ELUCIDATION OF THE PAPER ROAD BY DATA SCIENCE. BASED ON QUANTITATIVE, QUALITATIVE RESEARCH AND AI MULTIDIMENSIONAL ANALYSIS



doi 10.34920/2181-8207/2023/3-073



Koji Shibazaki,
Professor, Faculty of Art, Department of Design and Craft, Aichi University of the Arts. Japan

Consequently, there are numerous unexplained aspects of paper culture, but research to date has not tested established theories, and a substantial number of samples remain unconfirmed

The outlook of research into paper culture

Our research focuses on elucidating the «paper road» (the spread of paper), which has many unanswered questions to this day, and uncovering the truth concealed in paper culture. Art and data science are utilized to elucidate the diversity of paper culture throughout the world.

In order to decipher the history of paper culture, it is necessary to consider the period before the 18th century, when the technology of papermaking was not yet modernized. At the time, paper was made manually. First, in eastern Eurasia, from China to Japan, research into various plant materials utilizing plant bast continued, as did research into paper processing methods and painting and calligraphy styles that corresponded to the intended use of the paper.

In the west, the spread of paper from China to Samarkand in Central Asia during the latter half of the eighth century (Samarkand paper) and its subsequent spread are significant aspects of paper's history. This paper was used locally and in the Islamic cultural sphere as a substitute for the parchment used for the official Qur'an, as well as for miniatures with intricate drawings and gold-colored expressions, such as valuable books. After the Samarkand paper, it is believed that the spread of paper became the origin of paper in Europe, but there are many unknown points. Particularly unknown is its relationship to the era of paper manufacturing.

For important historical assets, the rule «non-destructive and non-contact» applies._ There is a diversity of paper manufacturing techniques in various regions of the world, which reflects the essence of culture. The artistic expressions (writing, drawing, etc.) created on paper have developed and evolved in tandem with papermaking technology. Even after the destruction of the ancient civilization, these paper cultural artifacts have been guarded, passed down, and preserved with great care. Paper transcends time and space, allowing us to relearn numerous aphorisms.

However, the rule «Non-destructive and non-contact» applies to valuable cultural assets, even if they are significant research works. Researching numerous cultural objects without being able to identify the type of paper used is a challenging issue on a global scale.

