History of paper

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Paper is a writing material that is said to have first been invented in ancient China.[1] Although contemporary precursors such as papyrus and amate existed in the African World and pre-Columbian Americas, respectively, these materials are unfortunately not defined as true paper. The first papermaking process was documented in China during the Eastern Han period (25-220 AD), traditionally attributed to the court official Cai Lun. During the 8th century Chinese papermaking spread to the Islamic world. By the 11th century papermaking was brought to medieval Europe, where it was refined with the earliest known paper mills utilizing waterwheels. Later Western improvements to the papermaking process came in the 19th century with the invention of wood-based papers.

Five seminal steps in ancient Chinese papermaking outlined in a Ming dynasty woodcut.

Contents

Precursors: papyrus and amate

The word "paper" is etymologically derived from *papyrus*, Ancient Greek for the *Cyperus papyrus* plant. Papyrus is a thick, paper-like material produced from the pith of the *Cyperus papyrus* plant which was used in ancient Egypt and other Mediterranean cultures for writing long before the making of paper in China.[2] Papyrus however are plants pressed and dried, while paper is made from fibers whose properties have been changed by maceration or disintegration.[3]

In the pre-Columbian Americas, a type of early bark paper known as *amate* was used as a folded writing

material for codices. The earliest sample of amate was found at Huitzilapa near the Magdalena Municipality, Jalisco, Mexico, belonging to the shaft tomb culture.[4] By the 16th century the Spanish introduced papermaking to the Americas (see section below).

Roman portraiture fresco of a young man with a papyrus scroll, from Herculaneum, 1st century AD

Early papermaking in China

Papermaking has traditionally been traced to China Cai Lun,[5] an official attached to the Imperial court during the Han Dynasty (202 BC-AD 220), created a sheet of paper using mulberry and other bast fibres along with fishnets, old rags, and hemp waste.[6] However, the earliest piece of paper found, at Fangmatan in Gansu province inscribed with a map, dates from 179-41 BC.[7]

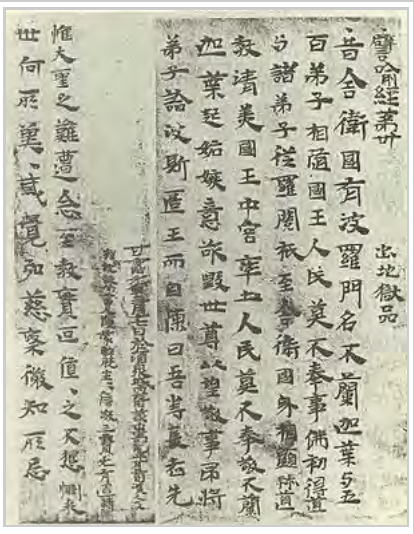
Techniques

During the Shang (1600–1050 BC) and Zhou (1050-256 BC) dynasties of ancient China, documents were ordinarily written on bone or bamboo (on tablets or on bamboo strips sewn and rolled together into scrolls), making them very heavy, awkward, and hard to transport. The light material of silk was sometimes used as a recording medium, but was normally too expensive to consider. The Han dynasty Chinese court official Cai Lun (ca. 50–121) is widely regarded as the inventor of the modern method of papermaking (inspired by wasps and bees) from rags and other plant fibers in 105. However, the discovery of specimens bearing written Chinese characters in 2006 at Fangmatan in north-east China's Gansu Province suggest that paper was in use by the ancient Chinese military more than 100 years before Cai, in 8 BC, and possibly much earlier as the map fragment found at the Fangmatan tomb site dates from the early 2nd century BC.[7] It therefore would appear that "Cai Lun's contribution was to improve this skill systematically and scientifically, fix a recipe for papermaking".[8]

Hemp wrapping paper, Western Han period of China, circa 100 BC

The record in the *Twenty-Four Histories* says[9]

> In ancient times writings and inscriptions were generally made on tablets of bamboo or on pieces of silk called chih. But silk being costly and bamboos heavy they were not convenient to use. Tshai Lun then initiated the idea of making paper from the bark of trees, remnants of hemp, rags of cloth and fishing nets. He submitted the process to the emperor in the first year of Yuan-Hsing (105 AD) and received praise for his ability. From this time, paper has been in use everywhere and is universally called the paper of Marquis Tshai.



