

Study on the Material Evolution of Chinese Paper-Based Calligraphy and Painting and Ancient Papermaking Techniques

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Abstract: Papermaking, as one of China's most influential technological inventions, laid the foundation for the development of writing, painting, printing, and cultural transmission. This study traces the historical evolution of ancient Chinese papermaking and the development of paper used for calligraphy and painting, drawing upon archaeological evidence, historical texts, and fiber analysis. From the emergence of early hemp paper in the Han dynasty and Cai Lun's innovations, through the technical refinements of the Wei-Jin and Northern-Southern dynasties, to the large-scale production and diversification of the Sui-Tang period, Chinese papermaking underwent significant transformation. The Song-Yuan period marked the integration of papermaking with printing, leading to the expansion of bamboo and mixed-fiber papers, while the Ming-Qing period represented the zenith of craftsmanship, with numerous renowned papers achieving standardized quality. Across these stages, papermaking evolved from a utilitarian craft into an art form that embodied material, aesthetic, and cultural values. The study not only outlines the technological trajectory of papermaking but also provides a theoretical reference for the conservation and restoration of traditional paper-based artworks.

1. Introduction

Paper has long served as one of the most significant material substrates for Chinese painting and calligraphy, playing a decisive role in shaping both the visual expression of art and the preservation of cultural heritage. As one of the earliest fibrous sheet materials invented by humankind, paper not only revolutionized modes of cultural transmission but also provided an adaptable and refined medium through which Chinese artistic traditions flourished. The invention and continuous refinement of papermaking in China marked a technological and cultural breakthrough that profoundly influenced the history of world civilization.

Within the field of painting and calligraphy, paper is not merely a physical support but a

composite product of fiber science, manufacturing technique, and aesthetic sensibility. Its material properties—fiber composition, degree of refining, sheet formation, and post-processing—directly determine ink absorption, surface smoothness, tensile strength, and chromatic response. Variations in raw materials and papermaking methods across historical periods produced a diversity of textures and visual effects, forming distinctive traditions of artistic practice and conservation[1]. Consequently, the study of paper transcends technical analysis, revealing how craftsmanship and aesthetic ideals evolved in tandem with the broader socio-cultural context.

In the conservation and restoration of paper-based artworks, a scientific understanding of the material foundation and its historical evolution is indispensable. The microscopic structure and chemical stability of paper fibers provide critical evidence for diagnosing deterioration and designing preservation strategies. Meanwhile, traditional naming conventions, regional production characteristics, and historical documentation offer essential clues for identifying the provenance and authenticity of ancient works.

This chapter aims to examine the material characteristics and technological evolution of paper used in Chinese painting and calligraphy. It begins by discussing the definitions and structural features of paper, as well as the traditional nomenclature system that reflects its cultural significance. It then traces the historical development of papermaking from the Han to the Qing dynasties, outlining key innovations in raw materials and production techniques that shaped the typology of artistic papers. Finally, it summarizes the broader implications of papermaking for the development of Chinese painting and calligraphy, emphasizing its foundational role in both artistic creation and cultural preservation.

2. Material Basis of Paper Books and Calligraphy

2.1 Definition and Basic Characteristics of Paper

Paper, as one of the most important material carriers of human civilization, serves as a fundamental medium for calligraphy, painting, printing, and packaging. The conceptual understanding of “paper” varies across academic disciplines, with definitions reflecting both its material characteristics and the evolution of papermaking techniques [2].

The American paper historian Dard Hunter, in his seminal work *The History and Technique of an Ancient Craft*, offered a precise definition: paper is “a thin material made from plant fibers, deposited upon a smooth, porous mold.” He further argued that to qualify as true paper, three essential conditions must be met: the material must be composed of separated plant fibers beaten into pulp; the fibers must be dispersed in water and collected on a screen or mold that drains the water through its pores; and finally, the fibers must interlace to form a coherent sheet that is dried into a stable film [3]. Hunter’s definition accommodates regional and historical variations in papermaking technology and remains particularly relevant for the study of handmade papers. It also provides a scientific framework for analyzing ancient papers and traditional papermaking processes.