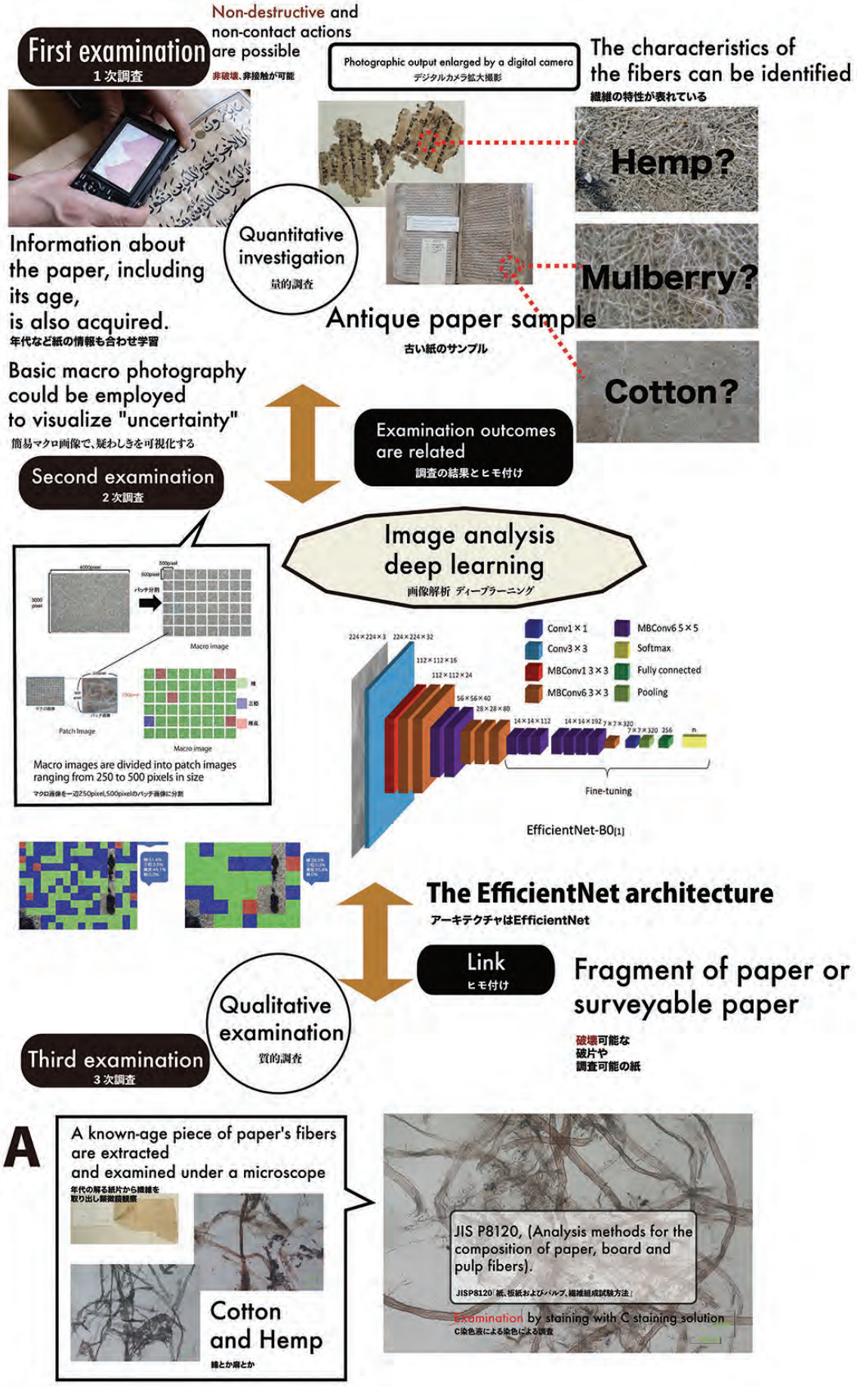
Connection of Paper Propagation_By observing numerous papers, we hope to confirm the distribution's transition or connections.

There is considerable ambiguity regarding the distribution of paper in various Eurasian regions. Throughout the course of human history, paper culture has been eradicated and reborn alongside the rise and fall of ethnic groups. After papermaking ceased, research stagnated and knowledge of papermaking techniques and methods as a whole dwindled, so research is frequently based on legend. Japanese Washi and other Shosoin documents are among the few instances that can be dated back to 1300 years ago.

