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# A Tale of Papermaking along the Silk Road

**Abstract:** This study is a tale of the early history of papermaking in the Chinese borderlands as perceived through the materials that compose the manuscripts discovered in Central Asia. The manuscripts and printed books on paper excavated from archaeological sites in the ancient Silk Road kingdoms of Chinese Central Asia were examined for the raw materials used in their manufacture and the technology behind their production. The data retrieved by material analysis revealed the materials used for making the books, and the way that the materials have evolved with technological innovation. A wide range of types and qualities of paper, when interpreted chronologically according to dates included in the manuscripts, contributed to the timeline of the early history of paper.

## 1 Central Asian manuscripts as repository of early paper

Ideas relating to the history of paper began to change at the beginning of the twentieth century, when archaeological excavations revealed vast new collections that were brought to Europe by, among others, Aurel Stein and Paul Pelliot. Many authors have described the complex history of the acquisition of these manuscripts. This is done especially vividly by Peter Hopkirk in *Foreign Devils on the Silk Road* and by Craig Childs in *Finders Keepers. A Tale of Archaeological Plunder and Obsession*.<sup>1</sup> China considers this plundering of its treasures the archaeological crime of the century. The same people who were considered great explorers by the West were referred to as thieves and fortune-hunters by official Chinese authorities. From whatever perspective, this was a time of immense archaeological richness and colonial freedom for Western powers.

These extensive collections of manuscripts and books printed on paper, which were excavated from archaeological sites in the ancient Silk Road kingdoms of Chinese Central Asia and from a hidden library cave to east of the Gobi Desert, are the earliest repositories of extant paper that bear witness to the early history of papermaking. These manuscripts are now dispersed among collections

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<sup>1</sup> See Hopkirk 1980 and Childs 2013, 119–131.

in Europe and Asia, and they have created new opportunities to review the history of paper. There are vast collections of manuscripts available for research: Britain holds a collection of about 50,000 manuscripts, paintings, and artefacts from Chinese Central Asia, as well as thousands of historical photographs, mostly from the first three Central Asian expeditions led by Stein.<sup>2</sup> Germany holds a collection of c. 40,000 fragments of text, and thousands of frescos and other artefacts yielded by four German expeditions to Turfan led by Grünwedel and Le Coq. France holds a collection of c. 30,000 manuscripts brought back by Pelliot, which also holds the entire collection of Nouette's photographs of the expedition and Pelliot's diaries and other archives. Japanese and Russian collections amount to c. 20,000 manuscripts each, and the Dunhuang materials in China amount to around 16,000 items. These vast collections that preserve the archives of early paper in Central Asia are available for study.

Dated between the third and thirteenth centuries CE, the extant manuscripts were written in over twenty languages and scripts, including those of the empires and kingdoms on the periphery of Central Asia during this period: Chinese, Tibetan, Iranian, Indian, and Turkic. The oldest paper manuscripts available for study are Sanskrit and Tocharian manuscripts found in Kucha and dated between the third and sixth centuries CE. At that time, paper was used for manuscripts that were written in Sanskrit or Khotanese, dated approximately between the fourth and the eighth centuries CE, and found in Khotan. By the fifth century, paper manuscripts were produced in Dunhuang, and this collection contains written and printed texts in Chinese, Tibetan, Khotanese, and Turkic, dated between the fifth and tenth centuries. Another repository of old paper from Central Asia is the Turfan collection in Chinese, Tibetan, Turkic, and Syriac and dated between the ninth and thirteenth centuries.

These manuscripts are often imprecisely dated with the exception of the group of Chinese manuscripts fortuitously fixed in time by dates given in colophons.<sup>3</sup> Further manuscripts, however, may also be fixed in time and place by other information, such as the names of specific people and places, or episodes associated with historical dates. Information regarding provenance derives from the archaeological contexts (all of the Silk Road period) in which manuscripts

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<sup>2</sup> See *British collections: Contents and Access*, International Dunhuang Project website <[http://idp.bl.uk/pages/collections\\_en.a4d#2](http://idp.bl.uk/pages/collections_en.a4d#2)> (accessed on 2 Oct. 2020).

