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# Research and Analysis of Woodblock Printing Ink from the Qing Dynasty Used in the Shuyede Press of Shandong

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**Abstract:** Archival writing material is an important carrier to record and reflect archival content, and its material and durability are closely related to the life of archives. The "Shuyede" press in Shandong Province, which originated in the reign of Kangxi (1662 AD–1722 AD) in the Qing dynasty, printed many important archives and ancient books of the Qing dynasty (1644 AD–1911 AD). In order to explore the material composition of woodblock printing ink from the Shuyede press, modern analytical and detection techniques such as scanning electron microscopy–energy-dispersive spectrometry (SEM-EDS), Fourier-transform infrared spectroscopy (FTIR), gas chromatography–mass spectrometry (GC/MS), and pyrolysis gas chromatography–mass spectrometry (Py-GC/MS) were applied for the analysis and identification of the ink on woodblock plates from the Shuyede press. The results showed that two kinds of printing ink—pine soot ink and oil soot ink—used were in these woodblocks from the Shuyede press in the Qing dynasty in the collection of Shandong Museum, and the binding material in the ink was animal glue, indicating that both pine and oil soot inks were used as printing ink in the Qing dynasty.

**Keywords:** Qing dynasty; Shuyede press; woodblock printing; ink; Py-GC/MS

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## 1. Introduction

Woodblock printing is considered as a "living fossil" in the history of Chinese printing, and its invention and development have left many valuable documentary materials in China [1,2]. Woodblock plates serve as a matrix of documents, storing most of the original information from the documents, and are important materials for the identification of versions of classical documents, research on printing history, and documentary studies. They are collected in museums, archives, libraries, and engraving institutions in China [3–5]. Due to the wooden nature of woodblock plates, they are not easy to preserve or transport, leading to a large number of woodblocks being damaged. The surviving woodblocks mostly date back to the Ming (1368 AD–1644 AD) and Qing (1644 AD–1911 AD) dynasties.

Ink is the most commonly used material for handwriting in woodblock printing and a crucial medium for recording ancient Chinese literature. It is primarily composed of black soot produced by incomplete combustion of materials such as pine, animal and plant oils, mineral oils, etc., mixed with glue as a binder, and sometimes seasoned with various spices and Chinese medicinal herbs as additional components. Based on the raw materials used, ink falls mainly into two categories: pine soot ink [6,7] and oil soot ink [8,9]. These two types of ink differ from each other in terms of darkness, water resistance, luster, stability, and other characteristics. Oil soot and pine soot both contain a certain amount of carbon in oxidized forms, such as C–O, C=O, and O–C=O. Oil soot has a higher variety of oxidized functional groups. The surface groups of oil soot are more complex, with a greater number of weak carboxylic acids, phenolic hydroxyl groups, and anhydrides, whereas

pine soot is predominantly composed of strong carboxylic acid groups with slightly more quinone and ether functional groups [10]. The history of ink in China is extensive. By the Wei and Jin dynasties, the production process of pine soot ink had been largely perfected. Jia Sixie's *Qi Min Yao Shu* from the Northern Wei (386 AD–534 AD) dynasty was the first description to document the method of ink production. From the Song (960 AD–1279 AD) dynasty onwards, oil soot ink began to thrive and eventually became the dominant type of ink in production.

Printing ink is different from writing ink, as ink that is too thick or too light can affect the quality of printed books, and it generally requires specialized blending. There are few records in the literature on the use of ink for engraving. Lu Qian recorded the preparation method of ink for engraving in *Shu Lin Bie Hua* [11]: "The method of making ink is to mix the smoke from the charcoal kiln with the cowhide glue and water to form a thick gruel, which then is mixed with wine, and stored for half a month to form a thin paste. Afterwards the ink gruel is mixed well, and put in a jar for storage. In plum rain season, the odor will overflow. However, it must be go through three or four plum rain seasons before the ink can be used. If it is urgently used, the ink color will float, and when it is touched, it will be shaded. The longer the ink is stored, the better it is. When printing a book, the ink gruel must first be filtered with horsetail sieve. After removing the dregs, the rest can be used to print books". Jinling Scriptural Press uses pine smoke, wheat flour, white liquor, vinegar, Cantonese gum, etc. as ink-making materials. After a certain process, the soot ink was prepared, put into an ink cellar for fermentation, and stored for three years before use. Dege Printing Academy generally used high-quality pine soot ink or roasted birch and rhododendron bark to make ink, and adds bergamot, ginseng, rosin, cow glue, etc. to improve the viscosity and ink quality.

In the Qing dynasty, folk carvings flourished in the Shandong region. As an important center for engraving and printing in China, Liaocheng had four major bookstores: Shuyede, Shanchengtang, Baoxingtang, and Youyitang. The Shuyede press was founded during the Kangxi period of the Qing Dynasty and was the first of the "Four Great Book Stores" in Liaocheng. At its peak, there were over 1000 types of book editions, with excellent woodblock printing, careful proofreading, and high-quality books. They were stored in various sub-libraries such as the "Classic and History Board Library", "Novel Board Library", "Medical and Miscellaneous Board Library", and "Enlightenment Book Board Library". Due to banditry, war, and other reasons, the vast majority of Shuyede's calligraphy boards were burned, and few have survived to this day. The Shandong Museum has a collection of approximately 600 carved blocks from the Shuyede press from the Qing Dynasty, all of which are inscribed with the words "Shuyede press" (Figure 1). These blocks have important physical value for studying the history of Shandong's book carving and the development of the Shuyede press in the Qing dynasty.

