Sonja Ulrike Klug

Passion for Compasses

Medieval Master Builders and their Cathedral Building Plans

Kluges Verlag

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Press reviews of the original German edition of this book

Published under the title "Zauberer des Zirkels" (2020):

"'Zauberer des Zirkels' is more than a work on the history of art and architecture in the Middle Ages. Medieval architecture was an expression of medieval culture. Thus, Klug's presentation includes cultural, cognitive, linguistic, literary, mathematical, graphic and technical aspects that not only support her thesis, but also provide interesting approaches to considering other phenomena of medieval culture.

Despite the demanding content the book is written in an understandable and entertaining way. Klug argues convincingly, using numerous quotations and examples to make her train of thought clear. Important findings and conclusions are highlighted in the text, and illustrations provide additional clarity. ...

Its multidimensional and interdisciplinary approach makes the book an interesting study of medieval culture and goes beyond the consideration of purely architectural phenomena. Klug's thoroughly researched work is therefore not only recommended for readers interested in architectural and art history, but also offers valuable insights and food for thought into the history of the Middle Ages."

(https://blog.histofact.de, 2020/09/28)

"I really liked the combination of engaging and sometimes humorous writing style with meticulous documentation supported by credible sources. The author not only demonstrates intelligence but also thoroughness and empathy."

(Online reviewer *Gute_Buecher999*)

"Ms. Klug clears up the misconceptions of historians and other authors and brings together proven evidence in such a way that we gain a new perspective on the great buildings, churches and cathedrals of the period. ...

The author's arguments are factual and comprehensible – there are at most one or two conclusions that one would like to interject with a 'Yes, but ...', at least once. However, these are by no means the cornerstones for her argumentation. ...

One can appreciate not only Sonja Ulrike Klug's expertise, but also her pleasant writing style. She explains her theory in an easy-to-understand and well-founded manner while incorporating historical context, which refreshes and supplements the reader's knowledge.

'Zauberer des Zirkels' is therefore not only interesting for experts, but for any reader who is enthusiastic about medieval architecture and history!"

(https://www.nightshade-magazin.de, 2020/09/17)

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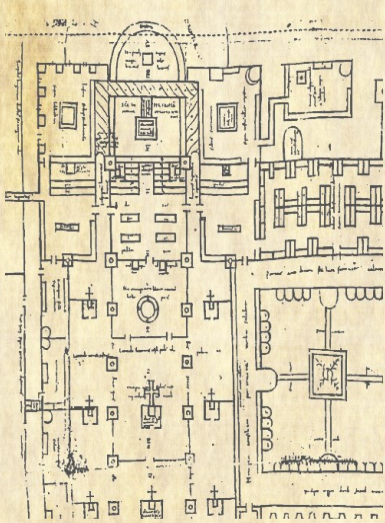
1. Master builders and master plans in the Middle Ages – Introduction



1.1 The "data" of the cathedrals

The fact that *Notre-Dame de Paris Cathedral* was massively damaged by fire in 2019 is – one might assume – not actually a bad thing. Although no medieval building plans have survived, scientific 3D data exist. These were created by various experts before the disaster and, along with further recordings, are being converted into a complete 3D model as part of a research project.[1]

3D data – three-dimensional and undoubtedly computer-generated survey data – will allow the cathedral to be faithfully reconstructed. Data that simulate, true to scale, what the building looked like in every facet and detail before the fire; data that allow almost every inch of the entire building to be shown from any direction and in a perfect 360-degree panoramic view; data that can be zoomed in on the smallest detail and out to lofty heights.

With such a complete design basis, rebuilding *Notre-Dame de Paris* must be easy, apart from the practicalities of construction. Since 2019, the fire at *Notre-Dame* has also made those responsible for other churches sit up and take notice: they have commissioned the digital surveying of architectural monuments to ensure faithful reconstruction in case future fires destroy larger parts of them.

In the Middle Ages, it was much more difficult to rebuild a church after it had burned down, which happened very often and was usually caused by lightning striking in a tower. How was a cathedral constructed (or reconstructed) in an era when there were no highly accurate computer-generated 3D data – indeed, when construction plans did not even exist?

A remarkable phenomenon of medieval architecture is the lack of building and construction plans, which are designed in such a way that they can be used to plan buildings as a whole. Partial plans of individual construction elements exist for a number of buildings, but overall plans have never been found.