<sup>3</sup> In 1919 Lionel Giles, newly appointed keeper in the Department of Oriental Printed Books and Manuscripts, undertook the compilation work, and between 1935 and 1944 he published a series of articles in the *Bulletin of the School of Oriental Studies* which formed a chronological list of dated manuscripts from Stein's collection (see Giles 1935, 1937, 1940, 1943).

were found, including Buddhist stupas, military forts, residential and official buildings, rubbish heaps, and tombs. The dated manuscripts allowed us to correlate technological and scientific data with the dates included in their colophons. The dated manuscripts were thus especially useful in reconstructing the time-line of paper history. To make sure, however, that my results are not limited to this group of manuscripts, I also studied undated manuscripts.

With respect to great numbers of books and large collections of manuscripts from along the Silk Road, it is difficult to pinpoint when a group of manuscripts is sufficiently large to create historically valid results. Since Julius von Wiesner's time at the beginning of twentieth century, scholars have managed to subject approximately 1500 manuscripts to fibre analysis.<sup>4</sup> Statistically it is probably still too few, though sufficiently large to complete a history of paper with a great deal of valuable information. This is significant in comparison to the scarcity and vagueness of information in the written sources.

## 2 Evidence of papermaking technologies along the Silk Road

Technology, the sum of techniques, skills, methods, and processes used in the production of paper, may also be understood to be an aspect of social and cultural transmission through time and space. The paper, thread, ink, pigments, and other constituent parts of the Silk Road manuscripts and printed books derive from different and often distant centres of production. The textiles that are found in the same archaeological contexts as the manuscripts and that in some cases form an integral part of them, such as the silk ties used to bind scrolls, the silk book covers, and the manuscripts written on silk, are similarly diverse, displaying a variety of materials, weaves, patterns, and pigments. Material culture, such as extant collections of manuscripts, is thus an ideal source for the study of technological developments such as the mass-production of paper, inks, pigments, and textiles, but the scientific analysis that has been carried out on these materials thus far has been drawn from small samples that cannot be considered fully representative. A recent study has shown that there is the potential for understanding cultural, technological, and religious

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<sup>4</sup> Julius von Wiesner was a pioneer of material analysis applied to the Silk Road manuscripts; see von Wiesner 1902 and 1903. For the history of fibre analysis of this early material, see Helman-Ważny 2020, 341–366.

transmission and interaction across the Silk Road through combining textual research with paper and pigment analysis.<sup>5</sup>

The development of mass-production in papermaking across the Silk Road in the first millennium CE constitutes one of the most important technological developments of the era.<sup>6</sup> The rise of these Central Asian trade routes coincided with the Han dynasty (206 BCE–220 CE) in China and with the appearance of paper as a new writing material (Fig. 1). Many commodities other than silk were traded along the Silk Roads, including paper. Of all the precious goods traded along these routes, silk was perhaps the most remarkable for the people of the West;<sup>7</sup> paper, on the other hand, was poorly understood until the sixth or seventh century of the first millennium. The technological development of paper, however, may have been closely linked to the trade in silk, as the increasing development of silk production along the Silk Roads brought about the establishment of papermaking workshops, since mulberry trees cultivated for silk production in the villages and oases of Central Asia could also be used for making paper.



**Fig. 1:** The Silk Road at the time of the origin and early paper. Map drawn by Dorota Helman and Olga Ważny.

<sup>5</sup> Van Schaik, Helman-Wazny and Nöller 2015.

<sup>6</sup> See Hansen 2016 for an overview of the Silk Road civilizations and trade.

<sup>7</sup> Frye 1996, 154.

