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Discovery of Beeswax as binding agent on a 6th-century BC Chinese Turquoise-inlaid Bronze sword

Wugan Luo [a,b], Tao Li [c,*], Changsui Wang [a,b], Fengchun Huang [d]

[a] Department of Scientific History and Archaeometry, Graduate University of Chinese Academy of Sciences, Beijing 100049, China
[b] Joint Laboratory of Human Evolution and Archaeometry, IVPP, Beijing 100044, China
[c] Department of Anthropology, University of Pittsburgh, 3302 WWPH, Pittsburgh, PA 15260, USA
[d] Hubei Provincial Institute of Cultural Relics and Archaeology, Wuhan 430077, China

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ABSTRACT

Recent archaeological field surveys and excavations at *Qiaojiayuan*, a platform 40 km west of the *Yun* County in present-day northwestern Hubei Province (central China), revealed four tombs (M_3, M_4, M_5 and M_6) dating back to around 6th to 5th century BC. The grave's layout, artifact assemblages and burial practice indicate that the owners of these four graves were aristocrats of the *Chu* state. Five turquoise-inlaid bronze artifacts (two swords and three dagger-axes) were excavated. The sword from M_4, imbedded with pieces of well-cut and finely-polished turquoise on its handle, was in a very bad state of preservation and underwent conservation treatment. Some sticky, whitish pastes were exposed when the inlaid turquoises dropped off. The pastes were supposed to be residues of unknown binding agents. Samples of the pastes were collected for FTIR (Fourier Transform Infrared Spectroscopy) and XRD (X-Ray Diffraction) analyses to determine the chemical component(s). The results revealed that the pastes were composed of almost pure beeswax. This indicated that beeswax was used as binding agent in turquoise-inlaid bronzes as early as the 6th to 5th century BC in China. Review of recent technical studies suggested that beeswax was used in early China in several different regions (mostly southern part of China) for at least two different purposes (binding agent and lightening).

1. Introduction

1.1. A brief summary of the inlay technique in early China (5000–221 BC)

The inlay technique, in its general sense, involves inserting precious or semi-precious stones, metals or other materials onto the surface of base materials (mostly inorganic materials such as metal, clay and stone) with or without binding agents. Archaeological evidence shows that the inlay technique was developed to make compound stone tools as early as the Late Palaeolithic Age world-wide. Flakes at the Paleolithic *Siyu* site (28,945 ± 1370 BP) in the *Shuo* County (Shanxi Province, central China) that are believed to be inserted into a wood or bone handle is such an example (MacCurdy, 1930; Wang, 2008). In the Late Palaeolithic Age, the inlay technique was used in the production of utilitarian tools; while in the Neolithic Age it was also used, and in some cases more frequently, to produce artifacts of ritual and ideological importance. Decorative treatment to form a beautiful contrasting surface to the base materials started to be highly valued during this period. There were many jade- and/or stone-inlaid artifacts with special shapes and designs that were often associated with ceremonial and ritual activities. Typical examples include the Turquoise Goddess (a human-sized female statue with eyes decorated with turquoises) from the Hongshan Culture (4500–2250 BC) and turquoise-inlaid jade artifacts from the Liangzhu Culture (5000–4800 BC) (Zhang, 1996; The Institute of Archaeology of Zhejiang Province, 2005; Guo, 2008). It is probably due to this reason that the need for more durable and beautiful artifacts emerged, which might lead to the rise of binding agents in the inlay technique. It is hard to tell whether or not binding agents were involved in the inlay technique in the Late Palaeolithic Age, due to poor preservation and lack of reliable analytical methods. However, it seems certain that binding agents were employed in the inlay technique in the early Chinese Neolithic Age. In the past half century unknown blackish or whitish sticky pastes on the inlaid artifacts have been discovered from many Chinese Neolithic sites, which were visually inspected and considered as residues of binding agents (Hao and Hao, 2002; Kong, 2002; The Institute of Archaeology of Zhejiang Province, 2005; Wang, 2008).

* Corresponding author. Tel.: +1 412 478 0368.
E-mail address: tao-li@live.com (T. Li).

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From the beginning of the legendary *Xia* through the whole Bronze Age (*Xia*, *Shang* and *Zhou* dynasties), the inlay technique was developed rapidly, the base materials extent to almost all kinds of commonly-used inorganic materials (metal, silicate and stone) and some organic materials such as wood, bone and ivory (Wang, 1983; Zheng, 2007). It has been archaeologically and/or technically confirmed that turquoise-inlaid bronzes occurred in the legendary *Xia*, followed by the use of copper and iron for bronze inlay in the *Shang* period. The use of gold and silver as bronze inlay, as well as the wide application of binding agents, began in the Spring and Autumn Period (771–476 BC), and reached the apex by the middle of the Warring States Periods (475–221 BC) (Hung, 1984; Hebei Provincial Institute of Cultural Relics and Archaeology, 1985; Cheng et al., 2008).