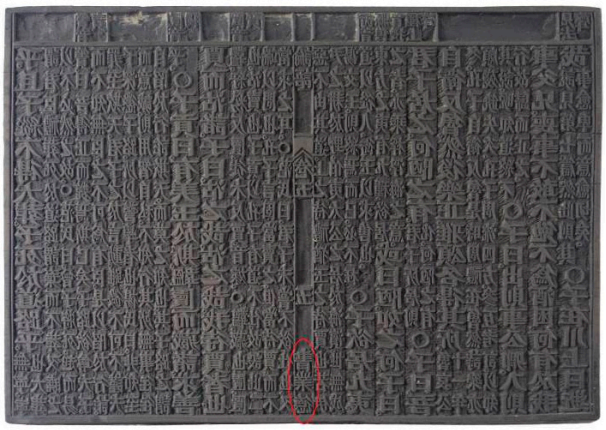


**Figure 1.** A woodblock printing plate from the Qing dynasty, titled "Shuyede press" (dimensions: 20.5 cm × 14.0 cm × 1.5 cm) (Shandong Museum collection).

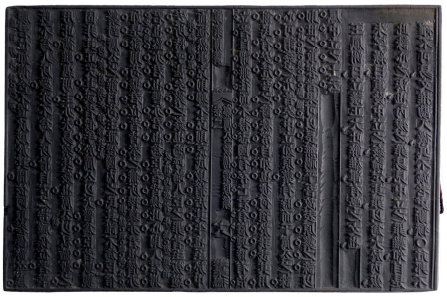
In this study, various analytical methods such as scanning electron microscopy–energy-dispersive spectroscopy (SEM-EDS) [12], Fourier-transform infrared spectroscopy (FTIR) [13], gas chromatography–mass spectrometry (GC/MS) [14,15], and pyrolysis gas chromatography–mass spectrometry (Py-GC/MS) [16–18] were used to analyze and detect the ink left on the Qing dynasty Shuyede woodblock plates in the collection of Shandong Museum. The type of ink and the binder in the ink were detected and identified.

## 2. Experimental Section

### *2.1. Sample Overview*

Two woodblock plates from the Shuyede press from the Qing dynasty in the collection of Shandong Museum were selected for ink analysis and testing based on the remaining ink traces. The sample information is detailed in Table 1.

**Table 1.** Sample Information.

| Sample Number | Sample Source | Dated | Cultural Relic Photo | Dimensions |
|---|---|---|---|---|
| M1 | The Wooden Carved Edition of *DongLaiBoYi* | The eighth year of the Guangxu reign of the Qing dynasty (1882 AD) |  | 24.8 cm × 16.2 cm × 1.5 cm |
| M2 | The Wooden Carved Edition of *Mathematics* | Qing dynasty (1616 AD–1911 AD) |  | 21.8 cm × 18.0 cm × 1.2 cm |

### *2.2. Experimental Instruments*

The instruments used in this study included the following: an HITACHI SU8020 Field Emission Scanning Electron Microscope (Hitachi High tech Company, Tokyo, Japan) with a cold field emission source electron gun, secondary electron resolution: 1.3 nm (at an accelerating voltage of 1 kV, WD = 1.5 mm), 1.0 nm (at an accelerating voltage of 15 kV, WD = 4 mm); Thermo Nicolet iS50 Fourier Transform Microscopic Infrared Spectrometer (Thermo Fisher Scientific, Waltham, MA, USA), maximum resolution: 0.09 $cm^{-1}$; a CDS Pyroprobe 5200 pyrolyzer (CDS Corporation, Blythewood, SC, USA); an Agilent 7890A gas chromatograph (Agilent, Santa Clara, CA, USA); an Agilent5975C MSD mass spectrometer (Agilent, Santa Clara, CA, USA)equipped with an electron impact ionization source (EI), programmable to 350 °C to enhance the signal intensity of high-boiling-point substances; a KQ-500E ultrasonic cleaner (Kunshan Ultrasonic Instrument Co., Ltd., Kunshan, China), ultrasonic cleaning frequency: 40 kHz; an Anke LXJ-IIB centrifuge (Shanghai Anting Scientific Instrument Factory, Shanghai, China), maximum speed: 5000 rpm (revolutions per minute), relative centrifugal force: 6000× *g*; and a microwave digestion instrument

MDS-8G (Shanghai Xinyi Microwave Chemical Technology Co., Ltd., Shanghai, China), microwave frequency: 2450 MHz.

### 2.3. Experimental Methods

#### 2.3.1. SEM-EDS

The samples of ink were collected from the detached woodblocks or scraped from the edges of the woodblocks. The samples' morphology was observed under SEM and the elemental composition of the samples was characterized using energy-dispersive X-ray spectroscopy (EDS). The testing conditions employed a high vacuum (60 pa) with an acceleration voltage of 1 kV.

#### 2.3.2. FTIR

A small sample of ink was scraped from the edge of the woodblock. A portion of 1–2 mg of this sample was mixed with 100–200 mg of dry KBr powder and thoroughly ground in an agate mortar to ensure even distribution of the sample within the KBr. A pressing plate was then created, with the thickness of the potassium bromide pressing plate being approximately 3 mm. Following this, the pressing plate was tested and characterized using FTIR. The testing mode was transmission, and the scanning spectrum range was 500–4000 $cm^{-1}$.

