Identification of 13th–14th Century Chinese Handmade Paper Fibers Collected in Yuan Dynasty Paper Currencies

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Abstract: The earliest paper currencies in existence in China were handcrafted during the Yuan dynasty. These currencies were scientifically excavated from different ruins or tombs, whereas scientific analyses of the papers are rare. This study used optical and scanning electron microscopy to examine the fibers collected in Yuan dynasty paper currencies in conjunction with the Herzberg staining method. Despite differences in circulation period, paper fibers in both *Zhi Yuan Tong Xing Bao Chao (two Guan)* and *Zhong Tong Yuan Bao Jiao Chao* (*one Guan* and *500 Wen*, issued in Zhi Zheng period) were identified as similar papermaking materials, bast fibers of mulberry bark. The results indicate that mulberry bark, a durable papermaking material used since ancient times, was mainly utilized as a raw material in these Yuan dynasty paper currency. This fiber identification work solved the critical problem of papermaking material in the Yuan dynasty paper currency and provided important information for conserving these precious cultural relics.

Keywords: paper currency; Yuan dynasty; mulberry bast; fiber identification

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1 Introduction

The earliest paper currency in the world was issued in China. As early as the Tang dynasty (618—907), a primitive form of paper currency called Fei Qian (flying money

in Chinese) was first used by merchants as an alternative to coins for convenience and security. The application of Fei Qian was limited to commercial activities only, not for general circulation in people's daily lives [1]. The world's earliest paper currency-Jiaozi (exchange bills in Chinese), which evolved from Fei Qian, was first officially issued by the Northern Song government for general circulation in 1023 within the issuing region, mainly in Sichuan province [2]. However, as an essential tangible cultural relic, Jiaozi has never been discovered materially, nether excavated from tombs, nor restored until today. The earliest paper currency still in existence within China was issued during the Yuan dynasty (1271—1368) and was called Jiaochao (evolved from Jiaozi) and Baochao [3]. Paper currencies, including Jiaochao and Baochao, were designated as fiat currencies in the Yuan Empire. These paper currencies have been discovered in archaeological excavations or handed down since ancient times [4-7].

As a renowned cultural tradition in East Asia, Chinese handmade paper was famous for using various raw materials. The earliest handwritten paper was excavated from Tianshui, Gansu Province, which was handmade using hemp fibers during the early Han dynasty [8]. The famous Xuan paper, traditionally used for painting and drawing in China, was mainly handcrafted with Wingceltis bast [9]. Bast fibers from mulberry and paper mulberry have also been used in papers because of their good properties, particularly excellent durability [10]. Considering durability issues, artisan were more likely to select bast fibers as raw materials in ancient China. The identification of fiber on paper currencies in the Ming and Qing dynasties has been reported extensively, while currency fiber in the Yuan dynasty was still unidentified [11].

The Qinghai Provincial Museum restores several Yuan dynasty paper currencies excavated from a farm in the Haixi Autonomous Prefecture in 1955 [12]. As they were diverted to museums, they have been laid aside in warehouses that still suffer severe damage. In this study, optical and scanning electron microscopy (SEM) were applied to examine the fibers collected in these Yuan dynasty paper currencies in conjunction with the Herzberg staining method [13], as research work on the composition of these paper currencies handcrafted in the Yuan dynasty. Furthermore, this study focused on the raw materials of the paper itself, which would also benefit the conservation of these paper currencies.

2 Materials and methods

2.1 Materials

Dispersed fiber specimens (tiny pumps or short fragments) collected from three paper currencies were examined in this study; including: ① Zhi Yuan Tong Xing Bao Chao (two Guan), which literally means treasure certificate circulating in the Zhi Yuan period (2000), as shown in Fig. 1(a) and Fig. 1(d); ② Zhong Tong Yuan Bao Jiao Chao (one Guan), which literally means exchange certificate circulating in Zhong Tong period (100), as shown in Fig. 1(b) and Fig. 1(e); ③Zhong Tong Yuan Bao Jiao Chao (500 Wen), which literally means exchange certificate circulating in Zhong Tong period (500), as shown in Fig. 1(c) and Fig. 1(f).

2.2 Optical microscopy

Fiber specimens were examined and photographed under white light using a Leica M205C optical microscope with a 10× ocular and 1.6× objective, coupled to a Leica MC170HD digital camera with an optical magnification ratio of 5.0×, adopting the Leica multi-focus photography mode.