Essentially, no comprehensive attempt has yet been made to understand the complexity, spread, and modes of change of the early papermaking technologies. We only have fragmentary evidence which has yet to show the whole picture. The physical nature of paper, textile and book, its full meaning and value, as well as the way technologies spread in ancient and medieval Asia are less thoroughly explored. Most of the information we have is retrieved for large, known centres of paper production, usually from Chinese, Korean, or Japanese sources.<sup>8</sup> Textual sources were commonly prioritized despite the fact that they clearly cannot provide conclusive historical evidence for the origins and dissemination of papermaking, weaving, printing, or other technologies related to book production. Archaeological and material evidence has recently gained in importance.

We know that these technologies were transmitted along the major trade routes, with papermaking and printing developing first in Asia during this period before their transmission to Europe. Aside from this very general statement, however, we know little about the way this transmission occurred. The adoption of these technologies in specific areas was uneven and dependent on a variety of factors, including long-distance trade, the availability of local materials, and cultural contexts, especially those related to religion.

Because we have an unclear knowledge of the driving forces behind the development of the technologies of the book, there is a need for an investigation into the relationships between the development of technologies, religion (especially Buddhism), and different linguistic cultures along the Silk Road. Among textual sources, many Buddhist scriptures encourage the reader to make physical copies of texts, which suggests that religious ideology served as a driving force behind the development of technology. The copies of scripture were made for the sake of religious merit, ensuring a better rebirth and future lives, as well as for the purpose of providing protection against various evils in this life. Passages from such texts could be copied and worn as amulets to protect the body, or they could be put inside statues or hoisted into the air as flags to protect the state. Buddhism, in particular, has been a key factor in the social and economic dynamics that drove the development of papermaking technologies in Asia,<sup>9</sup>

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<sup>8</sup> Tsien 1973, 1985, 2004; Hunter 1932, 1978; Pan 1981, 1998; Rischel 1985, 2004.

<sup>9</sup> Tsien 2004.

with the phenomenon of mass printing in particular being inspired by Buddhist ideas of the merit of scriptural reproduction.<sup>10</sup>

### 3 Material and methods

The visual appearance of paper is affected by the type of raw material used in its manufacture, the technology behind its production, and the tools used, as well as by the preparation of the leaves during the production of the book. Some of this evidence was either immediately visible or could be revealed through a variety of scientific analyses.<sup>11</sup>

Between 2005 and 2014, I studied a total of 350 manuscripts selected from the Dunhuang collections in the British Library in London, the National Library of France in Paris (Bibliothèque nationale de France), the Institute of Oriental Manuscripts in St. Petersburg (Институт восточных рукописей Российской академии наук) and from the Turfan collection in the Berlin Brandenburg Academy of Sciences (Die Berlin-Brandenburgische Akademie der Wissenschaften) and the Berlin State Library (Staatsbibliothek zu Berlin). My work initially focused on Chinese manuscripts found along the Silk Road and then expanded to include other manuscripts, such as Tibetan, Uighur, Sogdian, Tocharian, and Sanskrit. In these manuscripts I studied the raw materials, the various fibres, and the plants from which they derive. I then looked at other aspects of the papermaking process which influence the nature of the resulting paper, such as the degree of fibre blending, the type of papermaking mould used, and the preparation of the paper surface before a drawing, calligraphy, or a print was set upon it. A study of the various materials and methods provides us with a basis from which we can then begin to interpret and categorize the many ways these papers were made and used.

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<sup>10</sup> The importance of the ‘cult of the book’ in Buddhism of different regions has been addressed by many authors: see, for example: Schopen 1975; Kornicki 1998; Schaeffer 2009; Apple 2014; Diemberger et al 2014.

<sup>11</sup> Details on the scientific methodology used are to be found in the following articles: Helman-Ważny and van Schaik 2013, 720–721; Helman-Ważny 2016, 131–132; Durkin-Meisterernst et al 2016, 8.