#### 2.3.3. GC/MS

The gas chromatograph was equipped with a DB-5MS column (30 m × 0.25 mm × 0.25 μm). The inlet temperature was set at 280 °C, with an initial temperature of 100 °C held for 2 min before ramping up to 280 °C at a rate of 6 °C/min. Helium gas flowed at a rate of 1.5 mL/min in splitless mode. Mass spectrometry utilized an electron impact ionization source with an ionization energy of 70 eV, scanning the range of 50 to 800 amu. The mass of the ink sample was measured, and ammonia was added to the sample. The sample was then subjected to ultrasonic extraction to remove the binder, and the upper layer of the extract was obtained by centrifugation. Protein purification was carried out using a C4 column, followed by microwave digestion in 6 mol/L hydrochloric acid to hydrolyze the proteins into amino acids, which were then dried under nitrogen protection. Subsequently, 40 μL of pyridine, 10 μL of derivatization reagent, and 2 μL of triethylamine were added to the sample, which was then derivatized in a 65 °C oven for 30 min before GC/MS analysis.

#### 2.3.4. Py-GC/MS

The pyrolysis temperature was set at 600 °C for 10 s, with an interface temperature of 300 °C connecting the injector and the chromatograph. The gas chromatograph was equipped with a DB-35MS column (30 m × 0.25 mm × 0.25 μm) with an inlet temperature of 280 °C. The initial temperature of the column oven was set at 40 °C, held for 3 min, then ramped up to 325 °C at a rate of 5 °C/min and held for 5 min. Helium gas flowed at a rate of 1 mL/min with a split ratio of 20:1. Mass spectrometry utilized an electron impact ionization source and a quadrupole mass detector to obtain the mass spectra, with an ionization voltage of 70 eV and a scanning range of 50 to 750 $m/z$ over a scanning time of 62 min at a speed of 2.12 scan/s. Prior to each experiment, several empty sample scans were performed until the baseline was stable. A small amount of ink sample was taken in a dedicated sample bottle for pyrolysis and then placed in a quartz lining tube in the pyrolysis reactor for testing. Each sample underwent 3 parallel tests. The separated compounds were identified using the NIST 08 mass spectrometry database.

## 3. Results and Discussion

### 3.1. Microscopic Morphology

Using a scanning electron microscope, the microstructures of the Qing dynasty Shuyede printed ink samples were observed, as shown in Figure 2. Both samples exhibited numerous particles of varying sizes with smooth edges. The particles were predominantly

spherical or ellipsoidal in shape, with significant aggregation observed. Many clustered particles were present, with some particles adhering together due to the binder's effect.

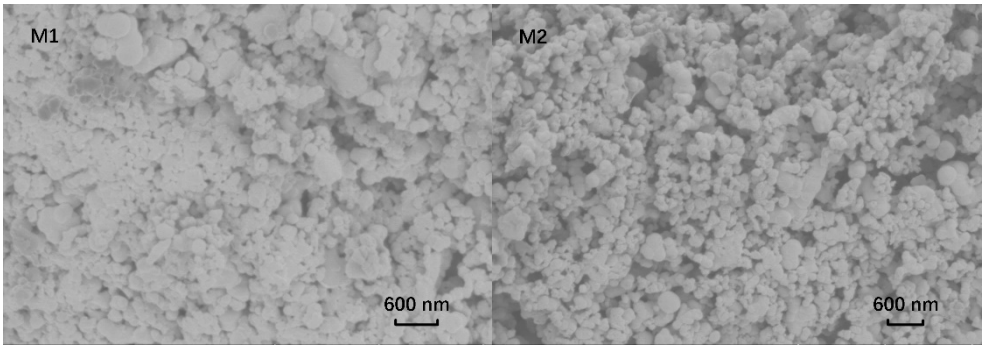



**Figure 2.** Scanning electron microscope images of the ink samples from the Shuyede printing woodblocks from the Qing dynasty.

Elemental analysis of the ink samples was conducted using energy-dispersive spectroscopy. As shown in Table 2, the elemental compositions of the two ink samples were generally similar. Apart from containing carbon (C) elements, they also included elements such as nitrogen (N), oxygen (O), sodium (Na), magnesium (Mg), aluminum (Al), silicon (Si), sulfur (S), potassium (K), and calcium (Ca). These elements are likely to have been derived from the binder and additives present in the ink.

**Table 2.** EDS mapping analysis results (wt%) of the ink samples from the Shuyede printing woodblocks from the Qing dynasty.

| Element | C | N | O | Na | Mg | Al | Si | S | Cl | K | Ca |
|---|---|---|---|---|---|---|---|---|---|---|---|
| M1 | 56 | 1 | 10 | 2 | 3 | 6 | 11 | 3 | 2 | 2 | 4 |
| M2 | 66 | 1 | 8 | 2 | 3 | 4 | 6 | 3 | 3 | 1 | 3 |