In China, paper historian Pan Jixing proposed a definition that emphasizes the technological process of papermaking. He noted that “traditionally, paper refers to a sheet-like material made from plant fibers that have been mechanically or chemically treated to produce relatively pure, dispersed fibers. When mixed with water, the pulp is poured over a porous mold, allowing water to drain while fibers interlock on the surface to form a wet layer. After drying, the fibers bond through hydrogen linkages to form a coherent sheet used for writing, printing, or packaging” [4]. Pan’s definition is both concise and comprehensive, applicable to both handmade and machine-made papers, while highlighting the physical property of paper as a cellulose-based structure formed by hydrogen bonding.

The basic process of papermaking includes the selection of plant fibers, impurity removal,

pulping, sheet formation, and drying. The strength of paper depends on hydrogen bonding among cellulose fibers rather than the use of adhesives. As a result, paper exhibits characteristic variations in strength during moisture cycles: the hydrogen bonds loosen and weaken when wet, but reform and recover strength upon drying. This structural property fundamentally determines the mechanical behavior and preservation characteristics of paper.

Historically, the concept of paper appeared early in Chinese literature. Xu Shen, in *Shuowen Jiezi*, defined paper as “zhi, xu yi ye,” where xu refers to the fibrous raw material and yi to the papermaking screen, thus implying the two essential components of papermaking. Modern lexicographical definitions, such as that in *Cihai*, describe paper as “a fibrous sheet product used for writing, printing, painting, or packaging, made through pulping, partial dehydration, pressing, and drying.” Such definitions, however, are influenced by modern industrial papermaking and may not fully apply to ancient paper, which was often produced without pressing or high-temperature drying.

From the perspective of traditional handmade paper production, Dai Jiazhang proposed that “paper should be defined as a thin sheet suitable for writing, made from plant fibers that have undergone cutting, boiling, pounding, and sheet formation, with or without additives, and finally dried to shape.” Wang Juhua and other scholars offered similar definitions, emphasizing processes such as fiber cutting, boiling, rinsing, pounding, molding on a screen, and drying to form a fibrous film [5]. These definitions, grounded in craft-based practice, are particularly suited to the study of traditional handmade paper, though an excessive focus on features such as visible screen marks or fiber cutting may exclude certain ethnic or folk papermaking traditions.

Synthesizing both domestic and international scholarship, the essential characteristics of paper can be summarized as follows: the raw material must be plant fiber; the fibers must be fully separated and dispersed as individual units; and through water suspension, screen formation, and drying, they must interlace to form a thin, cohesive sheet with tensile strength. The length and entanglement density of the fibers determine the paper’s durability and tensile properties—longer and more intertwined fibers result in stronger, tougher paper. This conceptual framework emphasizes that paper is not only a physical material but also a cultural medium—its structural and chemical properties underpin its role in human artistic and intellectual expression.

The definition of paper thus encompasses material, technological, and structural dimensions. In the study of ancient handmade paper, it is advisable to adhere to the definitions proposed by Hunter and Pan Jixing, which stress the importance of plant fibers and the processes of dispersion and formation, rather than the mechanical procedures of modern industrial papermaking. Fundamentally, paper is a thin fibrous material whose structural integrity ensures both its mechanical strength and its enduring value as a medium for writing, painting, printing, and cultural transmission.