### 3.1 Raw materials of Central Asian manuscripts

There is a wide range of types and qualities of paper found in the aforementioned manuscripts from Central Asia. Paper of recycled textile fibres from rags and paper of new bast fibres were both identified (Figs 2 and 3). Rag paper was most typically composed of hemp and ramie fibres in differing proportions, sometimes additionally mixed with scarce amounts of other fibres, such as paper mulberry/mulberry (*Broussonetia* or *Morus* sp.), flax, jute, silk, wool, or cotton. Manuscripts from the Dunhuang collection notably contained ramie- and hemp-rag fibres with an admixture of jute, flax, and silk, while in Turfan the same rag-fibre paper contained an admixture of cotton and wool. These additions may be used as a marker of particular areas, or time of use, if confirmed by future analysis.

The Tocharian manuscripts studied, probably the earliest dated, were made almost exclusively of rag paper. The pure mulberry fibres were in the minority in the group of Tocharian and Sanskrit manuscripts. Chinese manuscripts dated to the fifth and sixth centuries CE are almost exclusively on rag papers, and only a few manuscripts on rag paper are dated to between the seventh and ninth centuries, while the number of rag-paper manuscripts increases in the tenth century.<sup>12</sup> Similar results were obtained by Anna-Grethe Rischel and more recently by Lucas Llopis and Léon-Bavi Vilmont. Rischel's examination of Loulan manuscripts revealed that the third-century Loulan papers are a mixture of recycled hemp, ramie, linen, and mulberry fibres.<sup>13</sup> The same components with the occasional addition of sparse fibres of cotton were found in the remaining thirty-three manuscripts dated later or not dated, and in four cases the cotton fibres were also mixed with paper mulberry fibres.<sup>14</sup> Llopis and Vilmont identified hemp, linen, sometimes with addition of ramie or mulberry, in the paper of 350 Tocharian manuscripts. These raw materials again suggest that these papers were made of rags (textile waste).<sup>15</sup> Rag paper was also confirmed by Enami Kazuyuki, Sakamoto Shoji, Okada Yoshihiro, and Masuda Katsuhiko in manuscripts dated to between the fourth and eighth centuries CE, which were unearthed around the Tarim Basin and are now kept at Ryukoku University, the

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<sup>12</sup> Helman-Ważny 2016, 132–134.

<sup>13</sup> Rischel 2001, 179–188.

<sup>14</sup> Raschmann 2012.

<sup>15</sup> Arnaud-Nguyen 2020, 404–405.

Kyoto National Museum, and Toyo-Bunko (Asian Library). Thus, hemp, mulberry, cotton, and foxtail millet were detected in papers from Japanese collections.<sup>16</sup>

According to secondary literature on papermaking around the tenth century, the use of rag paper declined, possibly because of a shortage of raw materials and the consequent high production cost. The documents dealing with papermaking after the Song Dynasty (960–1279) also mention rag paper only occasionally, a fact confirmed by the greater variety of plant components identified in manuscripts dated later than the tenth century.

My sample of manuscripts revealed rag paper in all groups of manuscripts irrespective of the script in which they are written (Fig. 2). This includes a good many of the Sogdian and Turkic manuscript fragments produced in the Western regions of the Silk Road as far as Samarkand, located at the junctions of trade routes from China and India. The Arabs in the eighth century must therefore have witnessed the production of rag paper in Samarkand.

After rag paper the second largest group represented among the manuscripts studied comprise inner-bark (phloem) paper composed of woody plant, such as *Broussonetia* sp. (paper mulberry) or *Morus* sp. (mulberry), derived from living plants (Fig. 3). These fibres are considered the best material for producing high quality paper. In my sample I observed that bark (phloem) paper made of mulberry or paper mulberry began to attain an equal footing with rag paper at the end of the seventh century, and then to prevail in the eighth.<sup>17</sup> The inner white bark of paper mulberry from indigenous trees may have grown wildly or may have been cultivated for this purpose. In addition to paper mulberry in Tibetan manuscripts dated to the ninth century and later, *Daphne* sp. fibres were also found.