Oldest paper book, dating to AD 256

The manufacture may have originated from the practice of pounding and stirring rags in water, after which the matted fibres were collected on a mat. The bark of Paper Mulberry was particularly valued and high quality paper was developed in the late Han period, which used the bark of *tan*

(檀; sandalwood). In the Eastern Jin period paper began to be made on a fine bamboo screen-mould, treated with insecticidal dye for permanence. After printing became popular in the Song dynasty the demand grew more. Paper was often used as a levy, with one prefecture sending some 1.5 million sheets of paper to the capital as tribute up to the year 1101.[9]

The world's earliest known printed book (using woodblock printing), the Diamond Sutra of 868, shows the widespread availability and practicality of paper in China.

Uses

The first use of paper has been excavated in China dating to the reign of Emperor Wu of Han from the 2nd century BC, used for purposes of wrapping or padding protection for delicate bronze mirrors.[10] It was also used for safety, such as the padding of poisonous "medicine" as mentioned in the official history of the period.[10] Although paper used for writing became widespread by the 3rd century AD,[1] paper continued to be used for wrapping (and other) purposes. Toilet paper was used in China from around 875 C.E.[11] In 589, the Chinese scholar-official Yan Zhitui (531-591) wrote: "Paper on which there are quotations or commentaries from Five Classics or the names of sages, I dare not use for toilet purposes".[11] An Arab traveler to China once wrote of the curious Chinese tradition of toilet paper in 851, writing: "... [the Chinese] do not wash themselves with water when they have done their necessities; but they only wipe themselves with paper".[11]

During the Tang dynasty (618–907) paper was folded and sewn into square bags to preserve the flavor of tea.[10] During the same period, it was written that tea was served from baskets with multi-colored paper cups and paper napkins of different size and shape.[10] During the Chinese Song dynasty (960–1279) not only did the government produce the world's first known paper-printed money, or banknote (*see Jiaozi and Huizi*), but paper money bestowed as gifts to deserving government officials were wrapped in special paper envelopes.[11] During the Yuan dynasty (1271-1368), when there were the first well-documented Europeans in Medieval China, the Venetian merchant Marco Polo remarked how the Chinese burned paper effigies shaped as male and female servants, camels, horses, suits of clothing and armor while cremating the dead during funerary rites.[12]

Diffusion of paper

After its origin in central China, the production and use of paper spread steadily. It is clear that paper was used at Dunhuang by AD 150, in Loulan in the modern-day province of Xinjiang by 200, and in Turpan by 399. Paper was concurrently introduced in Japan sometime between the years 280 and 610.[13]

India

Chinese paper was first introduced to Medieval India in the 7th century.[14] However, the use of paper was not widely used there until the 12th century.[15]

Islamic world

After the defeat of the Chinese in the Battle of Talas in 751 (present day Kyrgyzstan), the invention spread to the Middle East.[16]

Paper page fragment from a Coptic language Bible from Egypt in the Islamic period, 700s AD or later

The legend goes,[17] the secret of papermaking was obtained from two Chinese prisoners from the Battle of Talas, which led to the first paper mill in the Islamic world being founded in Samarkand in Sogdia (modern-day Uzbekistan). There was a tradition that Muslims will release their prisoners if they can teach ten Muslims any valuable knowledge.[18] There are records of paper being made at Gilgit in Pakistan by the sixth century, in Samarkand by 751, in Baghdad by 793, in Egypt by 900, and in Fes, Morocco around 1100.[19]