Compared to the Romanesque period, the Gothic period saw great advances in building construction: the naves were wider than in the Romanesque

period, the vault construction allowed for higher ceilings due to the use of pointed arches, and in addition, the towers reached unprecedented heights of more than 131 yd. In addition, there were other innovations such as artfully designed and large stained glass windows. Despite all these advances over earlier buildings or predecessor churches from the Romanesque period, no overall plans, sketches or construction drawings have yet been found until today – neither for the Romanesque nor for the Gothic period.

1.2 Built for Eternity without plans?

Nevertheless, historians of architecture and art often assume that there must have been not only general plans, but also many other plans, which were used to construct the buildings in advance. For example, the structural engineer Dietrich Conrad, in his German standard work *Kirchenbau im Mittelalter* ("Church Construction in the Middle Ages"), states that about 2,200 copies of *medieval* plans have survived, but

> *"no drawings of the mass of medieval buildings have been preserved."* [2]

Have these construction plans ever existed? Have they been lost, burned, deliberately or accidentally destroyed? Are they, as the art historian Günther Binding notes,

> *"a mythical figure that is given reality and helped to actually exist? "*[3]

Or did they never exist?

Conrad notes a vacuum in the stock of drawings, especially between the 4th and the 13th centuries, which also surprises other architectural historians time and again. Merely one exception seems to have been existed: the famous monastery plan of St. Gall, an ideal plan that was created around 825 (cf. **Figure 1**, p. 12), but it was never implemented 1:1 in terms of construction. It seems to have served as a kind of "creative planning basis".

From the point of view of modern architects, engineers and structural engineers, it is indeed hard to imagine that the master builders of the early and high Middle Ages would have erected complex churches, castles and other buildings *without* drawings. The historian Max Hasak agrees with Conrad that architectural drawings have always been *"necessary, even indispensable aids to construction planning"* at all times.[4] Konrad Hecht, author of a well-known work on the St. Gallen monastery plan, believes that in the Middle Ages a building

> ***"was prepared not differently than today: with a design developed on the drawing board". [5]***

However, this is contradicted by the fact that detailed plans for individual elements of some buildings on wood or stone have survived from the time before the 13th century, but no draft or rough plans for *entire buildings* have survived.[6] It is only from the mid-13th century that plans at a scale of 1:1 as well as *"reasonably proportionate drawings"* [7] are preserved, as Binding notes. Scaled plans have existed since the 15th century.

The oldest true-to-scale plan dates from the 1420s from Bologna. A significant increase in the number of architectural drawings can be observed from the middle of the 14th century[8], and since the middle of the 15th century the number of architectural drawings has been on the rise.[9] From the 15th century onwards, drawings became legally binding and were part of the master craftsman's examination in some stonemasons' workshops (Bauhütten).[10]

