly rare products in early China (Needham 1962:108). However,

[10] Liu Sheng was the son of Emperor Jing (188-141 BCE) of the Han Dynasty, and the brother of Emperor Wu (156-87 BCE).
[11] Liu Dao was a king of the Chu state (Braghin 2002b:31).

numerous examples of Roman glass vessels dating to the Han period have been discovered.[12] Regarding archaeology, there is also the issue of preservation to consider. Excavated Chinese glass objects come almost exclusively from mortuary contexts, in which more ritual than practical objects are prevalent. Thus, even if glass vessels were produced in greater quantity than the evidence suggests, they would not survive in a non-mortuary setting due to their fragility.

Western scholars have also questioned the apparent lack of glass windows in China. One theory that accounts for this is that the warmer climate in China and the availability of good oiled paper negated the need for glass windows. Additionally, Chinese architecture did not support glass windows, since most houses were built of light wood and lattice (Macfarlane and Martin 2002:111). Interestingly, several textual sources seem to record the existence of glass screens or windows, although these are dubious for reasons I discuss below. In *Xijing Zaji* (Miscellany Concerning the Western Capital), Emperor Cheng of Han (32 BCE-6 CE), builds a bathhouse for his consort using green glass windows and one Man Fen mistakes "glass set into a screen for an opening" and walks into it, so transparent is the glass (Elisseeff 1983:164; Dien 2007:288). In the Six Dynasties text *Han Wu Gushi* (Tales of Emperor Wu of Han), Emperor Wu of Han (156-87 BCE) builds a temple with transparent glass doors (Elisseeff 1983:164). According to another legend of the emperor, glass was "one of the treasures of his 'Exotic Jewels Palace,' and the screen of an additional palace was made of 'white *liuli* [glass]'" (Liu 1994:60). The 7th century CE text *Beishi* also describes a palace of glass:

> During this time of the emperor Tai Wu [424-452 CE], traders came to the capital of Wei from the Da Yuezhi country [Central Asia, the territory of the former Kushan Empire], who said that by fusing certain minerals they could make the five colours of *liuli* glass. They then gathered (materials) and dug in the hills, and fused the minerals at the capital. When ready, the material so obtained was of even greater brilliancy than the *liuli* glass imported from the West. An edict was issued that a movable palace should be made of this material, and when it was done it held more than a hundred

[12] For more on Roman glass in China, see An 2002, An 1991, and Kwon 2001.

> people. It was a bright and transparent so that all who beheld it were astonished and thought it was made by magical power. After this, articles made of glass became considerably cheaper in China than they had been before, and no one regarded it as particularly precious. (Needham 1962:108)

Although—with the exception of *Beishi*—these texts contain stories of Han Dynasty emperors, they were compiled or written several centuries afterward. Thus, the descriptions therein more likely reflect glass of the Six Dynasties period rather than the Han period; while pre-Han glassmakers were able to mold-cast considerably large pieces of lead-barium glass fairly early on, it is doubtful they could produce glass transparent enough to elude notice.[13] An additional point of note in the passage above is the mention of Western traders coming into China and producing a new kind of glass, after which glass suddenly becomes inexpensive. I will revisit this detail in a later section.

Already, it is apparent that Chinese glass, while not as significant as bronze or ceramic, cannot be hastily written off simply as an "inferior substitute for precious and scarce substances, not as a wonderful material in its own right" (Macfarlane and Martin 2002:110). The material itself may have been comparatively cheap, but the process of production, which borrowed from metallurgy and pottery, was sophisticated.[14] Even so, Macfarlane and Martin are right to say that in China, glass' "principal attraction was as a way to imitate cheaply more precious substances such as mineral turquoise" (Macfarlane and Martin 2002:110). The chief function of lead-barium

[13] This is another reason the texts probably describe glass of the Six Dynasties period, because by that time, lead-barium glass was no longer in production in China. The potash glass prevalent then was more transparent than lead-barium.

[14] Some examples of borrowed technology include the refractory crucible, which was originally used to smelt ores, and the ability of potters to work with temperatures as high as 1,300-1,400°C (Gan 2009a:20; Cheng 1974:222). As in the West, glass was mold-cast prior to the introduction of glassblowing. As a general rule, molds appear to have been non-reusable; no two identical glass objects exist in the archaeological record (Kwon 2001:51). A variety of different types of molds were used. To give but one example, hollow objects such as ear studs and the cups we have seen above were produced using double-molds. Another type of mold was a "sandwich" mold used to produce *bi* disks, which I will discuss below. For more on molds, see Fig. 4 and 5.2. For more on the production of glass beads, see Braghin 2002b:5.

glass was indeed to imitate other precious materials. However, as I now explain, this did not make glass any less prized; if anything, it increased its significance.

3.2. LEAD-BARIUM GLASS AS IMITATION GEMSTONE

The etymology of the Chinese word for glass reflects its function in early China as a material that was made to imitate precious stones. In the Warring States period, the words for glass appear to have been *qiulin* 璆琳 and *luli* 陸離, which were in fact more often used to refer to jade. The word *liuli* 琉璃, by far the most common alongside *boli* 玻璃, first occurs in Han period texts (Dien 2007:287). There has been much debate as to what types of glass exactly these terms distinguish, but we may disregard *boli* in the present study, as it is a later term that does not apply to the Warring States and Han periods.[15] Doris Dohrenwend's definition of *liuli* is suitable: "small opaque items pre-dating the third century AD [CE]" (Liu 1994:58).

Recent scholarship suggests that the root of *liuli* is the Sanskrit word *vaidūrya*, which means lapis lazuli, beryl, or cat's-eye gem rather than glass (Liu 1994:59). The word *liuli*, too, was used to refer to a number of precious stones. It is not difficult to imagine that ancient writers, who were unaccustomed to handling luxury goods, at times may have been genuinely confused by what was and was not glass, unable to differentiate between precious stone and glass imitation. Furthering complicating the work of modern scholars is that *liuli* also appears to refer to concepts related to glass and precious stones. For instance, in *Kan Chhuan Fu* (Ode on the Sweetwater Springs)[16] by Yang Hsing, *liuli* means "radiance": "how attractive the radiance [*liuli*] of the red decorations!" (Needham 1962:104). In *Shanglin Fu* by Sima Xiangru (2nd century

[15] Possibly one the earliest occurrences of the word *boli* is in the 7th century CE text *Jinshu*, which recounts that the minister Wang Chi, "who was considered extremely generous and extravagant, entertained Emperor Wu [of Jin, 236-290 CE] with *boli* utensils" (Liu 1988:60).