The laborious process of paper making was refined and machinery was designed for bulk manufacturing of paper. Production began in Baghdad, where a method was invented to make a thicker sheet of paper, which helped transform papermaking from an art into a major industry.[20] The use of water-powered pulp mills for preparing the pulp material used in papermaking, dates back to Samarkand in the 8th century,[21] though this should not be confused with paper mills (see *Paper mills* section below). The Muslims also introduced the use of trip hammers (human- or animal-powered) in the production of paper, replacing the traditional Chinese mortar and pestle method. In turn, the trip hammer method was later employed by the Chinese.[22] Historically, trip hammers were often powered by a water wheel, and are known to have been used in China as long ago as 40 BC or maybe even as far back as the Zhou Dynasty (1050 BC–221 BC).[23]

By the 9th century, Muslims were using paper regularly, although for important works like copies of the revered Qur'an, vellum was still preferred.[24] Advances in book production and bookbinding were introduced.[25] In Muslim countries they made books lighter—sewn with silk and bound with leather-covered paste boards; they had a flap that wrapped the book up when not in use. As paper was less reactive to humidity, the heavy boards were not needed. By the 12th century in Marrakech in Morocco a street was named "Kutubiyyin" or book sellers which contained more than 100 bookshops.[26]

The earliest recorded use of paper for packaging dates back to 1035, when a Persian traveler visiting markets in Cairo noted that vegetables, spices and hardware were wrapped in paper for the customers after they were sold.[27] Since the First Crusade in 1096, paper manufacturing in Damascus had been interrupted by wars, but its production continued in two other centres. Egypt continued with the thicker paper, while Iran became the center of the thinner papers. Papermaking was diffused across the Islamic world, from where it was diffused further west into Europe.[28] Paper manufacture was introduced to India in the 13th century by Muslim merchants, where it almost wholly replaced traditional writing materials.[24]

Europe

The oldest known paper document in the West is the Mozarab Missal of Silos from the 11th century, probably using paper made in the Islamic part of the Iberian Peninsula. They used hemp and linen rags as a source of fiber. The first recorded paper mill in the Iberian Peninsula was in Xàtiva in 1056.[29][30] Papermaking reached Europe as early as 1085 in Toledo and was firmly established in Xàtiva, Spain by 1150. It is clear that France had a paper mill by 1190, and by 1276 mills were established in Fabriano, Italy and in Treviso and other northern Italian towns by 1340. Papermaking then spread further northwards, with evidence of paper being made in Troyes, France by 1348, in Holland sometime around 1340–1350, in Mainz, Germany in 1320, and in Nuremberg by 1390 in a mill set up by Ulman Stromer.[31] This was just about the time when the woodcut

printmaking technique was transferred from fabric to paper in the old master print and popular prints. There was a paper mill in Switzerland by 1432 and the first mill in England was set up by John Tate in 1490 near Stevenage in Hertfordshire,[32] but the first commercially successful paper mill in Britain did not occur before 1588 when John Spilman set up a mill near Dartford in Kent.[33] During this time, paper making spread to Poland by 1491, to Austria by 1498, to Russia by 1576, to the Netherlands by 1586, to Denmark by 1596, and to Sweden by 1612.[19]

A copy of the Gutenberg Bible, printed on paper during the 1450s, in the New York Public Library

Arab prisoners who settled in a town called Borgo Saraceno in the Italian Province of Ferrara introduced Fabriano artisans in the Province of Ancona the technique of making paper by hand. At the time they were renowned for their wool-weaving and manufacture of cloth. Fabriano papermakers considered the process of making paper by hand an art form and were able to refine the process to successfully compete with parchment which was the primary medium for writing at the time. They developed the application of stamping hammers to reduce rags to pulp for making paper, sizing paper by means of animal glue, and creating watermarks in the paper during its forming process. The Fabriano used glue, obtained by boiling scrolls or scraps of animal skin to size the paper; it is suggested that this technique was recommended by the local tanneries. The introduction of the first European watermarks in Fabriano was linked to applying metal wires on a cover laid against the mould which was used for forming the paper.[34]

They adapted the water wheels from the fuller's mills to drive a series of 3 wooden hammers per trough. The hammers were raised by their heads by cams fixed to a waterwheel's axle made from a large tree trunk.[35][36]

Americas

In the Americas, archaeological evidence indicates that a similar bark-paper writing material was used by the Mayans no later than the 5th century AD.[37] Called *amatl*, it was in widespread use among Mesoamerican cultures until the Spanish conquest. The paper is created by boiling and pounding the inner bark of trees, until the material becomes suitable for art and writing.