### *3.2. Fourier-Transform Infrared Spectroscopy Analysis of Ink*

Fourier-transform infrared spectroscopy was employed to analyze the samples of the Qing dynasty Shuyede printed ink, with results shown in Figure 3. The results of infrared spectroscopy analysis indicated that the primary constituents of the ink stain samples were soot and binder. The absorption peak near 1618 $cm^{-1}$ corresponded to the stretching vibration of the C=C bond in the benzene ring structure, and this was the main absorption peak for the soot material within the ink (either pine soot or oil soot) [19]. Both oil soot and pine soot contain certain amounts of carbon in oxidized forms (such as C–O, C=O, O–C=O), with the peak at 3416 $cm^{-1}$ corresponding to the stretching vibration of O–H. The peaks at 2922 $cm^{-1}$ and 2852 $cm^{-1}$ correspond to the symmetric and asymmetric stretching vibrations of C-H in methylene and methyl groups, respectively. The peak at 1384 $cm^{-1}$ corresponds to the asymmetric and symmetric vibrations of COO–, and the peaks at 1078 $cm^{-1}$ and 1034 $cm^{-1}$ correspond to the stretching vibrations of C–O, which are characteristic of various surface groups in pine soot ink and oil soot ink. The oil soot contained a higher number of various oxidized functional groups. In the figure, the infrared spectrum peak of M1 is higher than that of M2, which suggests that M1 is oil soot ink, and M2 is pine soot ink [10]. Additionally, the spectrum also exhibited characteristic bands of the protein amide group (–N(H) –C=O–), with the peak near 1653 $cm^{-1}$ corresponding to the stretching vibration of C=O, the peak near 1560 $cm^{-1}$ corresponding to the bending vibration of N-H, and the peak near 1420 $cm^{-1}$ corresponding to the stretching vibration of C–N, indicating that protein-based colloids had been added to the ink samples as binders [20].

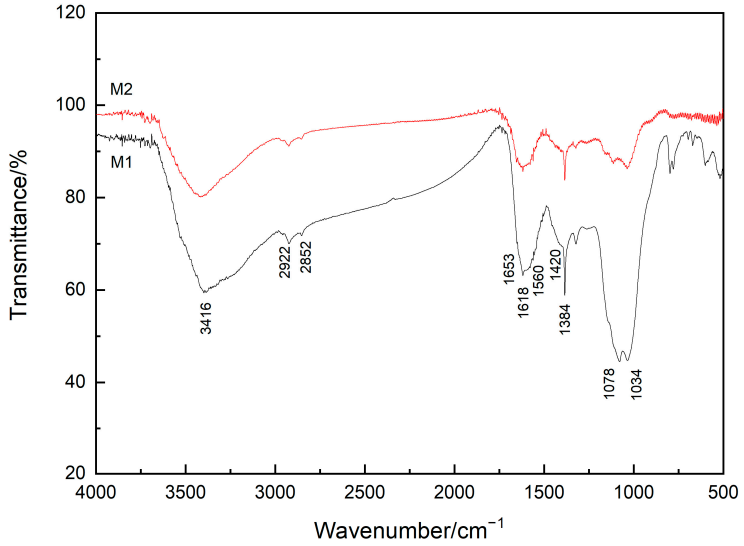



**Figure 3.** Infrared spectrogram of the ink samples from the Shuyede printing woodblocks from the Qing dynasty.

### *3.3. Amino Acid Analysis of Ink Binders*

To further analyze the types of protein binders in the printing and engraving inks of the Shuyede press in the Qing dynasty, amino acid analysis was performed on the samples using gas chromatography. The results are shown in Figure 4 and Table 3.

As shown in Figure 4 and Table 3, both M1 and M2 samples were analyzed to obtain 11 amino acids, namely alanine (Ala), glycine (Gly), valine (Val), leucine (Leu), isoleucine (Ile), serine (Ser), proline (Pro), phenylalanine (Phe), aspartic acid (Asp), glutamic acid (Glu), and hydroxyproline (Hyp). The content of hydroxyproline (Hyp) was 2.6% and 1.0%, respectively.

Preliminary research results indicated that hydroxyproline (Hyp) [21,22] is a characteristic amino acid of animal glue. It can be inferred that animal glue was the binding material in the two samples of Qing dynasty Shuyede printing and woodblock ink.

**Table 3.** Amino acid composition ratios (wt%) of the ink samples from the Shuyede printing woodblocks from the Qing dynasty.

| Amino Acid | M1 | M2 |
|---|---|---|
| Alanine (Ala) | 12.9 | 12.8 |
| Glycine (Gly) | 14.0 | 17.0 |
| Valine (Val) | 10.6 | 10.6 |
| Leucine (Leu) | 16.9 | 12.2 |
| Isoleucine (Ile) | 9.5 | 8.3 |
| Serine (Ser) | 9.3 | 10.5 |
| Proline (Pro) | 14.6 | 7.4 |
| Phenylalanine (Phe) | 3.8 | 5.0 |
| Aspartate (Asp) | 4.0 | 9.2 |
| Glutamate (Glu) | 1.8 | 6.0 |
| Hydroxyproline (Hyp) | 2.6 | 1.0 |

(Note: The detection limit of this analytical method is 0.24 μg; the quantification limit is 0.79 μg. Due to limited sample size and aging of the adhesive, the residual amount of protein substances in the sample was too low, and quantitative analysis of the detected amino acids could not be carried out.)