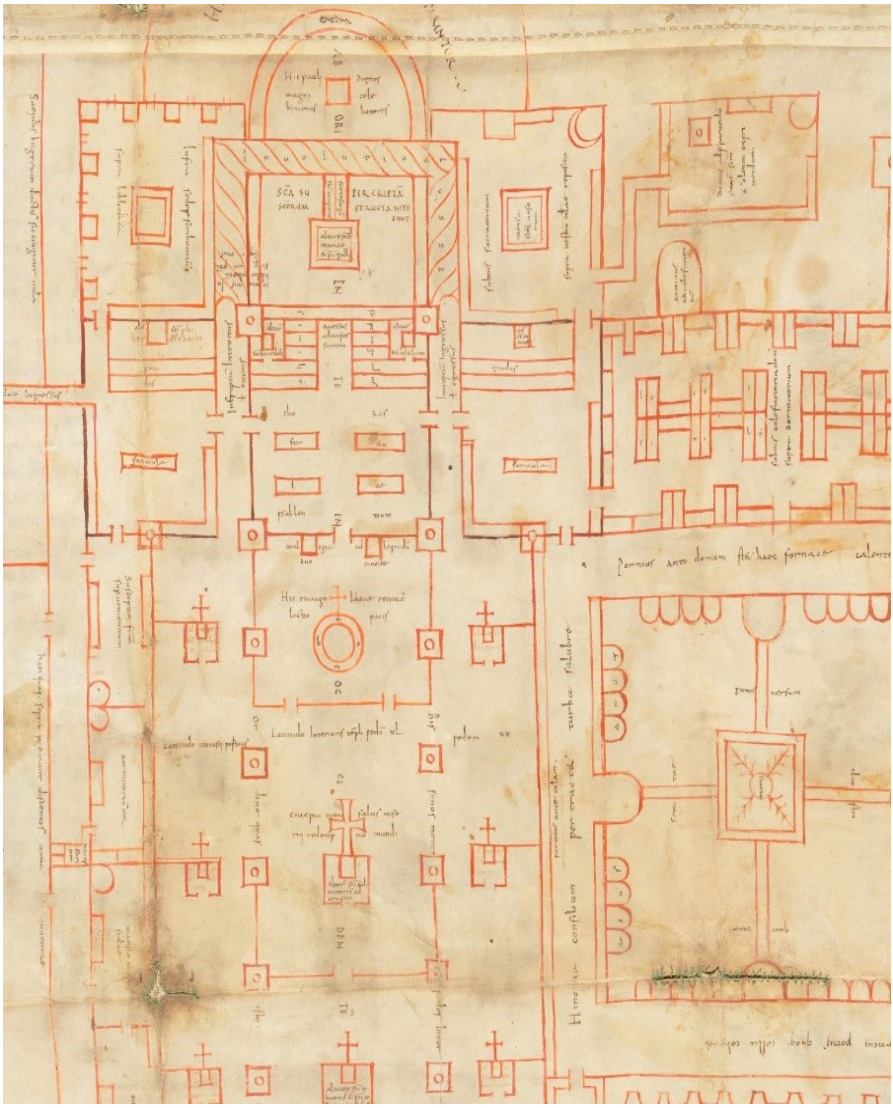


Figure 1: Small section of the plan of St. Gall monastery (on parchment). The lines were drawn freehand without compass or ruler, using marked pinpricks (cf. section 3.4).

1.3 Speculations about the whereabouts of the plans

The "gap" in the existence of building plans until the middle of the 14th century is explained by many architectural historians as having been lost or deliberately destroyed:

> *"Such drawings must once have numbered in the thousands. Only a vanishingly small part of them has survived. This remaining stock is almost entirely due to the preservation efforts of the stonemasons' workshops (Bauhütten) of western and southern Germany,"* says Hecht.[11]

Conrad agrees:

> *"The lack of drawings of buildings from Roman times to the 13th century can be explained by loss. Parchment and later paper – the main writing materials – were always particularly endangered by fire and water. [...] In these centuries, however, it was believed that what was built in stone would last forever and from this it was concluded that there was no need to preserve a drawing after the completion of a building. Due to the value of the drawing material (parchment and paper were very expensive), direct destruction was out of the question. The drawings were erased or scraped off and the newly obtained writing material (palimpsest) or the free 'backs' were used."* [12]

Jean Gimpel, an internationally renowned specialist in the history of medieval technology and author of the well-known book "The Cathedral Buil-ders" among others, agrees with Conrad that there would have been no reason to keep construction plans of completed buildings, and therefore they would have been destroyed.[13]

The engineer Paul Booz, former master builder of the cathedral in Freiburg im Breisgau (Germany), believes that drawings must have existed before the 13th century, but that they were destroyed during the transition from Romanesque to Gothic architecture because they were no longer usable.[14] However, the division into distinct stylistic periods, such as Romanesque and Gothic,

came much later. At the beginning of the Gothic period no one could foresee the further development of building styles or techniques. From the point of view of the former master builders, the transition from Romanesque to Gothic period was smooth. What we now consider a "different style" was certainly seen rather a "progress" in the art of building, as the Gothic period allowed for taller and wider church buildings with larger window areas.

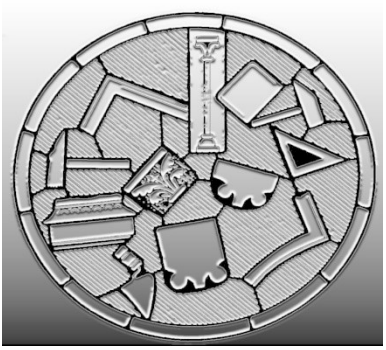


Figure 2: Schematic representation of a section of the stained glass window *Histoire des Saint Silvestre,* created around 1220, in the southeast ambulatory of Chartres Cathedral, with stonemasonry tools (hammer, pick, square, mortar trowel, stencils) and building elements (column, cornice and capital). A construction plan is not visible.