It has been assumed that paper mulberry bast was added to Cai Lun's paper reported in 105 CE in the *Hou Han shu* ('History of the Later Han Dynasty'). A record for that year (commonly cited as the date of the invention of paper) shows that the technique of papermaking was reported by the eunuch Cai Lun to the Eastern Han Emperor Ho, and that those first paper samples were made of tree bark, remnants of hemp, rags of cloth, and fishing nets.<sup>18</sup> The evidence collected from material analyses of Hedin's Chinese paper fragments from Loulan and according to Stein's Sogdian paper fragments suggest that the more advanced Chinese production of paper from pure new bast fibres had already

<sup>16</sup> Enami et al 2010, 12–22; Enami et al. 2012, <<http://turfan.bbaw.de/bilder/ct/vortrag-enami.pdf>> (accessed on 21 Feb. 2021).

<sup>17</sup> Helman-Ważny 2016, 134–135.

<sup>18</sup> Tsien 1985, 40.



developed in the third century. The technology did not spread westwards as far as Samarkand, but eastwards and northwards, where plants of the *Thymelaeaceae* and *Moraceae* families were available.

### 3.2 Mapping of materials and technology

The findings concerning the use and distribution of paper in the selected manuscripts show the range of materials which might point to the provenance of the paper.<sup>19</sup> If the fibre consists of pure mulberry and the mould screen is made of bamboo splits, the paper is most likely of Chinese or more Eastern origin, but if the paper consists of a mixture of rag fibres and the mould is made of reeds, the provenance cannot be given with any degree of precision, since rags could travel and be turned into paper anywhere. Rag paper may be produced anywhere along the Silk Road, but mulberry paper was only produced in regions where mulberry trees grew. It should be remembered, however, that paper mulberry could grow in desert oases, but was usually cultivated for silk production, which yielded much higher profits, and was thus less frequently used for paper production, with the exception of rare and specific circumstances.

The technological development and bast fibres allowed the production of thinner, more even, and better-quality paper, so we may hypothesize that the centres of rag-paper production were more often located in desert regions, where mulberry trees were sparse and used rather for the breeding of silk worms than for paper production. The rag technology continued unchanged in regions with no natural growth of the requisite plants for the production of paper, whereas the chemical maceration of new bast fibres continued in China and spread to Korea, Japan, Tibet, Nepal, and other regions where these plants grew.

The woven paper made with a textile sieve, in written sources assumed to be a characteristic of the oldest and most primitive technology, typifies a minority of my sample and, in dated papers, appeared only after 692 CE (Fig. 4). Woven paper was found more in samples of bark (phloem) paper made of paper mulberry and mulberry. It is also worthy of note that all of the oldest samples dated by colophons to the fifth century CE were made of ramie and hemp rags on laid patchy paper additionally characterized by irregular laid lines, suggesting the use of a sieve made of reed or grass rather than bamboo (Fig. 5). This type of paper, characterized by the abovementioned combination of features, does not

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<sup>19</sup> Nöller and Helman-Ważny 2013, 6–7.

appear in later dated manuscripts. The paper type I have found most widely associated with early paper produced locally in Dunhuang and Turfan is thus thicker rag paper characterized by twelve to eighteen laid lines per 3 cm, often with uneven fibre distribution within a sheet. A second type that could have been produced along the eastern part of the Silk Road is characterized by between twenty-seven and thirty-three laid lines per 3 cm, made of paper mulberry and mulberry.

Macroscopic observations suggest that the floating mould with a fixed screen of woven textile did not necessarily precede the dipping mould equipped with the loose screen. If it did, it was replaced by the dipping mould equipped with the loose screen made of reeds as early as the third century. Reeds were then used, and soon thereafter bamboo sieves took over in the areas where these plants grow, but that papermaking sieve screens were also traded along the Silk Road and occasionally used in the more deserted Western regions cannot be ruled out. In the Himalayan regions, woven moulds have been preferred until the present day.