[16] The Chinese *fu* is best understood as a "development of rhapsodic style of verse invented by Qu Yuan [339-278 BCE]" (Hook 1991:347). It is often translated rhapsody, ode, or rhyme-prose.

BCE), *liuli* appears "as an epithet for birds flying forth in all directions," a metaphor for dispersion, one that presumably paid homage to the refractive qualities of gemstones and glass (Needham 1962:104).

In the West, glass was also made to imitate precious stones: turquoise and lapis lazuli in Mesopotamia and Egypt, and rock crystal by Hellenistic and Roman glass (Braghin 2002b:17). The same was true of China, with one exception: Glass most commonly imitated jade, considered by the Chinese as the most precious of all stones. I will first discuss, however, the evidence for glass as imitation lapis lazuli and turquoise. One 4th to 5th centuries CE Buddhist text describes "the enlightened Buddha showing his hair, as beautiful as *liuli* [glass]." In this instance, *liuli* probably refers to lapis lazuli rather than glass, but the word could also refer to glass imitations of lapis lazuli (Liu 1994:59). Regarding turquoise, the sword of King Goujian (Fig. 5.1), which dates to the 5th century CE, has turquoise inlays on one side and blue alkali-lime glass inlays on the other (Gan 2009a:13), which suggests that the glass was made to imitate the turquoise.[17]

Glass also imitated rock crystal. In Chinese thought, the two substances were closely connected. Crystal, *shuijing* 水晶,[18] means "essence of water" or petrified ice (Schafer 1963:227). According to ancient Chinese folklore, millennium-old ice turns into glass (Hirth 1966:233). Often, it is difficult to identify whether ancient writers were referring to glass or crystal, as exemplified in the 1st century BCE text *Yan Tie Lun* (Discourses on Salt and Iron): "The furs or sables, marmots, foxes and badgers… fill the Imperial treasury, while jade and auspicious stones, corals and crystals, become national treasures. That is to say, foreign products

[17] Goujian's sword inlay is an additional example of the continuity from the 12th century BCE *qi* axe alkali-lime inlay discussed previously to the glass produced in the 5th century BCE.
[18] *Shuijing* is likely a later term. Crystal in the Han Dynasty would have been rendered *shuiyu* 水玉, literally "water jade" (Needham 1962:100).

keep flowing in, while our wealth is not dissipated" (Gale 1967:15). Here, the translator has opted to render as "crystal" what in the Chinese text is *liuli*. Given that both crystal and glass were prized imports from the West,[19] it is unclear in this instance to what the author was referring.

Alternatively, it is possible that the author did not realize Western glass vessels were not the same material as rock crystal. This confusing relationship between crystal and glass is captured in *Baopuzi* (Master Who Embraces Simplicity), a late 3rd to early 4th century CE text:

> The 'crystal' vessels, which are made outside China, are in fact prepared by compounding five sorts of (mineral) ashes. Today this method is being commonly practiced in Chiao and Kuang (i.e. Annam [Vietnam] and Kuangtung [Guangdong]). Now if one tells this to ordinary people, they will certainly not believe it, saying that crystal is a natural product belonging to the class of rock-crystal. (Needham 1962:108)

The passage clearly describes the production of glass by mixing together various components. However, the final sentence implies that the writer really considers these foreign "crystal" vessels to be crystal. Thus, the early Chinese appear to have thought that Roman glass was a kind of crystal rather than a material similar to lead-barium glass (Liu 1994:60). Although later post-Han writers appear to have realized that Western glass and rock crystal were not quite the same,[20] the fact remains that attempting to distinguish between rock crystal and glass in ancient Chinese texts is analogous to trying to figure out with linguistic evidence alone whether the Crystal Palace of Victorian England or the *cristallo* vessels of the Renaissance Venice were made of crystal or glass! One final point of note is that the passage traces the trade route by

[19] *Hou Hanshu* (Book of the Later Han) gives a brief description of what is most likely the Syrian province of the Roman Empire and lists its exports, which includes glass (Hill 2009: 25). In the 1st century CE, Han China expanded into Central Asia and controlled the conflict-fraught region for a short time. During this time, China had direct diplomatic relations with the Parthian Empire. In 97 CE, the chief administrator of the region, Ban Chao, sent an envoy, Gan Ying, further east. Gan Ying reached the Persian Gulf before turning back.

[20] In the 6th century CE text *Luoyang Qielanji* (A Record of Buddhist Monasteries of Luoyang), glass and crystal are clearly distinguished: "Among other drinking vessels were several scores of quartz [rock crystal] bowls, agate cups, glass bowls, ruby goblets—such marvelous craftsmanship was not to be found in China. All came from the Western Regions [Central Asia]" (Wang 1984:193).

which foreign glass vessels were imported: by sea through Southeast Asia and then to southern China.[21] Perhaps, then, Western glassmaking technology accompanied the actual wares to China; I discuss this possibility presently.

Even more than crystal, lapis lazuli, or turquoise, however, by far the most widespread use of lead-barium glass in early China was as imitation jade, a stone more precious than any other to the ancient Chinese. Jade had a number of symbolic and magical properties, including close association with immortality. Daoist alchemists believed that jade, along with gold, was the antithesis of decay because they did not corrode (Hill 2009:260). Ancient emperors, who often carried jade scepters and wore hats affixed with nine strings of jade, imbibed drinks mixed with jade powder and melted gold in the belief that they would prolong life or even grant immortality (Perkins 1999:180, 237). Due to these symbolic properties, jade was often buried in tombs to safeguard the dead, a practice that began in Neolithic times but proliferated particularly in the Western Han period (Braghin 2002b:22).