2.2 Traditional Naming Methods of Handmade Paper

In ancient China, the understanding and classification of paper were largely based on empirical knowledge and customary usage rather than on a strict differentiation of fiber sources. Papers were commonly named according to their place of production, associated historical figures, color, intended function, or distinctive manufacturing characteristics. These naming conventions not only reflect the cultural connotations and social circulation of paper but also provide valuable evidence for tracing ancient paper varieties and understanding their historical contexts of use. The traditional nomenclature of handmade paper exhibits remarkable diversity and can be broadly categorized into ten main types [6]:

1) **Named after historical figures**, such as Caihou zhi (Paper of Lord Cai), Zuobo zhi (Paper of Master Zuo), Xuetao jian (Stationery of Xue Tao), and Xie Gong jian (Stationery of Xie Gong);

2) **Named after production regions**, such as xuanzhi (from xuanzhou, anhui), shuzhi (from

sichuan), and chizhi (from chizhou, anhui);

3) **Named after raw materials**, such as ma zhi (hemp paper), shupi zhi (bark paper), teng zhi (vine paper), cao zhi (grass paper), and zhu zhi (bamboo paper);

4) **Named after color**, such as qing zhi (blue paper), dahong zhi or hongmei zhi (bright red paper), huang biao zhi (yellow ceremonial paper), and se jian (colored stationery);

5) **Named by appellation or honorific title**, such as Chushu Xiansheng (Master Chu Paper), Hao Ji Hou, and Taishi Lianzhi (Grand Historian Paper);

6) **Named after physical or surface properties**, such as yinghuang zhi (hard yellow paper), fenla jian (powder-waxed stationery), shuiwen zhi (water-pattern paper), and banshiwen zhi (stone-textured paper);

7) **Named by size or format, such as pi zhi (bundle paper)**, sichi dan (four-foot single sheet), and ping bachi (eight-foot scroll paper);

8) **Named after manufacturing process, such as tula zhi (wax-coated paper)**, yuban xuan (jade-finished Xuanzhi), and hupi xuan (tiger-skin patterned Xuanzhi);

9) **Named after function or use**, such as chuangu zhi (window paper), bianpao zhi (firecracker paper), baochao zhi (paper money), yusan zhi (umbrella paper), zhangce zhi (account book paper), and qiyue zhi (contract paper);

10) **Miscellaneous or unique names**, such as Yaohuang zhi, Erze zhi, and Yueguang zhi (Moonlight Paper).

These traditional naming systems illustrate the deep interconnection between material production, cultural symbolism, and functional utility in the history of Chinese papermaking, offering a vital framework for the modern study of historical paper typology and its role in art and documentation.

3. The Historical Development of Papermaking and Painting Paper in Ancient China

China is universally recognized as the birthplace of papermaking, a technological innovation that not only revolutionized the transmission of culture but also provided the fundamental material basis for painting, printing, and archival preservation. Since the Western Han dynasty, the history of Chinese paper has evolved from primitive prototypes to highly refined handmade papers, forming a continuous and richly diverse developmental trajectory. This evolution reflects not only technical sophistication but also distinctive regional characteristics and material selection patterns. Through fiber analysis of excavated artifacts and systematic study of historical documents, the technological and functional evolution of ancient Chinese paper can now be reconstructed with increasing clarity.

3.1 The Han Dynasty

The Han dynasty marked the formative period in the invention and early development of paper. During the Western Han, hemp fibers served as the primary raw material. The resulting papers were coarse, loosely interwoven, and relatively low in whiteness and smoothness. Most examples were used for writing, though their surfaces lacked the refinement and tensile strength of later periods.

One of the earliest known paper specimens is the Ba Qiao paper, unearthed in 1957 at the Baqiao Brick and Tile Factory site near Xi'an. Microscopic analysis revealed thick, poorly refined fiber bundles, uneven distribution, and low whiteness, with limited fibrillation—characteristics that identify it as a primitive form of paper [5]. Despite its rough texture, this material exhibits the essential structural features of true paper and is among the earliest examples known worldwide.