## 4 Concluding remarks

The data retrieved from material analysis of Central Asian manuscripts shows the materials that were used in the manufacture of books along the Silk Road in the first millennium CE and the way those books have evolved with technological innovation. The wide range of types and qualities of paper used in the book-making process was confirmed to include paper of recycled textile fibres from rags and the paper of new bast fibres (Fig. 6). Rag paper was most typically composed of hemp and ramie fibres in differing proportions, sometimes mixed with scarce amounts of other fibres, such as paper mulberry or mulberry (*Broussonetia* or *Morus* sp.), flax, jute, silk, wool, or cotton.

The fibre examination of these manuscripts has helped to establish a key for identifying the Central Asian plant fibres used in papermaking. I have created a collection of plants used for papermaking in Central Asia and prepared master samples for comparative fibre identification. An attempt to reconstruct their distribution in Central Asia in the past is an important step forward in finding the geographical origin of unknown books when compared with the results of fibre analysis performed on other manuscripts with a known plant composition. There remain, however, many problems to resolve in the future, including a more precise estimation of such plants' regional occurrence, which can be reliably

modelled for recent centuries, but not for the first millennium due to the lack of relevant climatic data.

Technological development in papermaking was conditioned by a number of coexisting factors, such as the local availability of raw materials and tools, as well as cultural habits originating from locally known technologies. Specific types of papermaking moulds were used in specific regions and possibly coexisted for periods in common areas. The results also show that artists and scribes made technological choices regarding paper, depending on the function of the objects they were creating. Understanding the broader Central Asian context of these results will depend on future analysis of material from other archaeological sites. The challenge for future work is also to learn more about the places in which the paper of those manuscripts was produced.

All these results are limited by the number of manuscripts tested. Additional data collected in the future may provide a more complete picture of the history of paper and allow us to map geographical locations together with time in order to pinpoint technological change, and ascertain what materials were outsourced and when. At this point, however, based on the limited collection of manuscripts tested, I can only share preliminary observations rather than a fixed overview.