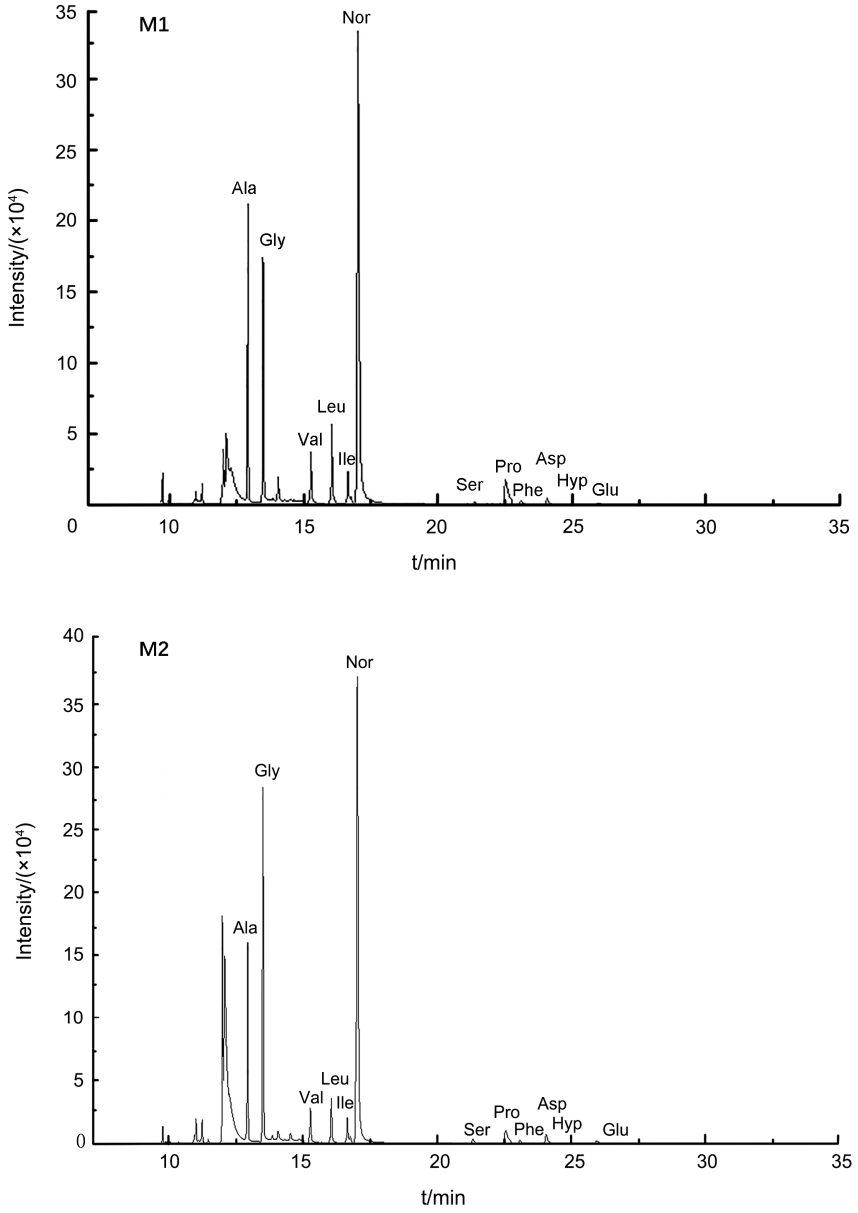



**Figure 4.** Amino acid analysis chromatograms of the ink samples from the Shuyede printing woodblocks from the Qing dynasty.

### *3.4. Pyrolysis Gas Chromatography–Mass Spectrometry Analysis of Ink*

According to the literature, Py-GC/MS has been successfully applied to the identification of pine soot ink and oil soot ink [20,23]. Therefore, in order to identify the types of ink used in woodblock printing in the Shuyede press during the Qing Dynasty, samples were analyzed by Py-GC/MS. The total ion flow diagram and main pyrolysis products of the Py-GC/MS analysis of the samples are shown in Figure 5 and Table 4, respectively.

According to the data, the main pyrolysis compounds in the ink samples of the Shuyede printing woodblocks from the Qing dynasty were divided into the following categories: (1) polycyclic aromatic hydrocarbons (PAHs) [24]: phenanthrene, fluoranthene, pyrene, benzo (a) anthracene, benzo [k] fluoranthene; (2) pyrrole substances: pyrrole, 2-methylpyrrole; (3) carbohydrates [25]: 1,6-dehydrated-β-D-glucopyranose; (4) aldehydes, ketones, and furan substances: furfural, 5-methylfurfural, 5-hydroxymethylfurfural, 2-cyclopentanone, 3-methylcyclopentane-1,2-dione, 2,3-dihydrobenzofuran; (5) phenolic substances: phenol, 4-methylphenol, 2-methoxy-4-ethylphenol, 2,6-dimethoxyphenol, 3-phenoxyphenol.

Among these, polycyclic aromatic hydrocarbons (PAHs) are the main pyrolysis products of soot in ink [24]. Pyrroles [26] are the characteristic pyrolysis products of animal glue in ink, which further confirms the amino acid analysis results. Carbohydrates (1,6-dehydrated-β-D-glucopyranose), aldehydes, ketones, and furans, as well as phenols, are pyrolysis products of cellulose, hemicellulose, and lignin, respectively. It is speculated that some wood chips were mixed in with the ink samples from the Shuyede printing woodblocks from the Qing dynasty.