Bi disks, of which there are examples in both glass and jade, are one of the most common and best understood types of such symbolic funerary objects.[22] The function of the jade *bi* disk was to guarantee the deceased a measure of protection against decay and to safeguard his journey to Heaven. The circular "donut" shape of the disk—the same shape as the ancient Chinese character for sun—itself represents Heaven (Childs-Johnson and Gu 2009:82). In the tombs of the nobility, jade *bi* would also symbolize the wealth and power their owners had in life. Glass *bi* disks, on the other hand, are found specifically in commoners' graves, for two reasons (Kwon

[21] According to the 1st century CE Greco-Roman text *Periplus Maris Erythraei* (Periplus of the Erythraean Sea), Roman glass vessels and raw glass ingots were shipped from Roman Egypt to the west coast of India (Casson 1989). Archaeological evidence supports the text; in fact, Roman glass dating to the early 1st millennium CE has been found as far afield as Korea and Japan. The *Hou Hanshu* (Book of the Later Han) also relates that in 166 CE, the Roman emperor Marcus Aurelius reputedly sent envoys to China via Vietnam. Scholars have dismissed this possibility, instead offering the interpretation that these "envoys" were in fact private merchants acting on their own. The gifts they bore—which failed to impress the Chinese—were likely obtained in Vietnam (Hill 2009).

[22] *Bi* disks were produced in quantity since the Neolithic period, well before the start of writing in China.

2001:238). First, it was during this time that lead-barium glass production in China was at its peak. Second, glass *bi* were much cheaper than jade, but could still be made to look deceptively similar to jade *bi.* For commoners, glass *bi* would have had the same symbolic properties as jade *bi*. Possibly, they even believed that glass was a more crude form of jade; barium has the property of inducing a turbid white color in glass, one of the colors of jade (Gan 2009a:26-7). However, glass *bi* could not be made to match the quality of jade *bi*. As previously mentioned, a particular type of "sandwich" mold was used to produce glass *bi* disks (Fig. 5.2). These molds were made of metal in order to withstand heat, since they were placed directly on burning furnaces and molten glass was then poured in. Glass *bi* produced in this fashion were unevenly decorated because glass on the bottom of the mold was closer to the fire, and set nicely, whereas the glass on the top was cooler so that the intended pattern would lack definition on that side (Fig. 5.3). Jade *bi*, which were carved by hand, did not have this flaw (Kwon 2001:54).

In the burial arrangement, *bi* disks were laid in the general vicinity of the body, often underneath the back. Plugs made of jade were also inserted into the body's nine apertures to prevent decay (Fig. 5.3); it was believed that doing so would make the soul of the deceased immortal (NPM 1970:83). The plug for the mouth was often jade carved into the shape of a cicada (Fig. 5.4), which symbolized purity and rebirth, not unlike the phoenix (Elisseeff 1983:164; Kwon 2001:250). Just as glass *bi* were made to imitate the jade equivalent, glass cicadas, eye covers, and nose plugs were made to imitate jade body plugs.[23] In the rarest of instances, the entire body was placed within a suit of jade. Such funerary garments were known from textual evidence well before the discovery of the first specimen in 1968 in the tomb of Liu

[23] For a more detailed treatment of the burial arrangement of lead-barium glass objects in relation to the body, see Braghin 2002b.

Sheng in Hebei (Fig. 5.5).[24] Since then, several other intact jade burial suits have been excavated. Remarkably, a fragmentary glass equivalent, belonging to a noble lady named Mo Shu, was found in Jiangsu. The suit is composed of lead-barium glass plaque-pieces of various shapes and patterns, and consists of about 600 pieces altogether (Cheng and Zhou 1991:21-2).

It is interesting to note that a number of texts make direct reference to glass in its role as imitation jade. According to Eastern Han scholar Wang Chong, "The jade made out of melted jade-like stone is as brilliant as real jade" (Liu 1994:60). Later writers have a more negative attitude. The Northern Song writer Su Shi (also known as Su Dongpo) writes, "It is deceitful to make jade by boiling lead with white stone" (An 1991:9). A similar idea is present in the later 1133 CE text *Yun Lin Shi Pu* (Cloud Forest Lapidary): "And at the western capital [Kaifeng] in the Lo River, they find pieces of bluish white stone with spots of five colors in it. The whitest of these are compounded with lead, and mixed with other minerals, then after heating it is all changed into 'false jade' or *liuli* [opaque] glass" (Francis 2002:73).

Later texts no longer regard glass as a valuable material. This trend probably began in the 5th century CE; as quoted above, *Beishu* specifically states that the value of glass drops after the introduction of glassblowing in China. Prior to that, however, the primary role of lead-barium glass was to imitate jade, and it was in fact the only material capable of doing so. Therefore, it must have been valuable for members of the lower strata of society who could not afford jade objects. Although no significant glass burial objects have been found in tombs of nobles, lead-barium glass must have been valuable to them as well under certain circumstances, for instance

[24] The adjacent tomb of Liu Sheng's wife Dou Wan also yielded an intact jade suit. Liu Sheng's suit was composed of 2,498 individual pieces and Dou Wan's 2,160 (Yang 2004:346).

when jade was unaffordable (for lesser nobility) or unavailable.[25] For most of its history, China's jade was nephrite, imported from Central Asia (Perkins 1999:237). It stands to reason that in times of political trouble, the supply of jade could very easily have dwindled.

The idea that glass was not an important product in early China, then, is at least too simplistic if not inaccurate. While glass did not achieve the same significance in China as it did in the West, where glass enjoyed widespread usage in vessels and windows, it was also significant in China, where it played a highly specialized ritual role, at least in a mortuary context, albeit in a different manner.

4. DECLINE

Given that it filled a significant niche in early China, the decline of the lead-barium glass tradition was extremely rapid, even taking into account the economic instability of China during the politically volatile Six Dynasties period. In reality, however, the decline began well before the fall of the Han Dynasty. For instance, only some 30 specimens of Western Han glass *bi* and no Eastern Han *bi* have been found (Braghin 2002b:26). There must then be factors in addition to the political landscape that contributed to the decline of lead-barium glass.