### Acknowledgements

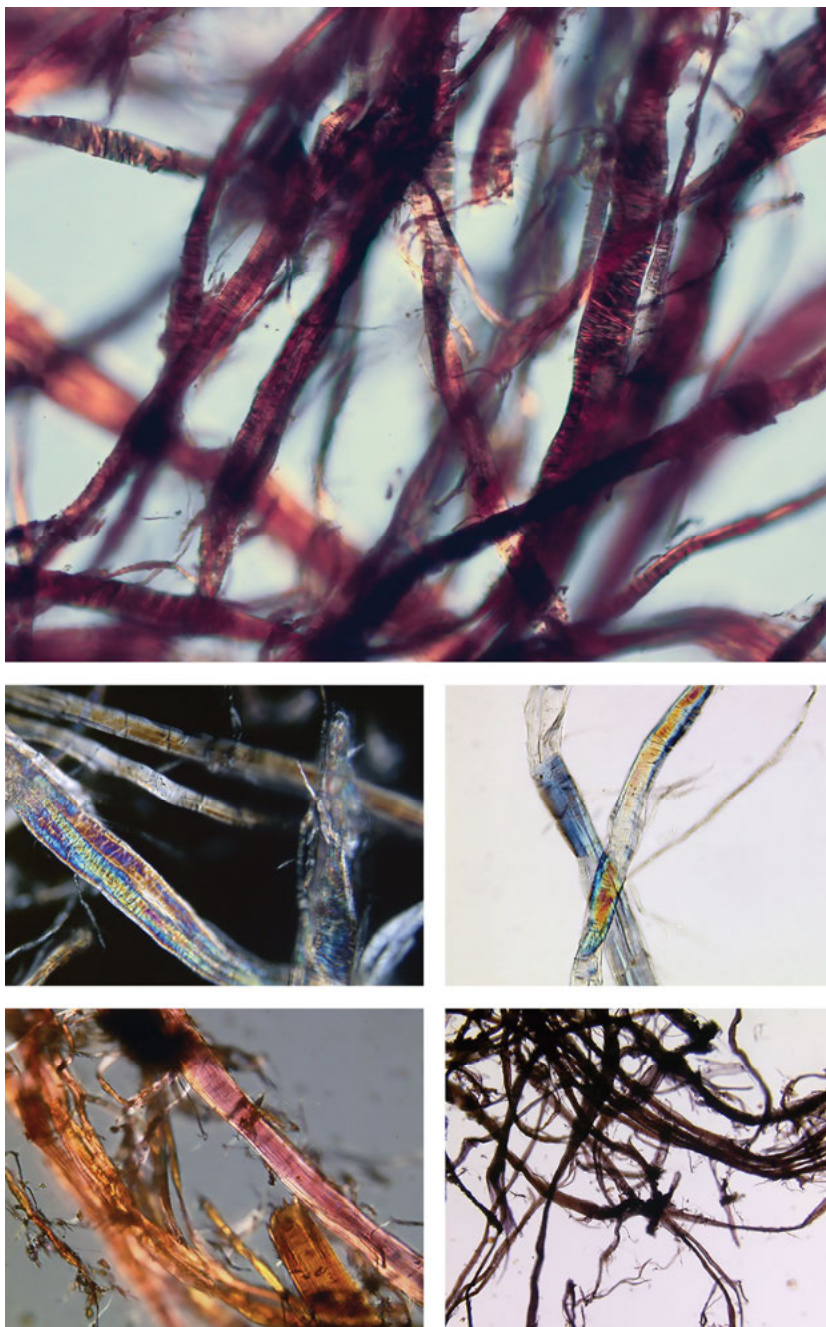
This research was funded by the German Research Foundation (DFG), Project No: 169966949, 08/11/2010 – 30/11/2013, PI: Prof. Michael Friedrich, entitled: *History and typology of paper in Central Asia during the first millennium AD: Analysis of Chinese paper manuscripts*, Department of Chinese Language and Culture, Asia and Africa Institute, University of Hamburg, Germany.