According to the data organization and analysis of the pyrolysis products of smoke soot, polycyclic aromatic hydrocarbons (PAHs) in the ink samples of the Shuyede printing woodblocks from the Qing dynasty mainly included phenanthrene ($C_{14}H_{10}$), fluoranthene ($C_{16}H_{10}$), pyrene ($C_{16}H_{10}$), benzo [a] anthracene ($C_{18}H_{12}$), and benzo [k] fluoranthene ($C_{20}H_{12}$), labeled as S1–S5, with chemical structures shown in Figure 6.

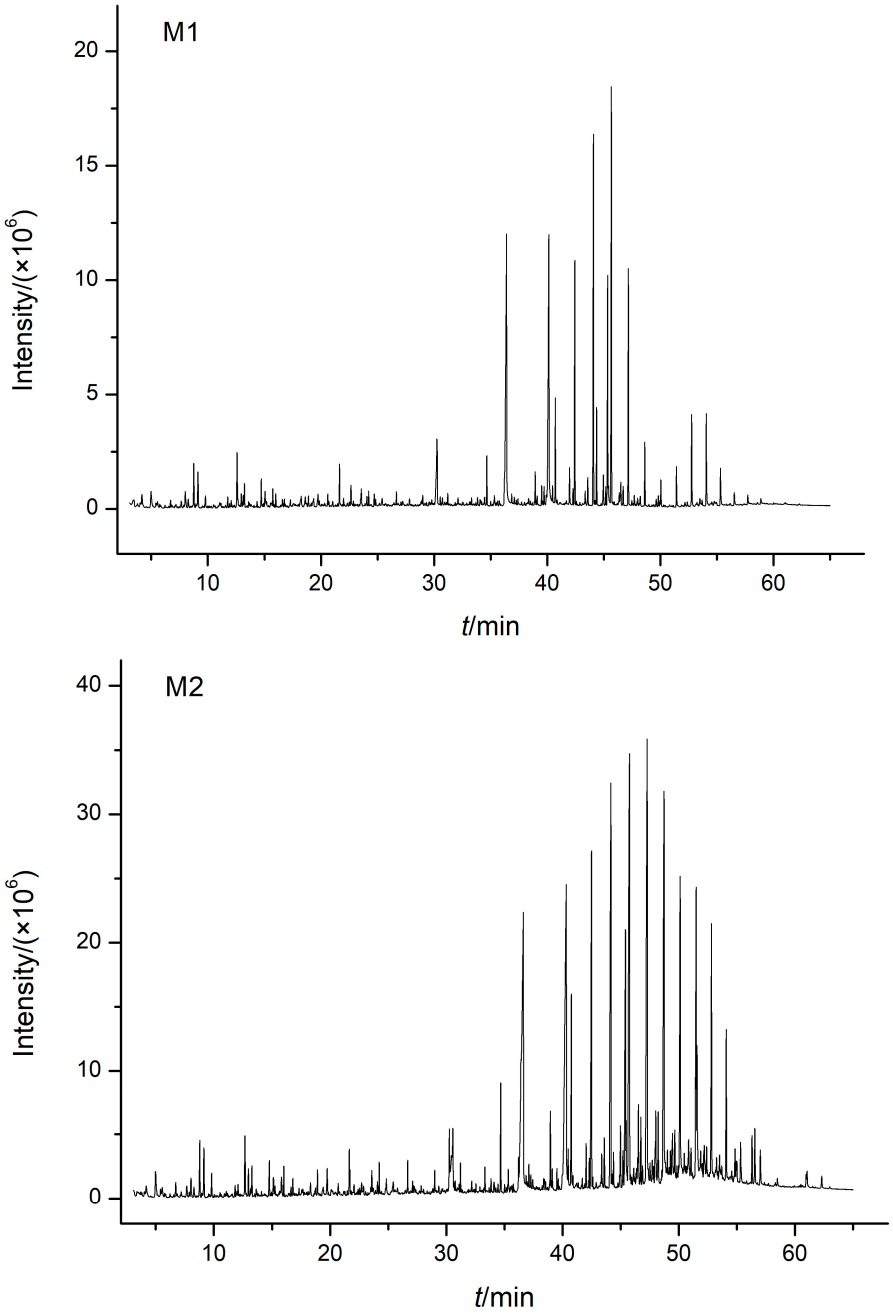



**Figure 5.** Total ion flow diagrams of the ink samples from the Shuyede printing woodblocks from the Qing dynasty.

**Table 4.** Characteristics of main pyrolysis products of the ink samples from the Shuyede printing woodblocks from the Qing Dynasty.