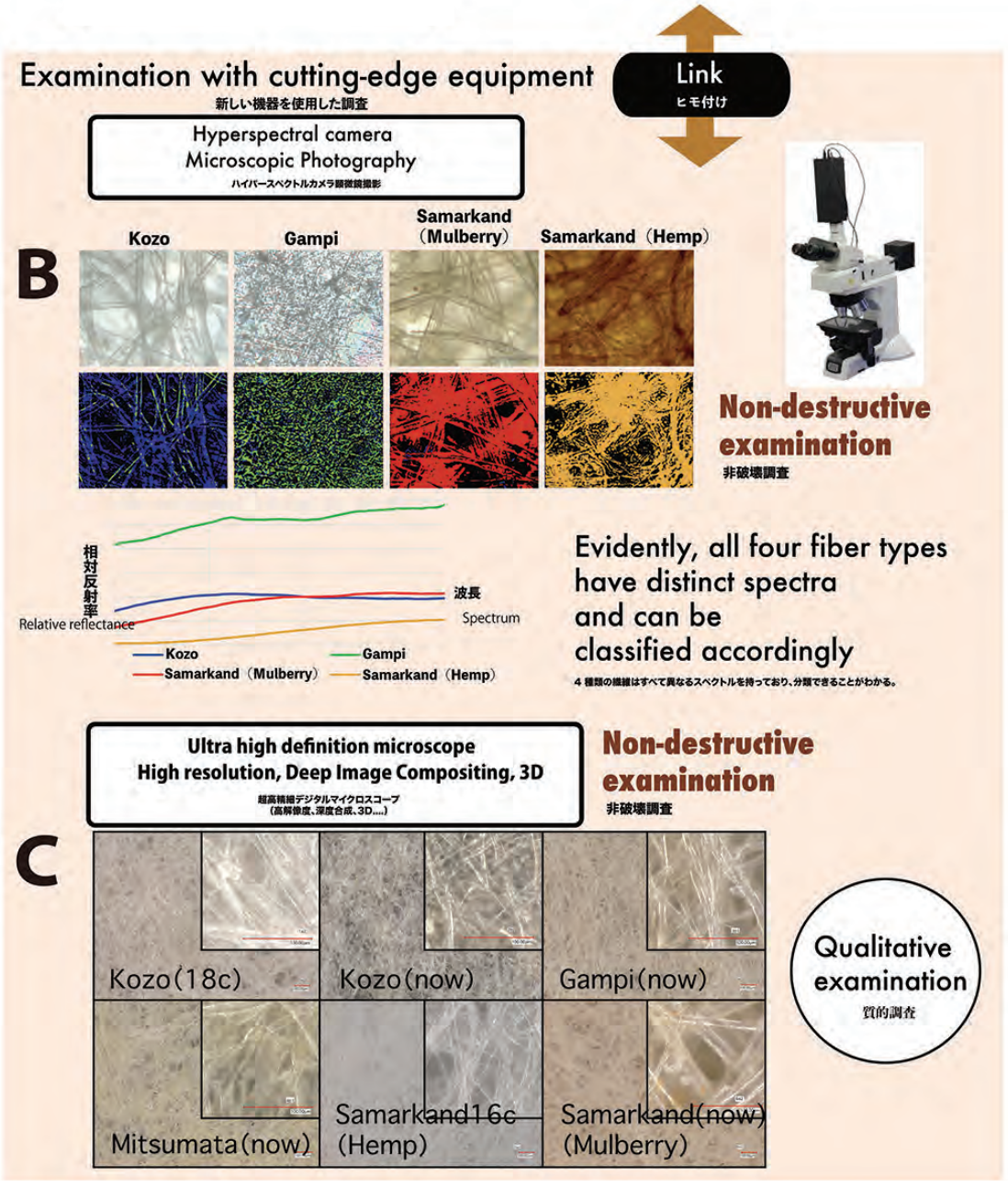
Consequently, there are numerous unexplained aspects of paper culture, but research to date has not tested established theories, and a substantial number of samples remain unconfirmed.

What method is used to conduct reconnaissance?

Initially, numerous images of paper fibers are captured with a simple macro photograph taken with a consumer digital camera. Deep learning is then used to identify the properties of the same or similar paper through image analysis. Various observations and measurements are made, and the results of the complex analysis are correlated with those of the simple macro photographs. Therefore, we developed a system that, from a simple macro image, can identify


First examination
1 次調査
Non-destructive and non-contact actions are possible
非破壊、非接触が可能
Photographic output enlarged by a digital camera
デジタルカメラ拡大撮影
The characteristics of the fibers can be identified
繊維の特性が表れている
Hemp?
Mulberry?
Cotton?
Quantitative investigation
量的調査
Information about the paper, including its age, is also acquired.
年代など紙の情報も合わせ学習
Antique paper sample
古い紙のサンプル
Basic macro photography could be employed to visualize "uncertainty"
簡易マクロ画像で、疑わしきを可視化する
Examination outcomes are related
調査の結果とヒモ付け
Second examination
2 次調査
Image analysis deep learning
画像解析 ディープラーニング
Macro image
Patch Image
Macro images are divided into patch images ranging from 250 to 500 pixels in size
マクロ画像を一辺250pixel,500pixelのパッチ画像に分割
Conv1 × 1
Conv3 × 3
MBConv1 3 × 3
MBConv6 3 × 3
MBConv6 5 × 5
Softmax
Fully connected
Pooling
Fine-tuning
EfficientNet-B0[1]
The EfficientNet architecture
アーキテクチャはEfficientNet
Link
ヒモ付け
Fragment of paper or surveyable paper
破壊可能な
破片や
調査可能の紙
Qualitative examination
質的調査
Third examination
3 次調査
A
A known-age piece of paper's fibers are extracted and examined under a microscope
年代の解る紙片から繊維を取り出し顕微鏡観察
Cotton and Hemp
綿とか麻とか
JIS P8120, (Analysis methods for the composition of paper, board and pulp fibers).
JISP8120「紙、板紙およびパルプ、繊維組成試験方法」
Examination by staining with C staining solution
C染色液による染色による調査