All in all, as we can see, there is a wealth of different opinions and interpretations as to why so few construction plans were preserved until the 13th century. The "flourishing" speculations suggest that unidentified causes underlie the phenomenon.

Finally, Conrad comes to a conclusion that is shared by other authors:

> *"The state of building since the 4th century, despite all discontinuities, makes it quite simply inconceivable that the buildings could have been erected without preparatory work in the form of drawings. Thus, it should be noted once again that the absence of medieval architectural drawings before the 13th century does not permit the conclusion that there were no drawings in that period."* [15]

I will show below that Conrad, Hasak, Hecht, Gimpel, Booz and other historians of architecture and art are nevertheless wrong when they assume a continuum of construction knowledge since antiquity or since Vitruvius and when they think that most plans must have been lost or deliberately destroyed.

Medieval design plans from the time before the 13th century did not disappear, but do not exist at all – despite the skill of the master builders of that time and the outstanding architectural achievements that can still be seen today in the Romanesque and Gothic churches, and in some cases also in the castles.

Beyond the history of art and the plans themselves, I will show this by tracing the cultural-historical lines of the epoch from the 11th to the 16th century, thus illuminating the subject from different perspectives:

- The availability of writing materials in the Middle Ages (papyrus, parchment, paper) and the nature of their use or applicability gives a first indication of why the number of surviving plans is comparatively small.
- Researchers have compiled a large number of sources on the level of literacy of the European population between the 4th and 17th centuries. They provide a reliable and sometimes surprising picture, which includes the profession of architect.
- The typical characteristics of oral or preliterate cultures compared to literate ones, where script and writing were common, shed light on the way people in the Middle Ages perceived and dealt with the written form.
- A linguistic analysis of some key formulations in Villard de Honnecourt's sketchbook in comparison to works by other authors provides further insight into the self-image of (book) authors of the Middle Ages and their relationship to the audience.

- The way in which some of the surviving plans are used allows conclusions to be drawn about supposedly missing plans.
- A comparative cultural analysis of Islamic architecture of the same period reveals that the Arab world is also familiar with the problem of "lost" drawings for epochal buildings, especially important mosques and medreses, from the 8th to the 14th century.
- The discovery of a mistranslation of Vitruvius shows the origin of the statement that in the Middle Ages building had to be done with the help of plans.
- Medieval education, including architectural training prior to the Renaissance, demonstrates the influence of building plans on the development of the architectural profession.
- The mathematical know-how available in the Middle Ages makes clear what master builders may or may not have known.
- The study of construction and construction instruments, especially different types of compasses, shows the possibilities and limitations of medieval planning and drawing.
- Closely related to the instruments is the art of drawing, which developed progressively from the 15th century onwards, producing various types of projection of three-dimensional bodies onto a two-dimensional surface and thus revolutionizing technical drawing.

2. Papyrus, parchment, and paper – the long road to writing media and written language

2.1 Mobile, easily portable and affordable writing materials

When Papyrus perished

In today's world, we have plenty of writing materials at our disposal, especially paper. For every note, every draft, every type of writing, every drawing, there is always enough inexpensive paper in all imaginable formats, colors, and qualities. The fact that this was not the case in earlier centuries, and that there was a real shortage of paper as well as other writing materials, is hard to understand from today's perspective. But the "luxury" of always having enough inexpensive paper available has only existed in Europe since the late 19th century.

Not much is known about the writing materials of the Middle Ages, except that parchment was predominantly used. Unfortunately, there are still a number of errors circulating in the specialist literature, mainly concerning the times when papyrus, parchment and paper were used and the reasons for their use. Here is a small compilation of inaccurate statements:

- The historian Otto Mazal believes that paper replaced papyrus as a writing material because papyrus production ceased under the pressure of growing paper production.[16] But this is not true: There is a gap of about 500 years between the cessation of papyrus production and the spread of paper in Europe, during which time paper was unknown and only parchment was used.
- Jean Gimpel claims that plans on parchment began to appear more frequently in the 14th and 15th centuries because *"the price of parchment had fallen in the meantime."* [17] But the opposite was true. From the 14th century onwards, paper became more and more widespread, and it became popular in the 15th century precisely because its price dropped ex-

tremely compared to parchment. Parchment, on the other hand, remained expensive and scarce. Construction plans, as well as other written documents, were increasingly drawn on paper instead of parchment from the 15th century onward.[18]

- The paleographer Karin Schneider believes that papyrus was replaced by parchment in the Middle Ages because the latter proved to be much more durable.[19] This is true in some respects, but parchment was already known as a writing material since pre-Christian times, and not just in Europe. This raises the question of why papyrus was used in Europe for so long, if parchment was supposedly more advantageous.
- The Germanist Karl-Heinz Göttert thinks that paper is an invention of the Arabs[20], although they only acted as intermediaries or merchants between East and West. Paper is a Chinese invention.