1.2. Turquoise-inlaid bronzes in the Three Dynasties (1900–221 BC) and related technical studies

Turquoise, highly valued for its vibrant hues from light green to dark blue since prehistoric times, is a hydrous phosphate of copper and aluminum, with the chemical formula $CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$. The mechanism that accounts for turquoise's varying colors is still unclear, although some hypotheses attributed this to the different chemical composition of copper, aluminum and impurities (such as iron) (Luan, 1989). Archaeological evidence shows that from early Neolithic Age through the Three Dynasties (*Xia*, *Shang* and *Zhou*) turquoise was used widely and consistently in ancient China due to easy availability and notice ability and/or people's strong preference for its unique, beautiful and mysterious hues, along with the growing use of inlaid artifacts (Hao and Hao, 2002; Luan, 2004; Shi and Cai, 2007; Wang, 2008).

To date, the earliest turquoise-inlaid bronze in China is an animal-faced bronze plaque embedded with finely-cut turquoises (Fig. 1), unearthed from *Erlitou*, a site believed to be built around 1900 BC and abandoned around 1500 BC, in Henan Province. The plaque, as well as turquoise-inlaid bronze artifacts and ornaments unearthed from remains of later periods (pre- and early *Shang*) at *Erlitou*, reflects the superb skills in inserting hand-cut turquoises into bronzes in the pre-writing period (Erlitou Archaeological Team of the Institute of Archaeology, CASS, 1984, 1986, 1992). The production of turquoise-inlaid bronze artifacts continued to develop due to the increasing importance of ritual bronzes in the *Shang* dynasty. A large number of high quality turquoise-inlaid bronze artifacts were discovered from middle *Shang* to early western *Zhou* dynasties. With the rise of copper-, gold and silver-inlaid bronzes in the Spring and Autumn Period, although the absolute counts of turquoise-inlaid bronzes were larger than before, the relative scale of turquoise-inlaid bronzes production started shrinking. By the beginning of *Qin* (221–206 BC), the first imperial dynasty of China, the turquoise-inlaid bronzes were made far less frequently (Wang, 1983).

One topic receiving increasing attention and interest among Chinese archaeologists and some geologists is the geographical and geological provenance study of early Chinese turquoises. According to *Chuo Geng Lu* (*Retirement To The Countryside*), a book of anecdotes written by Tao Zongyi in the late *Yuan* to early *Ming* period (around 14th and 15th century AD), three regions were well-known for abundance in turquoise of high quality – two in the present-day eastern Iran (Nishapur and Kerman) and one in the northwestern part of Hubei Province in central China (Xue, 1997). Modern geological investigations of turquoise mines have revealed that Iran, China, Egypt, United States and Chile are the five leading producers of high quality turquoises, and that turquoise mines in China are mostly distributed in the northwestern part of Hubei, southwestern part of Shaanxi and Henan, eastern part of Anhui and Xinjiang, and central part of Qinghai. Turquoise from Hubei is claimed to be of the best quality in China for its superb physical properties and esthetic values (He, 2004; Luan, 1989).

Fig. 1. The bronze plaque (81VM4:5), so far the earliest turquoise-inlaid bronze artifact in China, was unearthed from Phase II of the *Erlitou* site (ca. 1800–1770 BC) in 1981 in present-day Henan Province, which was believed to be the center of the Central Plains in the Three Dynasties.

More than 80 years' Chinese archaeological investigations and excavations have found thousands of pieces of turquoises including at least 150 turquoise-inlaid bronzes from the beginning of Neolithic Age to the end of Bronze Age. Table 1 and Fig. 2 summarize the archaeological sites and tombs where turquoise-inlaid bronzes of the Three Dynasties were excavated. About 75% of the turquoise-inlaid bronzes were distributed in central China (in Hubei and Henan Provinces to be more specific) (Hao and Hao, 2002; Kong, 2002). Fig. 2 also marks some well-known turquoise mines in modern China: *Yun* County (Hubei Province), *Yunxi* County (Hubei Province), *Zhushan* County (Hubei Province), *Baihe* County (Shanxi Province), *Xichuan* County (Henan Province) and *Ma'anshan* (Anhui Province). Recent geological investigations show that in *Yun*, *Zhushan* and *Yunxi*, where more than 70% of current Chinese turquoises are yielded, at least 40 turquoise mines were exploited and used by ancient Chinese (Zhao and Zhang, 1994).

Based on comparative studies of nationwide prehistoric turquoises, Chinese geologists proposed that turquoise mines in the northern part of Hubei and southwestern part of Shaanxi and Henan accounted for most of the turquoises at prehistoric sites in Hubei, Henan, Shandong, Shaanxi, Hunan and Gansu Provinces (Zhou and Wang, 2005). Chemical and geochemical methods such