In this study, we intend to investigate a methodology that refers to a large number of papers through a quantitative investigation employing simple macro images and first visualized through the use of Artificial Intelligence (AI), which appears to contradict the accepted theory



The conventional method, A, is destructive because it extracts the fibers. B and C are non-destructive surveys utilizing state-of-the-art equipment that are considered new techniques to be investigated in the future

the paper's material, origin, manufacturing year, manufacturing method, etc.

This is the same technology as facial recognition, which you employ on a daily basis to distinguish yourself from others around the world.

Methodology for locating papers of questionable age

In this study, we intend to investigate a methodology that refers to a large number of papers through a quantitative investigation employing simple macro images and first visualized through the use of Artificial Intelligence (AI), which appears to contradict the accepted theory.

Due to time and financial constraints, it is impossible to examine exhaustively the countless unaudited papers that exist around the world. However, when it becomes a significant cultural asset, it is nearly impossible to extract the fibers, let alone touch them.

First, we intend to develop a method by which different papers from around the world can be identified and their similarity to other paper fiber data can be determined with a high degree of certainty using simple macro photography with a consumer digital camera.

The [First examination] is a quantitative investigation involving visual observation and simple macro photography of paper of known ages to collect as many images of fibers and paper information as possible and build a database for training AI.

In the [Second examination], the potential properties of the paper contained in the image data are analyzed using deep learning, categorized, and visualized according to their various types.

The [Third Examination] is qualitative research that uses optical examinations to extract the fibers and non-destructive examinations with cutting-edge technology to accurately identify the raw materials, fiber properties, and impurities of the examined paper. In other words, it is an investigation to determine the correct paper fibers.

There are three qualitative research methods:

A. Using an optical microscope and the JIS P8120 (Paper, Board, and Pulp Fiber Analysis Method) method for analyzing fiber properties and impurities, damaged or naturally fallen paper fibers were collected and analyzed to determine fiber properties and impurities.

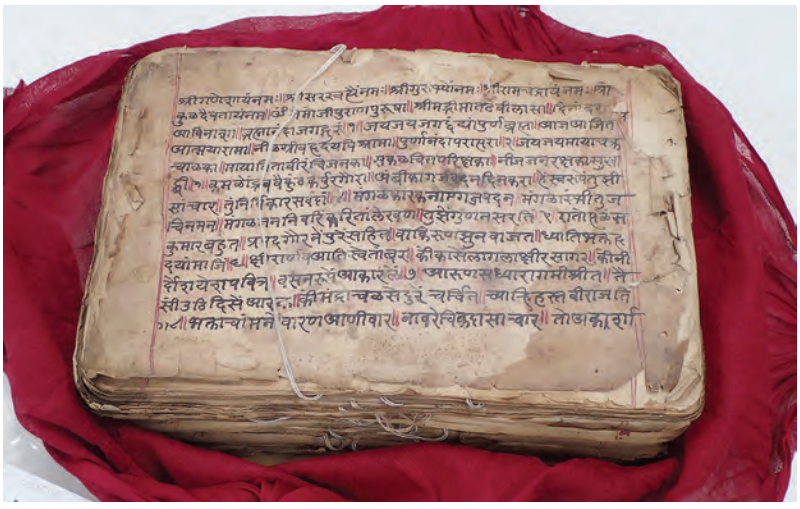
B. A hyperspectral camera attached to a microscope is used.On the image data, spectral separation is performed (points). In addition to visible lightseparation is performed (points). In addition to visible light (red, green, and blue, or RGB), non- visible light with shorter wavelengths can be observed.