| Sample Number | Peak | Retention Time | Main Ions | Compound |
|---|---|---|---|---|
| M1 | 1 | 4.98 | 51, 65, 73, (91) | Toluene |
| | Py1 | 5.569 | 52, 55, 60, (67) | Pyrrole |
| | 2 | 8.004 | 54, 67, (84), 95 | 2-cyclopentyl cyclopentanone |
| | Py2 | 8.271 | 51, 53, (80), 81 | 2-Methylpyrrole |
| | 3 | 8.75 | 67, 95, (96) | Furfural |
| | 4 | 12.584 | 55, 65, 66, (94) | Phenol |
| | 5 | 13.236 | 55, 84, (110) | 5-Methylfurfural |
| | 6 | 15.058 | 55, 69, 107, 108, (112) | 3-Methylcyclopentane-1,2-dione |
| | 7 | 15.734 | 77, 79, (107), 108 | 4-Methylphenol |
| | Nap | 19.732 | 51102, (128) | Naphthalene |
| | 8 | 22.654 | 53, 69, (97), 126 | 5-hydroxymethylfurfural |
| | 9 | 23.566 | 77, 107, 135, (150) | 2-Methoxy-4-ethylphenol |
| | 10 | 30.25 | 57, (60), 73 | 1,6-Dehydrated-β-D-glucopyranose |
| | S1 | 36.209 | 76, 89, (178) | Phenanthrene |
| | S2 | 42.285 | 88, 101, (202) | Fluoranthene |
| | S3 | 43.581 | 88, 101, (202) | Pyrene |
| | S4 | 49.622 | 113, (228) | Benzo [a] anthracene |
| | S4 | 49.967 | 113, (228) | Benzo [a] anthracene |
| M2 | 1 | 4.98 | 65, (91), 92 | Toluene |
| | Py1 | 5.569 | 52, 55, 60, (67) | Pyrrole |
| | Py2 | 8.271 | 51, 53, (80), 81 | 2-Methylpyrrole |
| | 2 | 8.782 | 67, 95, (96) | Furfural |
| | 3 | 12.67 | 55, 65, 66, (94) | Phenol |
| | Nap | 19.765 | 51, 102, (128) | Naphthalene |
| | 4 | 30.557 | 57, (60), 73 | 1,6-Dehydrated-β-D-glucopyranose |
| | S1 | 36.228 | 76, 89, (178) | Phenanthrene |
| | S2 | 42.301 | 88, 101, (202) | Fluoranthene |
| | S3 | 43.597 | 88, 101, (202) | Pyrene |
| | S4 | 49.983 | 113, (228) | Benzo [a] anthracene |
| | S5 | 54.838 | 113, 126, (252) | Benzo [k] fluoranthene |
| | S5 | 56.299 | 113, 126, (252) | Benzo [k] fluoranthene |
| | S5 | 56.542 | 113, 126, (252) | Benzo [k] fluoranthene |
| | S5 | 57.014 | 113, 126, (252) | Benzo [k] fluoranthene |

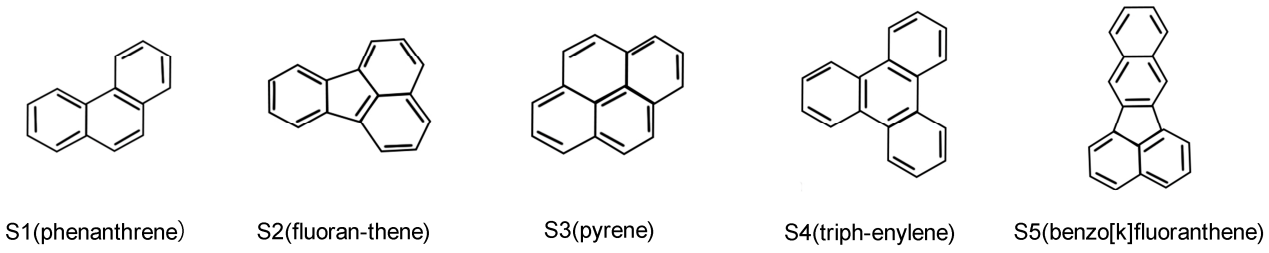



**Figure 6.** Chemical structure diagrams of polycyclic aromatic hydrocarbon compounds.

The relative content of polycyclic aromatic hydrocarbons (S1–S5) in the two samples was tested using a selective ion mode, and the selected ion chromatogram was extracted (Figure 7). The selected ions were S1 ($m/z$ 178), S2 ($m/z$ 202), S3 ($m/z$ 202), S4 ($m/z$ 228), and S5 ($m/z$ 252), and the relative content of the main polycyclic aromatic hydrocarbons (S1–S5) in the sample was calculated by integrating the peak area (Table 5).