Western glass vessels were in circulation in China during the early Han period. The previously quoted passage from *Beishi* describes Western glassmaking technology entering China by the land route ca. 424 CE. However, the passage from *Baopuzi* implies that a Western glassmaking technology may have entered China by sea along with its products a century beforehand. This technology is likely glassblowing, which was invented in the Roman world in the 1st century BCE. Foreign glass imports were highly prized in China from the Han period

[25] *Bi* disks were given to nobles of the fourth and fifth ranks (*zi* 子 and *nan* 男, roughly equivalent to viscount and baron), the two lowest ranks of Chinese nobility, by the emperor to affirm their statuses (Perkins 1999:237). This implies that jade *bi* disks were costly enough that only the higher ranks of nobility could afford them.

onwards, and were buried in tombs along with objects of jade and other precious materials. Only the wealthy could afford glass vessels, which were extremely expensive imports because they came from so far, as elaborated by *Liuli Wan Fu* (Ode on a Glass Bowl) by Pan Ni, a 3rd century CE poet:

> Examining those rarities among the regional tributary offerings,
> One prizes the uniqueness of this bowl.
> It would have had to cross the remote perils of the shifting sands
> And traverse the precipitous dangers of the Pamirs.
> The way it came was obstructed and distant,
> The place to which it was consigned was dark and deep.
> They would have drawn on the flowing splendor of glass
> And given orders to the excellent craftsmen of that far world.

The *fu* also reveals what qualities made Western glass imports desirable:

> Its gleam and glitter [match the] the sun's dazzle.
> Its roundness and repletion [mirror] the moon's fullness.
> Hairline blemishes are not to be found,
> And flying dust does not adhere.
> Its clarity and sparkle are on a par with a candle flame,
> Its outer and inner surfaces conform to [one] shape.
> Congealed frost is inadequate to match its purity.
> Limpid water unable to convey its clarity.
> Its hardness is beyond that of gold or stone,
> Its strength challenges the most excellent jade.
> Grinding does not wear it down,
> Besmirching does not soil it. (Dien 2007:291-2)

The demand for foreign glass vessels would have been high, triggering a new round of experimentation by Chinese glassmakers fueled by the diffusion of glassblowing technology from the West. Increasing the lead content of glass while subtracting barium made glass more suitable for blowing and also produced more transparent glass (Gan 2009a: 27-8). Thus, high lead-silica glass was developed around the time glassblowing was introduced in China, possibly sometime in the early Six Dynasties period. However, such high levels of lead were unsuitable for producing large batches of glass in the furnace because this corrodes the refractory crucible

(Gan 2009a:28-9). Changing the crucible frequently would have been an expensive process that also halted production for the duration of the repairs.

The Chinese discovered an alternate fluxing agent in saltpeter (KNO_3), an alkali based material known as early as the Spring and Autumn period as a medicinal compound (Gan 2009a:20). Saltpeter forms on the warm soil surfaces of Guangxi and Guangdong, where potash glass may have been produced during the Warring States period. In the post-Han period, Chinese glassmakers introduced saltpeter into high lead-silica glass to offset the high lead content and began producing potash-lead glass (Gan 2009a:29). A passage in the 4th century CE text *Nanzhou Yiwu Zhi* (Strange Things of the South) describes the use of saltpeter in glassmaking:

> The basic constituent of glass is stone. If you want to make glass vessels you need natural ash. Natural ash looks like fine sand that you find along the shore of the Southern Sea. It is also used to wash clothes; when you use it, it is not necessary to soak the garments. When you throw it into water, it becomes as slippery as a mossy stone. Without this type of ash, the batch will not fuse. (An 2002:46)

The production of lead-barium glass had largely ceased by the end of the Han Dynasty and was replaced by potash glass, which was in production as early as the 4th century CE (An 2002:47). As mentioned above, the late 3rd to early 4th century CE text *Baopuzi* mentions Western glassmaking technology adopted in Vietnam and Guangdong. This evidence challenges the commonly accepted theory that glassblowing was introduced to China ca. 424 CE, as described in *Beishu*. It appears that glassblowing may first have been introduced to south China, which had a long tradition of trade with the West. The political fragmentation of China during the 4th century CE explains why glassblowing remained a local technique and did not subsequently spread northwards.[26]

[26] For more on the subjects of Roman glass in China and domestic Chinese glass produced during the Six Dynasties period, see An 2002.

Further diminishing the importance of lead-barium glass was the introduction of new burial customs in which it was no longer necessary. In the immediate aftermath of the fall of the Han Dynasty, Emperor Wen of Wei (187-226 CE) decreed it illegal to bury the dead with "jade suits and jewels" (Yang 2004:352). The decline of glass burial objects would have followed the decline of their jade counterparts. There are then a number of factors that contributed to the decline of the lead-barium glass system in China. Increasing numbers of Western glass vessel imports and the introduction of Western glassmaking technology shifted demand in favor of foreign glassware. Consequently, Chinese glassmakers attempted—with limited success—to recreate Western glass, the properties of which are described elaborately in *Liuli Wan Fu*; the lead-barium glass system was unsuitable for this purpose. The political disunity of China following the fall of the Han Dynasty limited trade and slowed crafts production. Jade itself was largely out of reach for rulers of smaller and weaker states, as it had been in the similarly politically fragmented early Warring States period. Lavish burials were only reintroduced in the 5th century CE when the country was more reunified (Yang 2004:352). Another critical factor to consider is the influence of Buddhism on Chinese material culture from the Han period onwards. Although a discussion of Buddhism's influence on Chinese glass is beyond the scope of this study, the use of precious substances such as jade and probably glass as well did change significantly as a result of Buddhism.[27]

5. CONCLUSION

This study has explored the origins and decline of lead-barium glass in China to further complicate the debate surrounding the issue of the independent invention of Chinese glassmaking. While the predominant glass system of China was lead-barium, it was not the first.

[27] See Shen 2002 for a discussion on Buddhism's influence on glass. For a more general discussion on the subject of the influence of Buddhism on Chinese material culture, see Kieschnick 2003.