These materials made from pounded reeds and bark are technically not true paper, which is made from pulp, rags, and fibers of plants and cellulose.

European papermaking spread to the Americas first in Mexico by 1575 and then in Philadelphia by 1690.[19]

Paper mills

A paper mill is a water-powered mill that pounds the pulp by the use of trip-hammers. The mechanization of the pounding process was an important improvement in paper manufacture over the manual pounding with hand pestles.

While the use of human and animal powered mills were known to Chinese and Muslim papermakers, evidence for water-powered paper mills is elusive in both of them.[38][39][40][41] The general absence of the use of water-power in Muslim papermaking is suggested by the habit of Muslim authors to call a production center not a "mill", but a "paper manufactory".[42]

Donald Hill has identified a possible reference to a water-powered paper mill in Samarkand, in the

The Nuremberg paper mill, the building complex at the lower right corner, in 1493. Due to their noise and smell, paper mills were required by medieval law to be erected outside of the city perimeter.

11th-century work of the Persian scholar Abu Rayhan Biruni, but concludes that the passage is "too brief to enable us to say with certainty" that it refers to a water-powered paper mill.[43] While this is seen by Halevi nonetheless as evidence of Samarkand first harnessing waterpower in the production of paper, he concedes that it is not known if waterpower was applied to papermaking elsewhere across the Islamic world at the time;[44] Burns remains altogether sceptical given the isolated occurrence of the reference and the prevalence of manual labour in Islamic papermaking elsewhere.[45]

The earliest certain evidence to a water-powered paper mill dates to 1282 in the Spanish Kingdom of Aragon.[46] A decree by the Christian king Peter III addresses the establishment of a royal "molendinum", a proper hydraulic mill, in the paper manufacturing centre of Xàtiva.[46] The crown innovation appears to be resented by the local Muslim paper makering community; the document guarantees the Muslim subjects the right to continue their way of traditional paper making by beating the pulp manually and grants them the right to be exempted from work in the new mill.[46] Paper making centers began to multiply in the late 13th century in Italy, reducing the price of paper to one sixth of parchment and then falling further; paper making centers reached Germany a century later.[47]

The first paper mill north of the Alps was established in Nuremberg by Ulman Stromer in 1390; it is later depicted in the lavishly illustrated *Nuremberg Chronicle*.[48] From the mid-14th century onwards, European paper milling underwent a rapid improvement of many work processes.[49]

Fiber sources

Before the industrialisation of the paper production the most common fibre source was recycled fibres from used textiles, called rags. The rags were from hemp, linen and cotton.[50] A process for removing printing inks from recycled paper was invented by German jurist Justus Claproth in 1774.[50] Today this method is called deinking. It was not until the introduction of wood pulp in 1843 that paper production was not dependent on recycled materials from ragpickers.[50]

19th century advances in papermaking

Although cheaper than vellum, paper remained expensive, at least in book-sized quantities, through the centuries, until the advent of steam-driven paper making machines in the 19th century, which could make paper with fibres from wood pulp. Although older machines predated it, the Fourdrinier papermaking machine became the basis for most modern papermaking. Nicholas Louis Robert of Essonnes, France, was granted a patent for a continuous paper making machine in 1799. At the time he was working for Leger Didot with whom he quarrelled over the ownership of the invention. Didot sent his brother-in-law, John Gamble, to meet Sealy and Henry Fourdrinier, stationers of London, who agreed to finance the project. Gamble was granted British patent 2487 on 20 October 1801. With the help particularly of Bryan Donkin, a skilled and ingenious mechanic, an improved version of the Robert original was installed at Frogmore, Hertfordshire, in 1803, followed by another in 1804. A third machine was installed at the Fourdriniers' own mill at Two Waters. The Fourdriniers also bought a mill at St Neots intending to install two machines there and the process and machines continued to develop.