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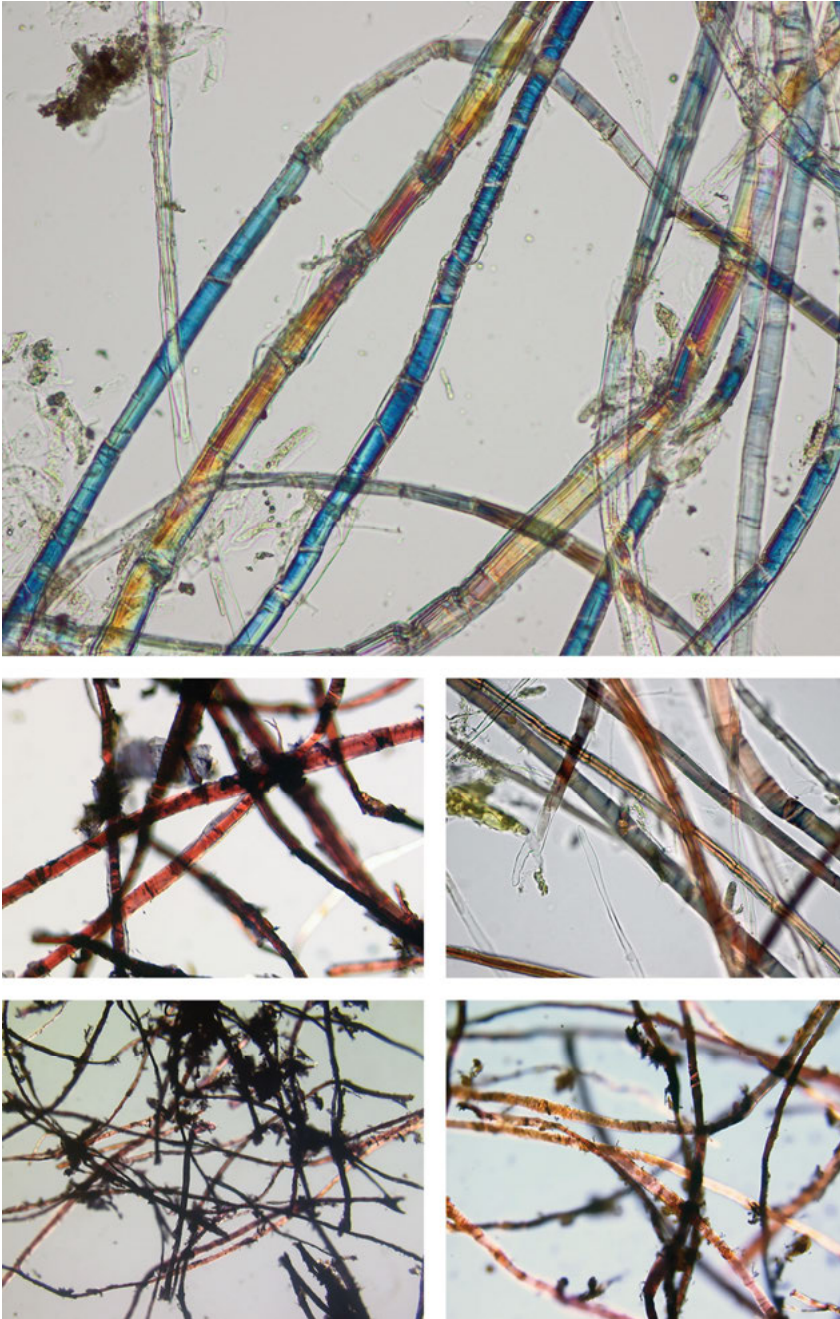
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**Fig. 2:** Rag paper under the microscope. Photographs by Agnieszka Helman-Ważny.



**Fig. 3:** *Paper mulberry* fibres under the microscope. Photographs by Agnieszka Helman-Ważny.





**Fig. 4a:** The woven paper made with a textile sieve in the manuscript archived as S238 from the British Library.



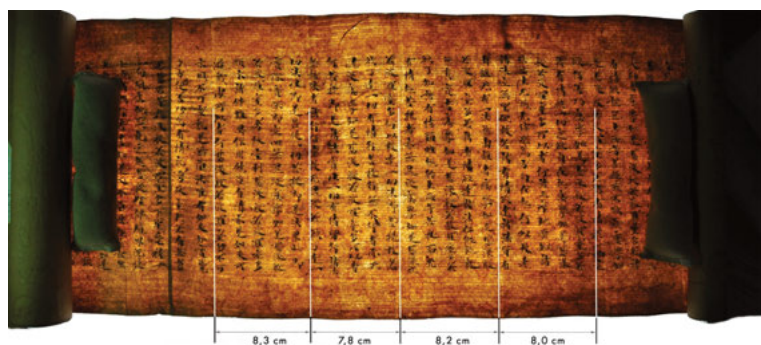
**Fig. 4b:** Technology of papermaking with a textile sieve.

Figs 4a–b: Photographs by Agnieszka Helman-Ważny.





**Fig. 5a:** Number of laid lines in 3 cm.



**Fig. 5b:** Chain lines intervals.



**Fig. 5c:** Laid paper made with the mould equipped with the bamboo sieve.  
Figs 5a–c: Photographs by Agnieszka Helman-Ważny, diagrams by Dorota Helman.



**Fig. 6:** Examples of the paper observed against light in the manuscripts from the Silk Road. Photographs by Agnieszka Helman-Ważny (paper fragments from the manuscripts preserved in the British Library).