The continuity between the earlier potash-lime glass system and lead-barium glass, as well as that from lead-barium to high lead-silica and eventually potash-lead glass, suggests that the Chinese were consciously and continually experimenting with glass. Glassmaking techniques from the West no doubt played a significant role in China, especially in later periods. However, the basic technology of making glass may have been developed independently in China.

This study has also explored the ritual usage of lead-barium glass in early China. Lead-barium glass played a highly specified role in early China as imitations of objects made of precious stone. This did not decrease its value, however. The linguistic evidence highlights the close relationship between glass and precious stones. Lead-barium glass was fashioned into some of the most symbolically important objects, the same ones made of jade. The value of an object in early China does not seem to have been derived solely from the material it was made of, but also arose from the nature of the object itself.

In closing, I would like to recommend further avenues of study to better understand the glass of early China. I have already noted the wealth of information further studies on early Chinese glass beads and the relationship between early Central Asian and Chinese glasses will undoubtedly yield. One other elusive question is the human aspect of glassmaking in early China. To draw a parallel, potters and bronze masters of the Shang and Xia periods appear to have achieved a high social standing: They lived in residences not unlike those of nobles, and in some cases, were even conferred noble ranks (Cheng 1974:224, Cheng 1982:23). Were glassmakers afforded the same status? The answer to this question will go a long way in illuminating the relationship between the glass, metal, and ceramic industries in early China as well as the role of glass outside the mortuary context in early Chinese society.

FIGURES

Dates	Period		
ca. 2000-1500 BCE	Xia Dynasty		
1700-1027 BCE	Shang Dynasty		
1027-221 BCE	Zhou Dynasty		
	1027-771 BCE	Western Zhou	
	770-221 BCE	Eastern Zhou	
		770-476 BCE	Spring and Autumn
		475-221 BCE	Warring States
221-207 BCE	Qin Dynasty		
206 BCE-220 CE	Han Dynasty		
	206 BCE-9 CE	Western Han	
	9-24 CE	Xin (Wang Mang Interregnum)	
	25-220 CE	Eastern Han	
220-589 CE	Six Dynasties		
	220-280 CE	Three Kingdoms	
	265-420 CE	Jin Dynasty	
	420-589 CE	Southern and Northern Dynasties	
581-617 CE	Sui Dynasty		
618-907 CE	Tang Dynasty		
907-960/1125 CE	Five Dynasties and Ten Kingdoms/Liao Dynasty		
960-1279 CE	Song Dynasty		
	960-1127 CE	Northern Song	
	1127-1279 CE	Southern Song	

Fig. 1.1: Timeline of Chinese history from the Xia to Song Dynasties.

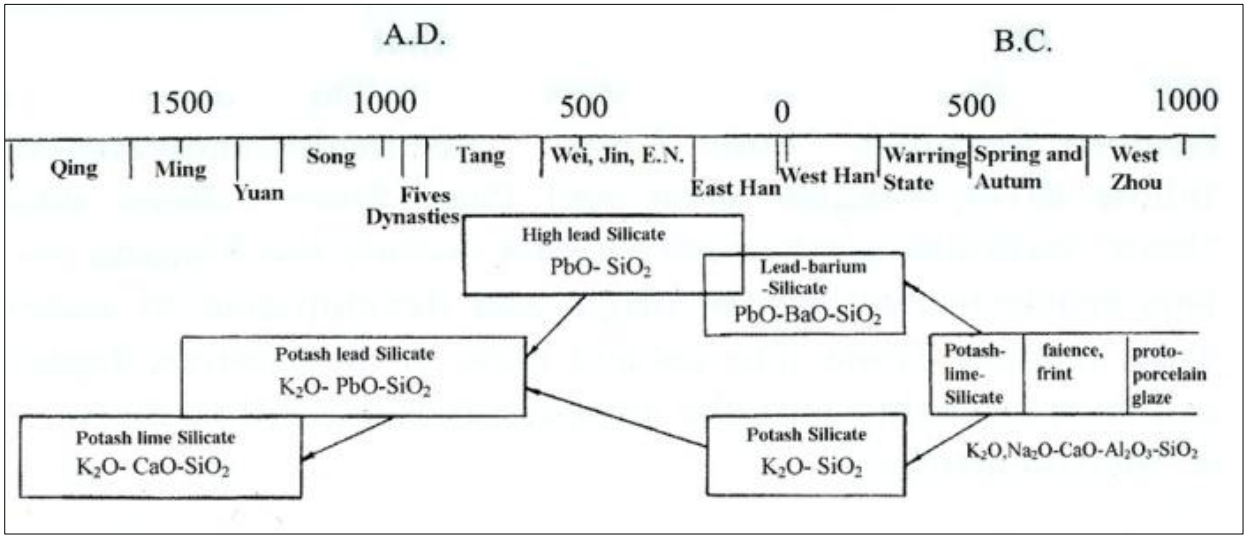

Fig. 1.2: Development of the chemical compositions of ancient Chinese glasses. *Source*: (Gan 2009a:8).

Fig. 2.1: Map of modern China. *Source*: http://www.chinapage.com/map/map.html.