However, experiments with wood showed no real results in the late 18th century and at the start of the 19th century. By 1800, Matthias Koops (in London, England) further investigated the idea of using wood to make paper, and in 1801 he wrote and published a book titled *Historical account of the substances which have been used to describe events, and to convey ideas, from the earliest date, to the invention of paper.*[51] His book was printed on paper made from wood shavings (and adhered together). No pages were fabricated using the pulping method (from either rags or wood). He received financial support from the royal family to make his printing machines and acquire the materials and infrastructure needed to start his printing business. But his enterprise was short lived. Only a few years following his first and only printed book (the one he wrote and printed), he went bankrupt. The book was very well done (strong and had a fine appearance), but it was very costly.[52][53][54]

Ancient Sanskrit on Hemp based Paper. Hemp Fiber was commonly used in the production of paper from 200 BCE to the Late 1800's.

Then in the 1830s and 1840s, two men on two different continents took up the challenge, but from a totally new perspective. Both Friedrich Gottlob Keller and Charles Fenerty began experiments with wood but using the same technique used in paper making; instead of pulping rags, they thought about pulping wood. And at about the same time, by mid-1844, they announced their findings. They invented a machine which extracted the fibres from wood (exactly as with rags) and made paper from it. Charles Fenerty also bleached the pulp so that the paper was white. This started a new era for paper making. By the end of the 19th-century almost all printers in the western world were using wood in lieu of rags to make paper.[55]

Together with the invention of the practical fountain pen and the mass-produced pencil of the same period, and in conjunction with the advent of the steam driven rotary printing press, wood based paper caused a major transformation of the 19th century economy and society in industrialized countries. With the introduction of cheaper paper, schoolbooks, fiction, non-fiction, and newspapers became gradually available by 1900. Cheap wood based paper also meant that keeping personal diaries or writing letters became possible and so, by 1850, the clerk, or writer, ceased to be a high-status job.

The original wood-based paper was acidic due to the use of alum and more prone to disintegrate over time, through processes known as slow fires. Documents written on more expensive rag paper were more stable. Mass-market paperback books still use these cheaper mechanical papers (see below), but book publishers can now use acid-free paper for hardback and trade paperback books.

Determining provenance

Determining the provenance of paper is a complex process that can be done in a variety of ways. The easiest way is using a known sheet of paper as an exemplar. Using known sheets can produce an exact identification. Next, comparing watermarks with those contained in catalogs or trade listings can yield useful results. Inspecting the surface can also determine age and location by looking for distinct marks from the production process. Chemical and fiber analysis can be used to establish date of creation and perhaps location.[56]

See also

- History of origami
- Paperless office

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> It has also become universal to talk of paper "mills" (even of 400 such mills at Fez!), relating these to the hydraulic wonders of Islamic society in east and west. All our evidence points to non-hydraulic hand production, however, at springs away from rivers which it could pollute.

41. Thompson 1978, p. 169:

> European papermaking differed from its precursors in the mechanization of the process and in the application of water power. Jean Gimpel, in *The Medieval Machine* (the English translation of *La Revolution Industrielle du Moyen Age*), points out that the Chinese and Muslims used only human and animal force. Gimpel goes on to say : "This is convincing evidence of how technologically minded the Europeans of that era were. Paper had traveled nearly halfway around the world, but no culture or civilization on its route had tried to mechanize its manufacture.'"

42. Burns 1996, pp. 414f.:

> Indeed, Muslim authors in general call any "paper manufactory" a *wiraqah* - not a "mill" (*tahun*)

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