By contrast, the jinguan paper, discovered in 1977 at the jianshui jinguan site in gansu, shows more advanced fibrous characteristics—tightly interlaced fibers, uniform distribution, and higher whiteness—fully meeting the technical criteria of paper. Similarly, the Fangmatan paper, excavated at Tianshui, Gansu, is smooth and compact, with visible ink drawings of mountains and rivers. It is

regarded as the world's earliest known paper-based map [5]. These archaeological discoveries indicate that the prototype of paper had already matured by the Western Han, laying the groundwork for Cai Lun's technological reforms in the Eastern Han.

Cai Lun's improvements represented a watershed in the history of papermaking. He was the first to employ chu bark (*Broussonetia papyrifera*) as a fiber source, moving beyond recycled textiles and rope fragments. Extracting bast fibers from bark required more complex processing, marking a major technological breakthrough. Cai Lun also refined the use of hemp fibers from fishing nets and standardized production methods, significantly improving paper quality. Another of his key contributions was the formal proposal to popularize papermaking and the use of paper, which received imperial approval, leading to widespread adoption across the empire.

According to Pan Jixing's *History of Chinese Papermaking*, experimental reconstructions suggest that Han-dynasty papermaking involved twelve sequential steps: soaking, cutting, washing, alkaline treatment with plant ash, boiling, washing, pounding, washing again, pulping, sheet forming, drying, and peeling [4]. Only through this rigorous process could papers of the Jinguan and Fangmatan type be produced. Following Cai Lun's refinements in the Eastern Han, the process became more precise, yielding smoother, stronger, and more durable paper, which provided a stable foundation for later artistic and documentary applications.

3.2 The Wei, Jin, and Northern–Southern Dynasties

During the Wei, Jin, and Northern–Southern Dynasties, papermaking advanced in both material selection and processing techniques. In addition to hemp and chu bark, papermakers began using fibers from vines, mulberry bark, and *Daphne* species, which increased both the quantity and quality of paper production. Improvements in pulping, pounding, rinsing, and boiling techniques led to finer fiber dispersion, while innovations such as gelatin sizing and the use of patterned screen molds enhanced uniformity and surface quality. As a result, papers of this period were thinner, whiter, and more refined than those of the Han, with reduced fiber clumping and distinct screen patterns.

Paper gradually replaced silk, bamboo, and wooden slips as the principal writing medium. From the Eastern Jin onward, the wide availability of smooth, flexible, and durable paper led to the decline of traditional silk and bamboo manuscripts, ushering in a new era in written culture. Historical records note the imperial decree mandating “paper in place of bamboo slips,” accelerating the nationwide dissemination of paper use [7].

Secondary finishing processes became crucial for enhancing paper performance. Techniques such as coating, burnishing, sizing, and dyeing improved surface smoothness, tensile strength, and ink absorption. Yellow-dyed paper, produced with *Phellodendron amurense* bark, symbolized solemnity and sanctity and was often used for official documents and scroll mounting—indeed, the Chinese term *zhuanghuang* (mounting) originates from this practice. Coating and polishing not only filled inter-fiber gaps but also increased fiber cohesion, making paper more suitable for writing and painting.

The Jin dynasty produced several renowned papers. Celi paper, made from seaweed fibers, displayed interwoven vertical and diagonal patterns and was valued for its soft, thick texture, commonly used in calligraphy. The *Shiyi ji* records that Emperor Wu of the Jin rewarded the scholar Zhang Hua with ten thousand sheets of Celi paper for his *Bowuzhi*, demonstrating the prestige of this paper type. During the Northern and Southern Dynasties, silk cocoon paper (also called *jianzhi*), a blend of silk and hemp fibers, was prized for its thickness and durability. Tradition holds that Wang Xizhi used this type of paper for the Preface to the Orchid Pavilion, though scholarly consensus remains inconclusive regarding its precise composition.