2.3 SEM analysis

The specimens were uncoated and examined using a JEOL SEM (JCM-6000plus) with an accelerating voltage of 5 kV, photographed under SED mode at 200× magnification. Diameter measurements of the fiber specimens were performed using the built-in software of the JEOL system.

2.4 Herzberg reagent

The Herzberg reagent used in this study was formulated by mixing a zinc chloride solution (20 g $ZnCl_2$ in 10 mL deionized water) and an iodine solution (0.1 g I_2

(a) Back side of Zhi Yuan Tong Xing Bao Chao, two Guan; (b) Back side of Zhong Tong Yuan Bao Jiao Chao, one Guan; (c) Back side of Zhong Tong Yuan Bao Jiao Chao, 500 Wen; (d) Front side of Zhi Yuan Tong Xing Bao Chao, two Guan; (e) Front side of Zhong Tong Yuan Bao Jiao Chao, one Guan; (f) Front side of Zhong Tong Yuan Bao Jiao Chao, 500 Wen

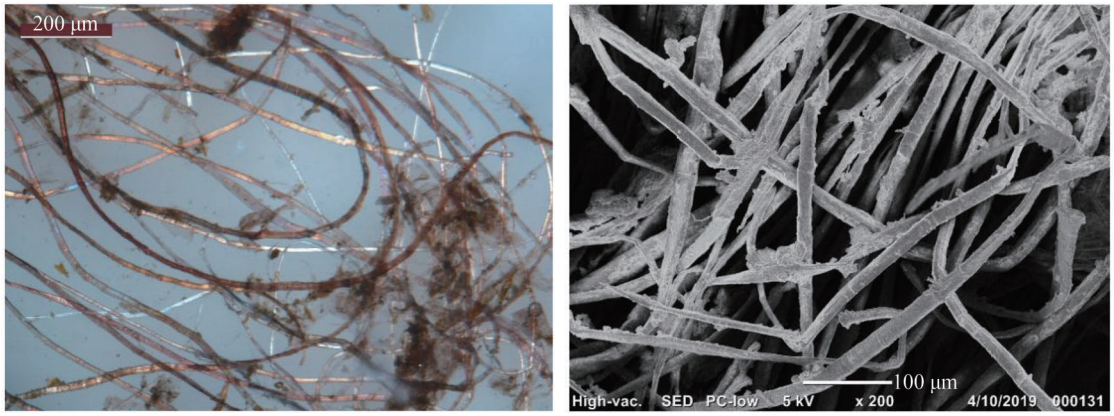
Fig. 1 Photographs of Yuan dynasty paper currencies

and 2.1 g KI in 5 mL deionized water). This mixture was poured into a long tube and allowed to stand overnight until clear, after which the supernatant was decanted into a dark bottle to avoid undue exposure to light and air. Finally, a small amount of excess iodine was added for better storage stability [14].

3 Results and discussion

3.1 Zhi Yuan Tong Xing Bao Chao (two Guan)

After staining with Herzberg reagent, fibers collected from Zhi Yuan Tong Xing Bao Chao (two Guan), with an accession number of QB5466, presented a wine red to brown-yellow color , as shown in Fig. 2(a). Fibers in QB5466 have a uniform thickness at an average diameter of 18.5 μm, with relative high longitudes, as shown in Fig. 2(b). Because of the absence of the associated cells commonly observed in bamboo, rice, and wheat straw (parenchymal cells or coarsely serrated cells), these kinds of papermaking fibers cannot be used as raw materials for QB5466 [15]. The significant characteristics of the fibers collected from



(a) (b)