The reason for the demise of papyrus and parchment as writing materials, and the time when paper was introduced and spread throughout Europe are largely unknown in terms of cultural history. However, the development and availability of mobile, easily portable, and sufficiently inexpensive writing materials is important in terms of when construction drawings might have been created.

In Europe, from about the 5th century B. C.[21] to about the 7th century A. D., people wrote on papyrus, made from the papyrus plant, traditionally and apparently exclusively in Egypt, where it had been known since the 4th or 3rd millennium B. C.[22] For centuries, it was exported from there in large quantities to Europe via Byblos, a city in Syria, and exchanged for other goods. Papyrus was also the predominant writing material of ancient Greece and the Roman period. Before that, only clay, stone, wood, or leather had been available, but papyrus offered many advantages: It is pliable, transportable, easy to write on,

and can be glued into rolls of any length. It was papyrus, with its massive distribution, that spurred the development of ancient scholarship and writing in antiquity.

Due to the many political crises and upheavals in Egypt, which was conquered several times by different Islamic groups from the 7th century onwards, there was apparently a crisis in papyrus production. Some researchers believe that the papyrus areas shrank massively due to the expansion of agriculture[23], causing the papyrus plants to wither. Since the 7th or 8th century, no more writing material could be produced from the plant or exported.

The last written documents in Christian Europe on papyrus date from about the middle of the 7th century from the Merovingian dynasty. The very last verifiable papyrus document was issued by the Vatican in 1057, but by that time the Vatican was using parchment almost exclusively and was probably using up its last supplies of papyrus.[24] Without papyrus, Europe "sat on dry land", and the previously flourishing distribution and reproduction of written documents dried up. Only in Italy the situation was somewhat better, as papyrus continued to grow in large quantities in Sicily where the plant was probably used to make writing materials until the 12th or 13th century.[25] It is possible that Sicily already had access to paper exports from the Arab world.

Parchment replaces papyrus

After the loss of papyrus, people in Europe turned to parchment, which was already common and occasionally used in in both Europe and the Orient in ancient times.[26] Parchment is made from the skins of cattle, calves, sheep, and goats, although sheepskin was the preferred material in Europe. Unlike leather, parchment is not tanned. The skins of the animals are soaked, cleaned and placed in a lime solution to remove hair and any adhering particles of flesh. The skin is then stretched in a frame and treated with knives to remove hair and imperfections and to create a smooth surface. After drying, the parchment

is smoothed with chalk and pumice stone to make it writable, and cut to the desired size (cf. **Figure 3,** p. 22).[27]

Parchment has the advantage of being more durable than papyrus, it can be written on both sides and lasts longer. Both papyrus and parchment can be washed and reused. This is evidenced by the numerous so-called palimpsests – parchment sheets (and very few preserved papyri) whose texts were erased so that they could be reused and re-inscribed.

But parchment also has its disadvantages: As an organic material, it is sensitive to moisture. If it comes into direct contact with water, it will begin to rot after a while. However, undesirable changes can also occur without direct contact with water and can be caused by excessively humid air. This allows the parchment to turn glassy and to expand; when it dries, it shrinks and becomes wavy. If the parchment is repeatedly moistened and dries again, the ink on it will flake off.

Obviously, all of this has negative consequences for architectural drawings. They could become distorted in their proportions or illegible. This is pointed out by parchment experts as well as by architectural historians who have studied medieval drawings on parchment.[28]

Another disadvantage of parchment was its high price. Because it was so expensive, it was mainly used for documents and books, but was not usually available for everyday writing. In this case, wax tablets were used as mnemonic devices (cf. section 3.3) – or one simply had to give up writing.

Figure 3: "The Parchment Maker" or "Permennter" From the *Ständebuch* by Jost Amman / Hans Sachs (Nuremberg 1568) – plus the text by Hans Sachs:

"I buy skins of sheep, rams and goats. I put the skins in the pickle.
Then I clean them and stretch each single skin on a frame.
After that I scrape it and make parchment out of it,
with a lot of work in my house.
From ears and claws I make glue,
and sell it all at home."