Another significant variety, Shan vine paper, was produced in the Shanxi region from young vine fibers. It was known for its whiteness, smoothness, and excellent ink receptivity but eventually disappeared by the Tang–Song period due to overharvesting, serving as an early cautionary tale of unsustainable resource use [8]. Huangma paper, developed by the Daoist Ge Hong, combined hemp fibers with *Phellodendron* extract. Though coarse and odorous, it was widely used in temples and government offices.

3.3 The Sui, Tang, and Five Dynasties Periods: The First Flourishing Age of Papermaking

The Sui, Tang, and Five Dynasties periods marked the first major peak in the technological and practical development of Chinese papermaking. During this era, paper evolved from a mere writing medium into a versatile material for painting, mounting, printing, and rubbing, and specialized paper types for artistic purposes began to emerge. The expansion of cultural production and religious activities stimulated large-scale papermaking, sharply increasing demand and driving both technological innovation and diversification of raw materials.

In addition to traditional bast fibers such as mulberry (*Morus alba*), *Broussonetia papyrifera*, and hemp, a wide variety of fibers—including vines, *Daphne* bark, *Hibiscus mutabilis*, and bamboo—were introduced. Pulping and sheet-forming techniques reached new levels of refinement, with bamboo screens as fine as 0.05 cm in spacing [9]. The addition of herbal additives improved pulp suspension and sheet formation, enhancing fiber uniformity and production efficiency.

While unprocessed “raw paper” (*shengzhi*) remained common for writing, numerous secondary processing techniques—sizing, waxing, coating, dyeing, embossing, “wine polishing,” and burnishing—were widely developed, giving rise to a rich variety of papers. Representative processed papers included *yinghuang zhi* (hard yellow paper), waxed decorative papers (*fenla jian*), Xue Tao paper, and *Chengxintang* paper. The latter, named after the “Hall of Pure Mind” (*Chengxintang*) of Southern Tang Emperor Li Jing, was made from paper mulberry bark pulped in ice water during winter, producing an exceptionally white and smooth sheet that became an imperial-grade material emulated for centuries.

Tang-dynasty papermaking also yielded an abundance of regional varieties. Paper mulberry paper (*chupi zhi*), soft and absorbent, became a favored medium for writing and painting—seen in surviving works such as Mi Fu’s *Poems on the Qiaoxi River*. Rattan paper (*zhui zhi*), made from vine fibers, was labor-intensive but durable and smooth. Waxed and powder papers were developed further into decorative *xuanjian* for calligraphy and printing. Fish-egg paper (*yuzijian*) featured raised dot patterns, while gauze paper (*luowen zhi*) incorporated patterned bamboo screens, creating translucent grid designs suited to painting and mounting. Other celebrated papers included Goryeo paper—white, firm, and made from cotton and cocoon fibers—and Xue Tao’s pink paper from hibiscus bark, used for poetry. The Southern Tang’s *Chengxintang* paper, made from Huizhou’s mulberry fibers, was so thin and lustrous that it remained prized by imperial courts and literati for generations [9].

3.4 The Song and Yuan Dynasties: The Second Flourishing Age

The Song and Yuan dynasties represent the second golden era of papermaking in China. With the widespread adoption of woodblock and movable-type printing, demand for paper—especially for books, paintings, and calligraphy—rose dramatically. Technical progress during this period was marked by advancements in raw materials, pulping methods, and product diversification.

Three main innovations characterized Song–Yuan papermaking: (1) the widespread use of water-powered hammers, which refined fiber pulping; (2) the introduction of herbal paper additives to improve pulp suspension and sheet evenness, simplifying drying and separation; and (3) the

emergence of mixed-fiber papers, combining long bast fibers with shorter bamboo or grass fibers to balance strength and smoothness.

Paper types became increasingly specialized: bamboo paper (zhuzhi), soft and absorbent, became the standard for printing and daily use; bast-fiber papers (pizhi) were preferred for calligraphy and official documents; hemp papers declined due to limited supply, surviving mainly in northern regions.