Fig. 2 Optical (a) and SEM images (b) of QB5466

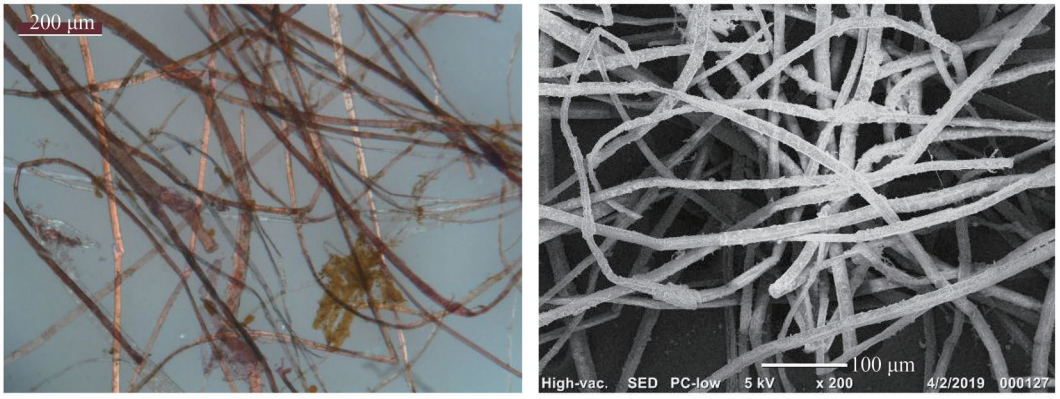
QB5466 were their well-pronounced cross-striations at frequent intervals to form nodes in optical and SEM photographies, a shape characteristic of bast fibers such as hemp, mulberry, and paper mulberry [16]. Because longitudinal striations are a diagnostic feature for hemp fiber and calcium oxalate crystals for paper mulberry fiber, in this study, the absence of such features discards the potential composition of hemp fiber or paper mulberry fiber.

Around most fibers in Zhi Yuan Tong Xing Bao Chao (two Guan), deep brown-yellow pectin was observed; they were amorphous and attached to the surface of the bast fibers. In the bottom-right corner of Fig. 2(a), a mass of pectin formed a deep brown-yellow lump, which might result from pulping process. In mulberry bark, pectin usually has a relatively high content in bast fiber composition; thus, relatively high amounts of pectin supported the conclusion that fibers in QB5466 are more likely to be mulberry bast [17].

Zhi Yuan was first used as the title of the Kublai reign (1264-1294). Thus, Zhi Yuan Tong Xing Bao Chao was first issued as fiat currency during the Kublai reign. As the first emperor of the Yuan dynasty, Kublai permitted his chancellor to issue paper currency in his vast empire with the initial edition of Zhong Tong Yuan Bao Jiao Chao [18]. However, due to overissuance and severe inflation, Zhi Yuan Tong Xing Bao Chao was issued to replace Zhong Tong Yuan Bao Jiao Chao from the 24th year of the Zhi Yuan period (1287) till the end of the Yuan dynasty, and the latter was finally abolished the following year [19]. As the longest circulation and largest issued currency of the Yuan dynasty, Zhi Yuan Tong Xing Bao Chao retained a relatively large quantity throughout China. Owing to its durability, the mulberry bast has played an essential role in the good conditions of these paper currencies for over 700 years.

3.2 Zhong Tong Yuan Bao Jiao Chao (one Guan)

Zhong Tong Yuan Bao Jiao Chao (one Guan), with accession number QB5621, presented a dark brown appearance similar to that of QB5466 (Fig. 1(a) and Fig. 1(b)), while most fibers were stained with a deep brown color, unlike QB5466's wine red color (Fig. 3(a) and Fig. 2(a)). Despite tiny differences in diameter (average at about 19.5 μm), fibers in QB5621 have the same characteristics as those in QB5466: long thin fibers with well-pronounced cross striations at frequent intervals to form the nodes; thus, the raw material for paper in Zhong Tong Yuan Bao Jiao Chao (one Guan) was also identified as the same bark fiber and bast fiber from the mulberry tree. Compared to QB5466, both optical and SEM images of QB5621 showed significantly more "clean" appearances with relatively low amounts of inclusion between fibers. This might be due to the light beating degree of pulp during the papermaking process, while most inclusions were still attached to fibers and did not tear apart from fibers, such as QB5466 [20]. In this way, the paper would finally form a smoother and glossy surface than that with a high beating degree [21]. Fig. 1(a), Fig. 1(b), Fig. 1(d)



(a) (b)

Fig. 3 Optical (a) and SEM images (b) of QB5621

and Fig. 1(e) show this significant difference.