C. An ultrahigh-definition microscope is used to observe details. Utilized features include high resolution, deep image composition, and element measurement.

The conventional method, A, is destructive because it extracts the fibers. B and C are non-destructive surveys utilizing state-of-the-art equipment that are considered new techniques to be investigated in the future.

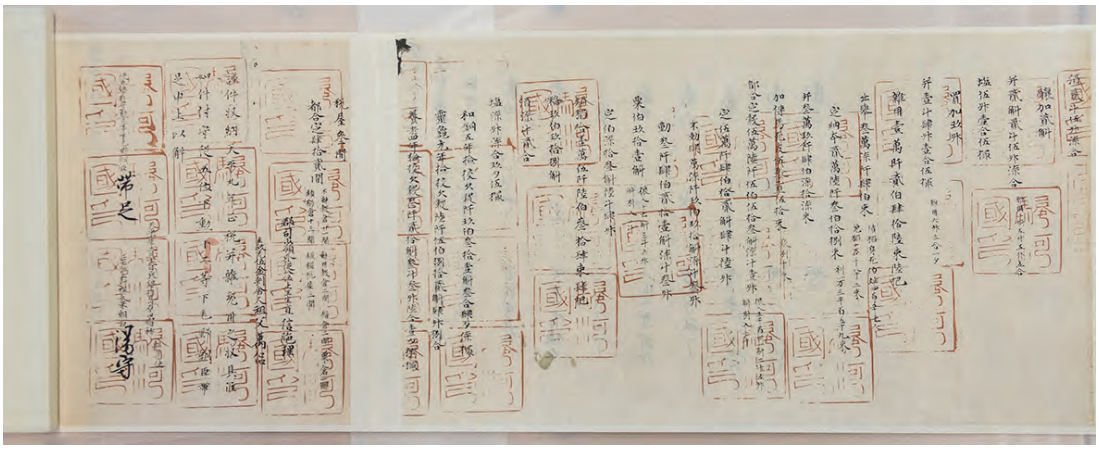
Deep learning is used to connect and learn the images and data from these [first, second, and third examination].

These methods have the potential to enable nondestructive, in-depth analysis of paper using macro photography with a standard digital camera.





If this methodology can be applied globally, it could be a scientific approach that can unearth history that has been buried in the past due to unrevealed facts or competing historical interpretations. ■





A global perspective on paper culture r

紙文化研究の世界観と、

Paper is an evolved form of papyrus and parchment
紙はパピルス、羊皮紙の進化形

Parchment. The origin dates to 2500 B.C?
Contemporaneous with the papyrus, 1000 B.C～?
羊皮紙 原点は紀元前2500年～?
パピルスと同時代、紀元前1000～?



Paper is an alternative to parchment
(Owned by Shibazaki)
紙は、羊皮紙の代用
(申請者所蔵)



Paper is an evolved form of papyrus
(Metropolitan Museum of Art, USA)
紙はパピルスの進化形
(メトロポリタン美術館)

The transitional period from papyrus to paper
The 9th through 10th centuries
パピルスから紙に変わる時代 9～10c

The origins of modern paper production
近代製紙の幕開け

Réaumur (France) focused on raw wood materials (1719)
レオミュール(仏)、木材原料に着目(1719年)

France's Louis Robert invented the Fourdrinier paper machine (1798)
ルイ・ロベール(仏)、紙漉機械(1798年)

Keller (Germany) initiated chemical pulp-based mechanical papermaking (1840)
ケラー(独)木材パルプでの機械製紙(1840年)

The connection between calligraphic exp
書画表現と紙の関係

Central Asia

Paper values that have survived in the world
世界に残る紙の資産

Investigate the dates of known ancient Qurans and Miniatures
年代のわかる古いコーラン、ミニアチュールから、紙を調査する。



(Scientific Library of



Both made in Bukhara in the 16th century, Metropolitan Museum of Art, US
Is this the most advanced level currently offered?