Original in German:

„Ich kauff Schaffell / Böck / vnd die Geiß /
Die Fell leg ich denn in die beyß /
Darnach firm ich sie sauber rein /
Spann auff die Ram jeds Fell allein/
Schabs darnach / mach Permennt darauß /
Mit grosser arbeit in mein Hauß /
Auß ohrn vnd klauwen seud ich Leim /
Das alles verkauff ich daheim.“)

From about the 12th century, the volume of written correspondence in Europe increased considerably, especially in political administration and at courts. This is clearly illustrated by the example of England: between 1250 and 1350, the amount of writing materials and sealing wax increased tenfold to twentyfold. At the beginning of the 13th century only a few dozen sheep had to

give their lives on the occasion of a royal court day, but by 1283 the number of animals had risen to 500.[29] The situation was similar in France, the Vatican, and Germany. Statistical counts showed that the number of documents increased tenfold from the 11th to the 12th century and doubled again in the 13th century; at the same time, the number of court chanceries increase significantly.[30] According to a statistical study, manuscript production increased ninefold throughout Western Europe from the 11th to the 12th century, and quadrupled again from the 12th to the 13th century.[31] In the absence of other writing materials, parchment was used without exception.

As the number of written documents increased, it was foreseeable that parchment would become increasingly difficult to supply. Animal skins were too expensive in the long run, especially since animals served multiple functions as food and raw material suppliers for the textile industry. It was not possible to slaughter animals for every document, every letter, every court decision (or every architectural drawing) that needed to be written. This would have led to the complete exodus of cattle, calves, sheep and goats, whose wool and milk were urgently needed for clothing and food. Concerning wool, for example, there were long-term contracts between agricultural suppliers, e. g. the Cistercian Order in England, and the clothing industry in Italy.

If papyrus had still been available at that time, it would have been obvious that it would have continued to be used as a writing material in addition to parchment due to the high demand. But the paleographic evidence clearly shows that this was not the case: papyrus had already completely disappeared in Europe by the 11th century.

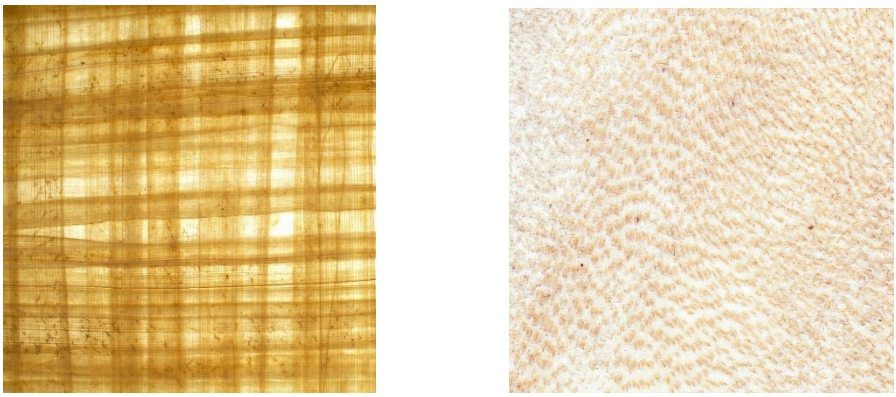


Figure 4: Structural comparison of papyrus (left) and parchment (right). Papyrus consists of transverse and longitudinal fibers of the plant held together by starch. The parchment reveals the uneven surface of animal skin.

The need for writing materials grew due to the lack of papyrus. Parchment was expensive and not in short supply. This was the situation when the Gothic period began to flourish in Europe in the 12th century, and Europeans first came into contact with the new, unknown type of paper through Muslim-occupied Spain.

The Umayyads, who had been driven out of their ancestral empire by the Abassids, wandered through North Africa and finally founded the Emirate of Cordoba in the south of the Iberian Peninsula in al-Andalus in 756 A. D. They brought with them the already well-developed Arabic knowledge and literature and, within one or two centuries, also introduced the know-how of paper production, which the Arabs had taken over from the Chinese. Around 750, the Arab world first came into contact with paper invented by the Chinese through the trading hub of Samarkand (now Uzbekistan), located on the Silk Road, and the region around Khorasan.