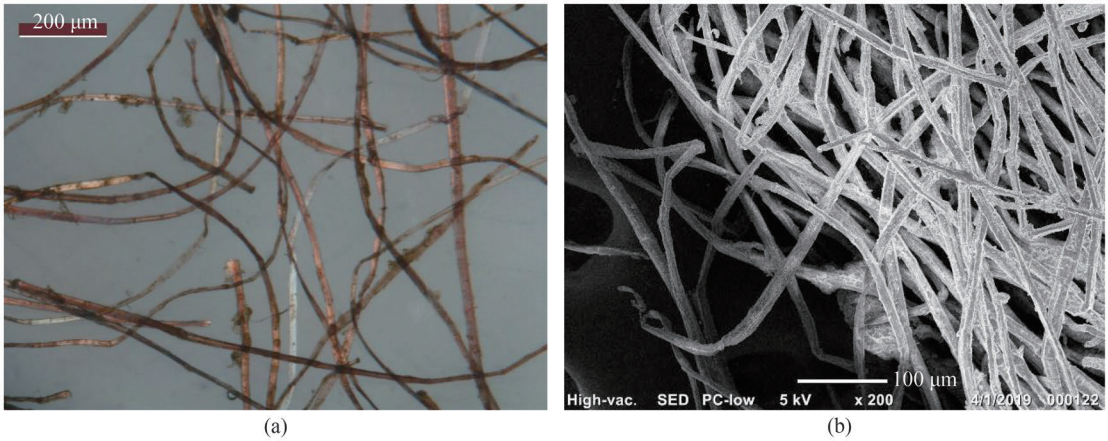
Transparent thin films surrounding several fibers of QB5621 were observed (bottom-left corner of Fig. 3(a)). These transparent films are analyzed to be intact pectin tiers attached tightly to the fibers because these thin films barely reacted to the Herzberg reagent. These transparent films are actually intact pectin tiers attached tightly to the fibers [22]. A wax-shaped pectin lump was observed at the bottom right of Fig. 3(a), representing a deep yellow color. These features also fit the micro characteristics of mulberry bast fibers.

Although the words *Zhong Tong Yuan Bao Jiao Chao* were printed on the front side of the paper currency with accession number QB5621, this currency was issued during the Zhi Zheng period (1341—1368), as the seal inscription on the back side of *Zhi Zheng Ying Zao Yuan Bao Jiao Chao* means paper currencies handcrafted and printed in the Zhi Zheng period (Fig. 1(e)), the last emperor reign of the Yuan dynasty rather than the Zhong Tong period, the first emperor reign of the Yuan dynasty.

3.3 Zhong Tong Yuan Bao Jiao Chao (500 Wen)

Fibers collected from Zhong Tong Yuan Bao Jiao Chao (500 Wen), with accession number QB5677, presented nearly the same deep brown color as QB5621 (Fig. 4(a)). The characteristics in both optical and SEM images fit mulberry bast fibers in the same way as those of QB5621; therefore, fibers in Zhong Tong Yuan Bao Jiao Chao (500 Wen) were readily identified as mulberry bast. Meanwhile, this paper currency was also issued in the Zhi Zheng period rather than in the Zhong Tong period, according to the seal inscriptions on its back side (Fig. 1(f)). In summary, QB5621 (one Guan) and QB5677 (500 Wen) were almost the same, except for the difference in their values.

Although there were many similarities, visible color



(a) (b)

Fig. 4 Optical (a) and SEM images (b) of QB5677

discrepancies were noticed between QB5621 and QB5677; the latter presented a much more gray color with a deep brown appearance (Fig. 1(b) and Fig. 1(c)). Some researchers believe that the gray color might arise from the addition of mulberry bast to other raw materials, including cotton and hemp [23]. In this study, the long twisted fiber with edge thickening feature was not observed, which discards the presence of cotton [24]. The longitudinal striation feature of the hemp fiber was not observed, which discards the presence of hemp [25]. In fact, the papermaking material in this paper currency was identified as a relatively pure mulberry bast fiber. Therefore, we believe that such appearance discrepancies resulted from technique differences during papermaking process rather than differences in raw materials.

4 Conclusions

Papermaking fibers in Yuan dynasty paper currency sourced from the Qinghai Provincial Museum's collection, Zhi Yuan Tong Xing Bao Chao (two Guan) and Zhong Tong Yuan Bao Jiao Chao (one Guan and 500 Wen, issued in the Zhi Zheng period) were identified as similar papermaking materials, which were bast fibers of mulberry bark, despite discrepancies between their appearances, values, and circulation periods. It was the first time that raw materials of the earliest paper currency still in various physical materials were identified. Owing to the durability of the mulberry bast, these precious paper currencies handcrafted during the Yuan dynasty have maintained relatively stable conditions until today. The results prompted the conservators who focus on preserving paper currency issued during the Yuan dynasty to choose the best matching material, mulberry bast, to coordinate with the currency's raw material in their conservation work.

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