There are also paper materials that have been dispersed throughout the world
海外に散逸した紙資料も

During the e

Europa

Gutenberg Bible
グーテンベルク聖書

In approximately 1445, Johannes Gutenberg invented typography

1445年頃に
ヨハネス・グーテンベルクが
活版印刷術







In the 15th century, when parchment and paper were combined in a single book
(Bavarian State Library)

15世紀、羊皮紙と紙が
同じ本に混ざる時代
(バイエルン州立図書館)

Ancient Western paper was made from cotton and linen fibers
Photograph by portable microscope camera(University of Indiana, Lily Library, USA)
古い洋紙は、コットン、リネン
携帯顕微鏡写真(インディアナ大学Lilly Library)

Excellent paper values are preserved as an art form.
Their connection has also been studied.
優れた紙の資産は芸術として残されている。
年代も研究されている。

Is th
the
紙の伝
タラス

The scene of collecting fabric
布を集める様子



Local History Museum of Kokand in Uzbekistan
コーカンド博物館資料

USA
(Philadelphia)
1690

What was the first type of paper produced in the West?
西洋で最初に作られた紙は、どんな紙か?

Are cloth and bast fibre the origins and raw materials of western paper?
洋紙の原点、原料は布・靭皮?

France
(Hérault)
1189

Germany
(Mainz)
1320

Samarkand pape
サマルカンド紙

Western paper
洋紙

Spain
(Xàtiva)
1150

Damascus
10Century

Samarkand
757

Morocco
1100?

Baghdat
795

Libya
1040

Egypt
(Cairo)
960

Italy
(Montiphano)
1276

Pre-17th century Samarkand paper
Traces of fabric and distinctive fiber crimping
17世紀以前のサマルカンド紙。
布であった痕跡、繊維の独特の縮れ

Derived from cotton fabric 綿の布由来



The modern Samarkand paper is made of bast fibers.
Its fibers are similar to Washi
現在の靭皮によるサマルカンド紙。
繊維は和紙に近い。

Mulberry bark(plant origin)
桑の靭皮(植物由来)



What is Samarkand paper exactly?
サマルカンド紙の実体は?

Is the Rag paper made from discarded fabric?
古布から作るラグペーパー?

South Asia



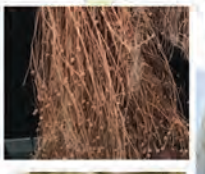
The fibers are similar to Western paper.
繊維は洋紙に似ている。
18th century Indian manuscript
(National Museum of Ethnology)
インドの写本18c (国立民族学博物館)

The history and conn
are particularly unkn
Moreover,At the same
difficult to conduct re
紙の生産と接続性が特に
同時に調査困難エリア。

Paper can be recovere
and composition is kn
原料や紙の情報がわかれば

Pen-and-ink W

Linen
亜麻



Cotton
綿



Hemp
麻



Ramie
苧麻





Derived from fabric
布由来

Characteristics of Western paper



硬筆 西洋紙の特徴

esearch and historical considerations

歴史における注目すべきトピック

pression and paper

Samarkand State University, Uzbekistan)

Only if the paper itself is damaged can the fibers be extracted for analysis.
繊維がもらえるケース

Right: The Quran has been ravaged by rats and other vermin
右：ネズミ被害などにより破損したコーラン解説書

Numerous ancient Islamic books have not been studied
多くのイスラム古書が未調査

examination in Uzbekistan, photographs were taken
ウズベキスタン調査にて撮影

Was Samarkand paper made from mulberry fibers? サマルカンド紙は桑かも?