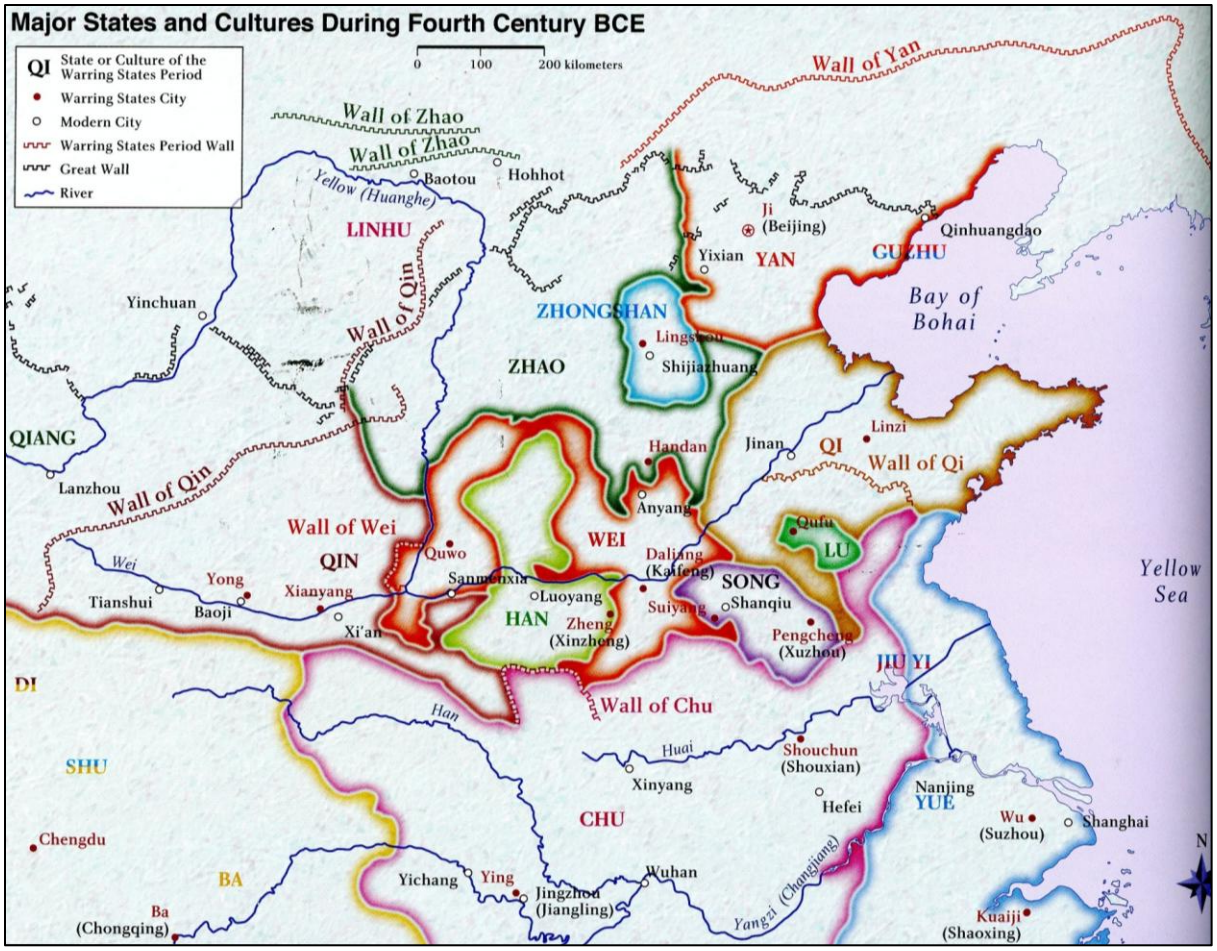

Fig. 2.2: Map of late Warring States period. Note that the Chu state encompasses most of the Yangtze River valley. *Source*: (Yang 2004:270).

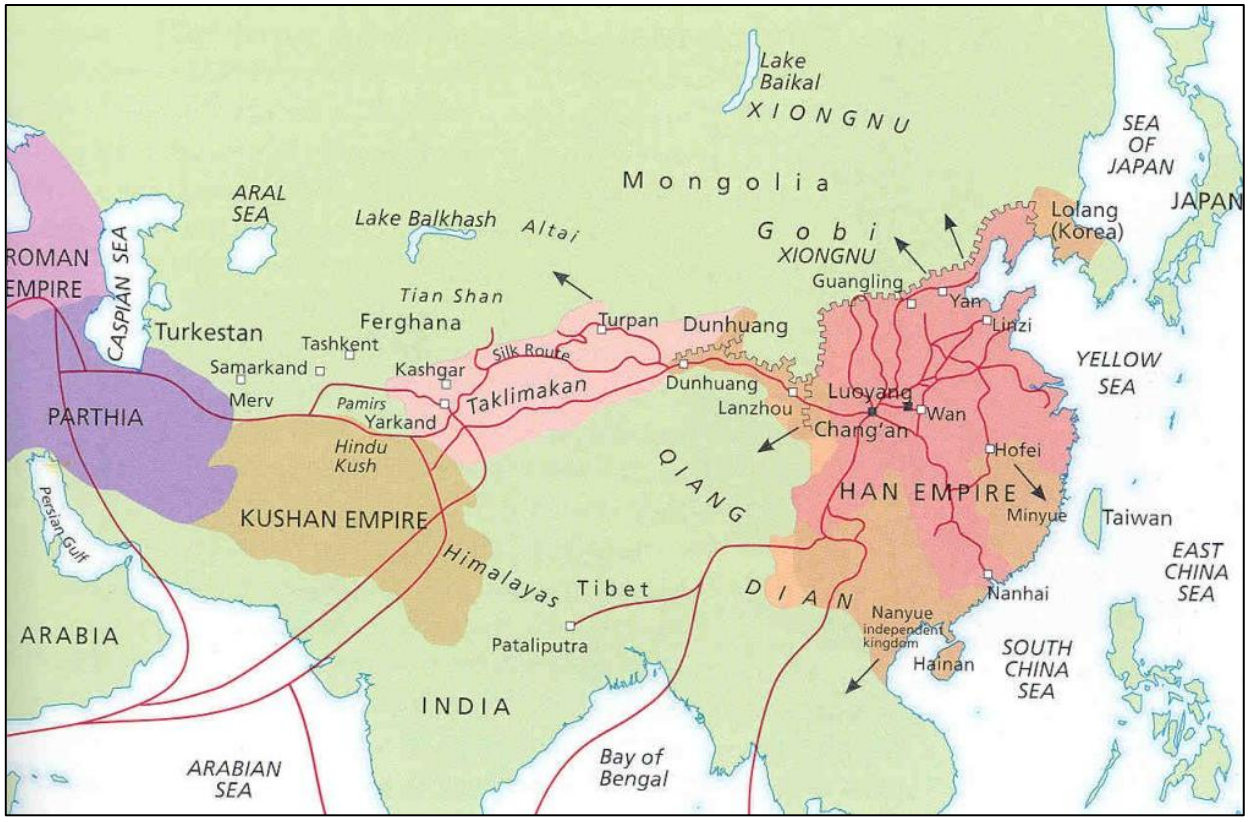

Fig. 2.3: Map of the Han Dynasty in relation to the neighboring Parthian and Kushan empires. The Talkimakan region in light pink was a Han protectorate in the 1st century CE. Trade routes are shown in red; the easternmost, entering the Bay of Bengal from the sea and passing over Annam (Vietnam), is the subject of *Baopuzi*. *Source*: http://bladams.tripod.com/empire/han_e/maps.html.