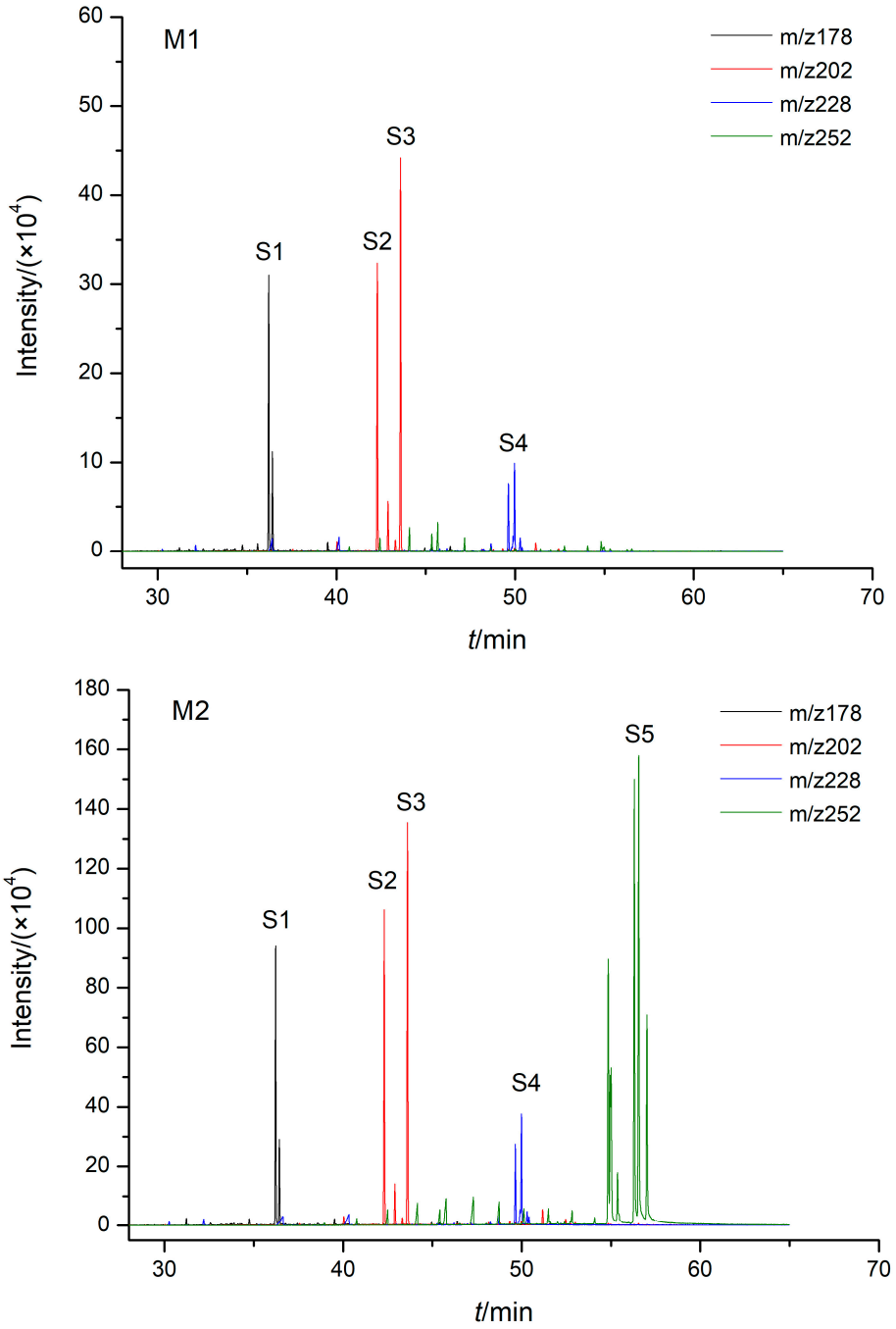



**Figure 7.** Selected ion chromatograms of the ink samples from the Shuyede printing woodblocks from the Qing dynasty.

**Table 5.** Relative content (%) of main polycyclic aromatic hydrocarbons of the ink samples from the Shuyede printing woodblocks from the Qing Dynasty.

| PAHs | M1 | M2 |
|---|---|---|
| S1 ($m/z$ 178) | 37.9 | 9.8 |
| S2 ($m/z$ 202) | 41.8 | 11.1 |
| S3 ($m/z$ 202) | 17.9 | 14.7 |
| S4 ($m/z$ 228) | 2.4 | 4.3 |
| S5 ($m/z$ 252) | - | 60.1 |

From Figure 7 and Table 5, it can be seen that the ink sample M1 from the Shuyede printing woodblocks from the Qing dynasty did not include detectable levels of benzo [k] fluoranthene (S5), suggesting that the S5 content of the sample was very low and had aged, while the relative content of S5 in the ink sample M2 was relatively high, at 60.1%. Preliminary research results indicate that the relative content of benzo [k] fluoranthene (S5) in polycyclic aromatic hydrocarbons can be used to distinguish between pine soot ink and oil soot ink. The relative content of S5 in pine soot ink is higher than that in oil soot ink. From this, it can be inferred that the printing ink used for sample M1 from the woodblock was oil soot ink, while the printing ink used for sample M2 from the woodblock was pine soot ink.

In addition, additives with special effects such as borneol, cloves, and camphor were often added in the ancient ink-making process to improve the durability, permeability, odor, color, and anti-corrosion and anti-decay properties of ink. No characteristic compounds related to additives were detected in the ink samples from the Shuyede printing woodblocks from the Qing dynasty [27].

## 4. Conclusions

Like ancient literature, woodblock printing is an important carrier of Chinese civilization, carrying the wisdom and memory of the working people of China. It is a valuable physical material for studying the history of Chinese classics and printing. The ink materials used in woodblock printing are closely related to the handwriting materials of ancient literature.

On this study, various analytical methods including scanning electron microscopy–energy-dispersive spectroscopy (SEM-EDS), Fourier-transform infrared spectroscopy (FTIR), gas chromatography–mass spectrometry (GC/MS), and pyrolysis gas chromatography–mass spectrometry (Py-GC/MS) were utilized to analyze the ink on the woodblock plates from the Shuyede press in the collection of Shandong Museum. It was observed that the two Shuyede woodblocks had different printing inks. The *DongLaiBoYi* woodblock was found to be printed using oil soot ink, while the *Mathematics* woodblock was printed using pine soot ink. These findings contribute to an enhanced understanding of traditional Chinese printing materials and techniques, providing references for the analysis and identification of archival printing ink. Furthermore, due to the different physical and chemical properties of pine soot ink and oil soot ink, this study aids in the selection of more targeted and appropriate methods for the conservation of woodblock artifacts based on the specific type of ink used.

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