Processed papers such as Biyunjian, Chunshuzui jian, Jinhua jian, and Guanyin paper continued Tang-dynasty traditions while incorporating new decorative techniques [10]. Bamboo paper, produced from young bamboo culms, was soft yet durable, with excellent ink absorption. Cotton-fiber paper (mianzhi), derived from *Broussonetia* bark, was dense and flexible with silk-like texture. Yuan book paper (yuanshuzhi), made from *Phyllostachys pubescens* in Fuyang, featured clear screen marks and was used for practice calligraphy and ritual manuscripts. Mulberry-bark paper from northern regions, thin and even, was favored for scripture copying and painting. Imitation Chengxintang paper, recreated by Song official Pan Su in Huizhou, preserved the elegance of its Tang prototype and was treasured by scholars. Jinsu Mountain Sutra paper, produced for Buddhist temples, displayed yellowish wax tones and mottled textures, later adopted for mounting precious scrolls [11].

3.5 The Ming and Qing Dynasties: The Zenith of Traditional Papermaking

The Ming and Qing dynasties witnessed the zenith of traditional handmade papermaking in China. Regional specialization was pronounced: southern regions focused on bamboo paper production, while northern workshops emphasized hemp, and bast-fiber papers flourished nationwide. A multitude of renowned papers emerged—white cotton paper, Xuande paper from Jiangxi, and Jing County paper (later known as xuan paper) from Anhui—each representing a pinnacle of craftsmanship [12–17].

White cotton paper was smooth, bright, and durable, ideal for calligraphy. Xuande paper, a refined bast-fiber product comprising seventy-two production steps, served as an imperial tribute paper. Jing County paper, originally made from *Pteroceltis tatarinowii* bark and rice straw, evolved during the late Ming to mid-Qing period into xuan paper, the most celebrated medium for painting and calligraphy.

By this time, the paper industry had formed a fully developed system of raw (shengzhi) and processed (shuzhi) papers, with standardized procedures and stable material sources. Techniques such as gilding, coloring, waxing, and embossing reached artistic sophistication. Decorative and luxury papers—gold-sprinkled paper, flowered paper, sheep-brain paper, among others—reflected both imitation of earlier traditions and creative innovation.

Distinctive papers from the Ming era included bang paper (used for imperial announcements), jade-plate xuan (multi-layered, luminous paper suited for albums and fans), and sheep-brain paper (made with sheep brain paste and ink soot for scripture copying) [12–15, 18]. During the Qing dynasty, gold-painted decorative papers flourished, featuring gold or vermilion patterns on xuan or bast-fiber bases. These luxurious materials, employed for both courtly and civilian uses, epitomized the technical and aesthetic culmination of traditional Chinese papermaking [17].

4. Conclusions

In summary, the development of ancient Chinese papermaking technology exhibits distinct chronological stages. During the Western and Eastern Han dynasties, the rudimentary form of paper emerged, and Cai Lun's technical innovations laid the foundation for its widespread use. In the Wei, Jin, and Northern–Southern Dynasties, paper gradually replaced bamboo slips and silk as the

dominant writing medium, accompanied by the rise of secondary processing techniques. The Sui, Tang, and Five Dynasties period marked the first golden age of papermaking, characterized by diversified uses and large-scale production. In the Song and Yuan dynasties, the flourishing of printing technology spurred further industrial expansion, leading to the prominence of bamboo paper and the introduction of mixed-fiber varieties. By the Ming and Qing dynasties, papermaking reached its peak: production systems matured, numerous renowned papers appeared, and craftsmanship achieved unparalleled refinement.

Throughout these historical phases, continuous technological innovation not only satisfied the evolving needs of writing, painting, and printing but also provided the essential material foundation for the preservation and transmission of Chinese culture. Archaeological discoveries, historical literature, and fiber analyses together offer scientific evidence for understanding the evolution of ancient papermaking, while also providing valuable references for the restoration of paper-based artworks and the study of traditional craftsmanship.

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