Fig. 3.1: Two glass cups founds in the tomb of Han prince Liu Sheng (d. 113 BCE) in Hebei. *Source*: (Kwan 2001:47).

Fig. 3.2: Two glass cups found in the tomb of King Liu Dao (d. 128 BCE) of the Chu state in Jiangsu. They were probably glass imitations of jade imitations of lacquer vessels. These cups were initially categorized as jade by excavators (Braghin 2002b:32-3). *Source*: (Kwon 2001:46).

Fig. 4: Left, a diagram of a double-mold used to make ear studs. Clay residue in the hollow areas of these ear studs suggest that after annealing, the outer mold was broken off while the inner mold was melted with water. Right, the resulting hollow glass ear studs. *Source*: (Kwon 2001:53, 225).

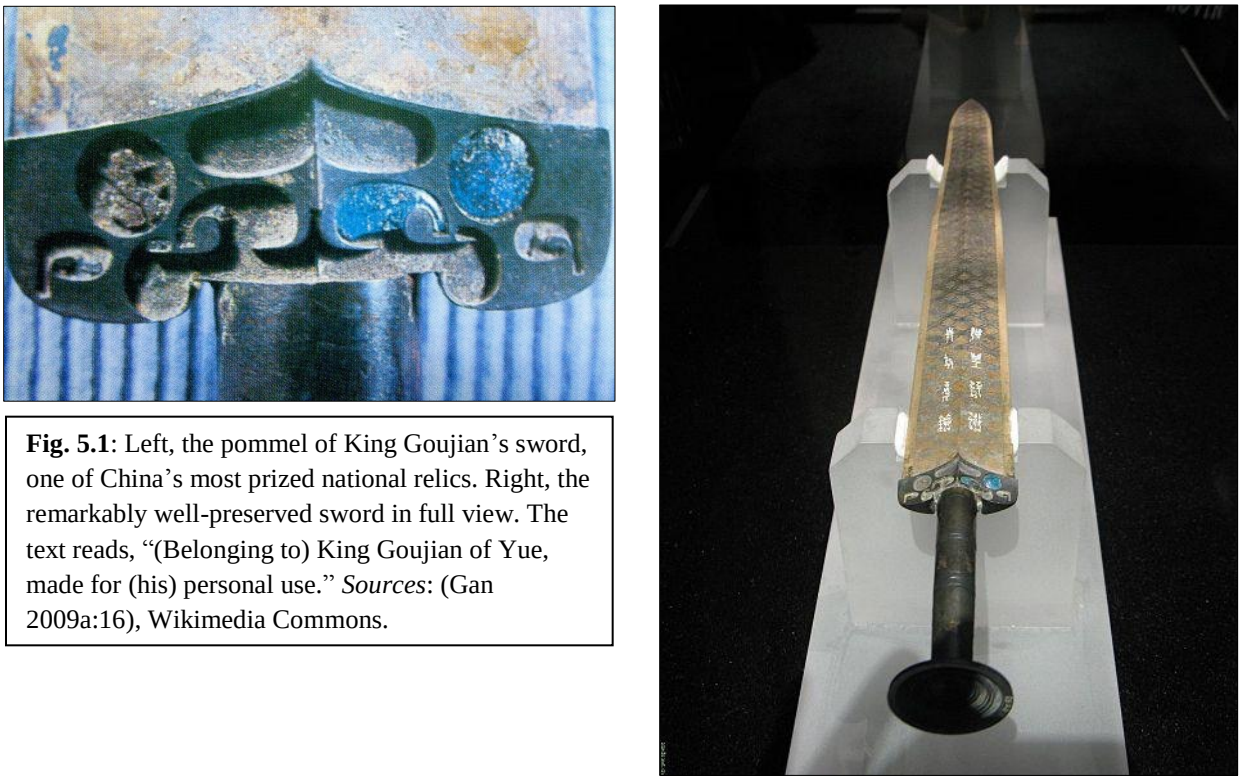

Fig. 5.1: Left, the pommel of King Goujian's sword, one of China's most prized national relics. Right, the remarkably well-preserved sword in full view. The text reads, "(Belonging to) King Goujian of Yue, made for (his) personal use." *Sources*: (Gan 2009a:16), Wikimedia Commons.

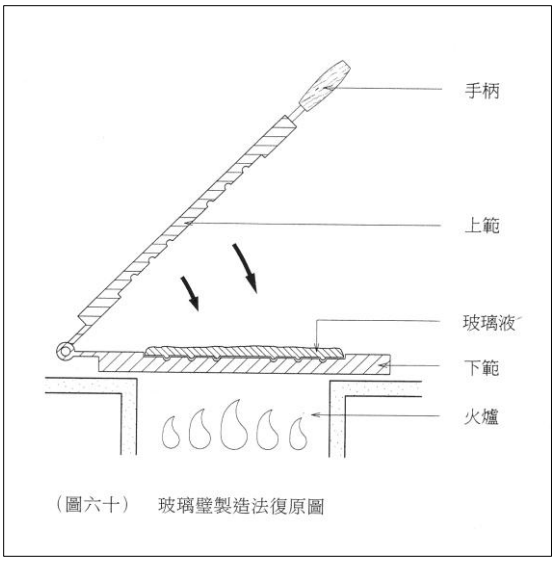

Fig. 5.2: Diagram of a "sandwich" mold used to make glass *bi* disks. *Source*: (Kwon 2001:54).

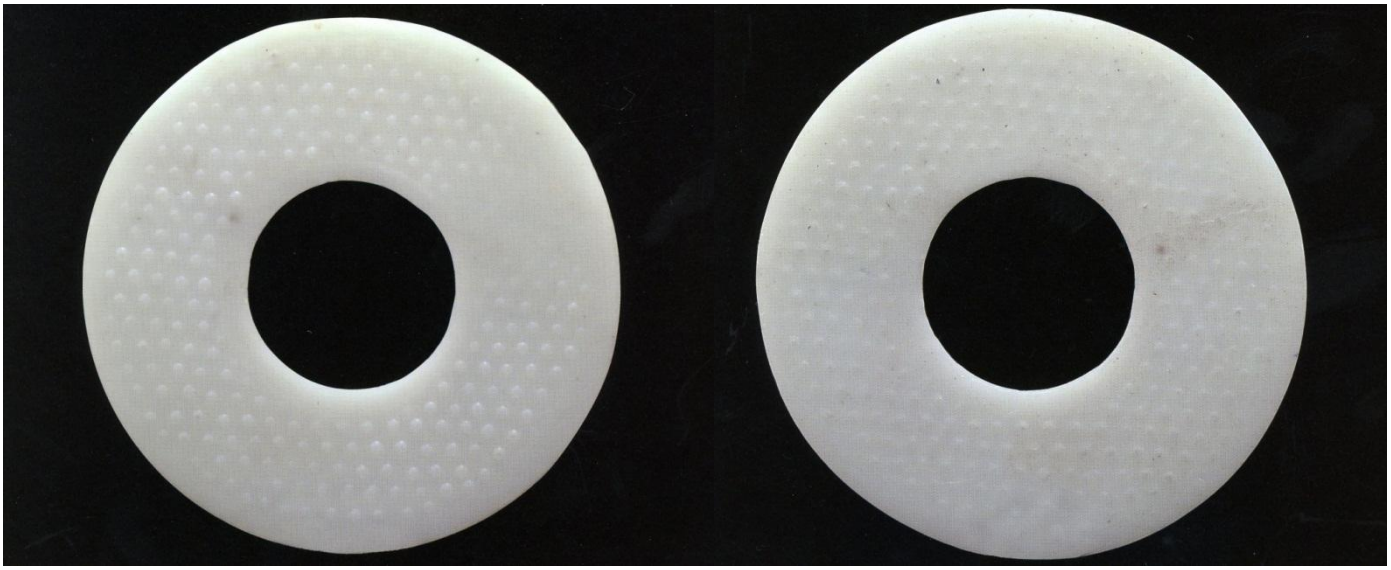

Fig. 5.3: Western Han glass *bi* from Hunan. Note the difference in the definition of the pattern on the obverse (clear) and reverse (faint). *Source*: (Kwon 2001:241).

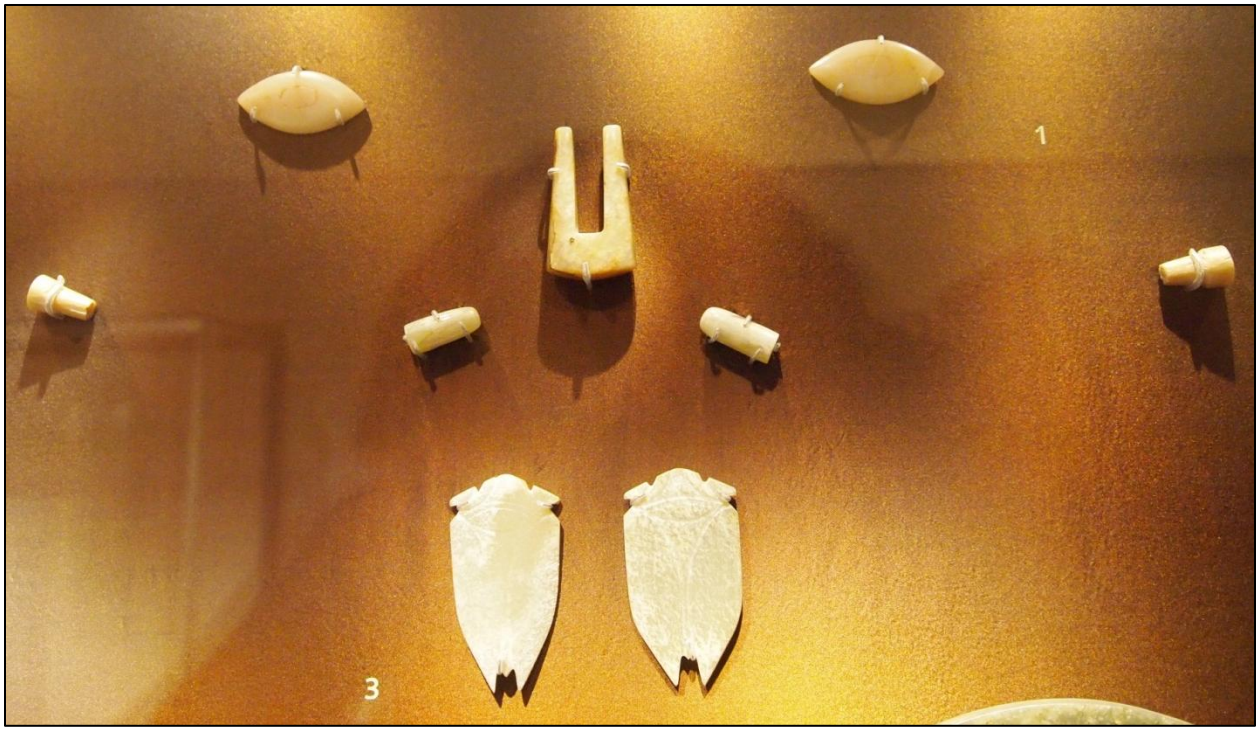

Fig. 5.4: Jade body plugs in the British Museum. In appearance, they are identical to glass body plugs.

Fig. 5.5: Glass cicadas from Henan, 2nd century BCE. Cf. the jade cicadas in Fig 5.4. *Source*: (Kwon 2001:253).

Fig. 5.6: Jade burial suit of Liu Sheng (d. 113 BCE). Various body plugs are arrayed beside the right arm. *Source*: (Yang 2004:346).

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