China

From the earliest Fangmatan paper (hemp) to the Tang Dynasty, only fragmentary records are known to exist.
Little is known about paper prior to the Yuan Dynasty
最古の放馬灘紙(麻)から唐時代まで、部分的な記録のみ。
元以前の紙の情報は少ない。



Tang Dynasty ,Paper Buddha
唐の時代紙の仏



During the Yuan Dynasty, the first banknotes were made by "mulberry paper."
元時代、世界初の紙幣"桑紙"を使った?

Additionally, the Xoten manuscripts contained mulberry family fibers (8th century).
ホータン文書(8世紀)からは、クワ科繊維も出る。





Reexamination in 2019 at our university
2019 年本学にて再調査

Principal theories constituting the paper road theory

紙の道の説を形成する形成する主要な学説

・Arab Paper（1887 年），Joseph von Karabacek,
Arab Paper (1887) by Joseph von Karabacek, research into the Rainer collection
Defined as Linen
Rainer Collectionの調査
リネンと結論



Papermaking:
The History and Technique of an Ancient Craft, by Dard Hunter (1943)
・ダードハンター
「古代製紙の歴史と技法」(1943年)

Former Soviet researcher P.I.Pashino(1868) Samarkand paper as part of historical research by former
・旧ソ連の研究者P.I.Pashino(1868)をはじめ歴史研究の一端としてサマルカンド紙



"History of Paper" (1911) by Kuwahara Jitsuzo
・「紙の歴史」(1911年)桑原隲蔵

Photograph by National Diet Library, Portraits of modern Japanese
国立国会図書館「近代日本人の肖像」

Japan

"Nihonshoki" mentioned the significance of records in 403.
(Chronicles of Japan in Separate Writings)
In 610, papermaking was documented in Nihonshoki
403年『日本書紀』記録の重要性
610年日本書紀に製紙の記録

The papermaking process is detailed in Engishiki Volume 13 Zusho-ryo
延喜式巻13図書寮式には、製紙に関する記述。

Shōsōin Documents (702) (The oldest paper with known age, various papers)

Even in Japan, where there is a great deal of information, ambiguity abounds
情報が多い日本でも、不明が多い





Hyakumantō Darani (770)
The oldest prints of known age
(Todaiji Culture Center)
『百万塔陀羅尼』(770年)(年代がわかる現存最古の印刷物)
(東大寺総合文化センター)

There are a variety of paper types, but is it blended with Chinese paper?
紙は幾つかのタイプがあるが、中国紙と混在?

The disparity in paper analysis is currently a problem!
現在、紙分析の相違が問題に!

he paper propagation factor
cause of The Battle of Talas?
捕の要因は
河畔の戦い?

Otani Collection
Dunhuang Manuscripts
大谷コレクション
敦煌文書

The Battle of Talas?
751 タラス河畔の戦

Xote Manuscripts
ホータン文書
(Xoten)

ections of paper manufacturing
own in this region.
e time, this is an area that is
search on.
不明なエリア。

Origin of paper 紙・起源

China The Yellow River Basin
105 蔡倫、『後漢書』、紙の確立
105 Cai Lun, "Hou Hanshu" (Scriptures of the Later Han), Determined the formulation of papermaking.

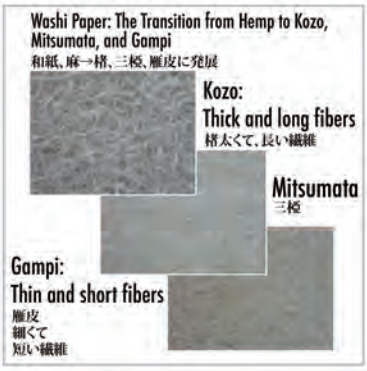
Chinese paper
中国紙

Japan
610～
The development of washi paper
和紙へ発展



Bast fibers of Moraceae, Thymelaeaceae, etc.
クワ科、ジンチョウゲ科
などの靭皮繊維

Washi Paper: The Transition from Hemp to Kozo, Mitsumata, and Gampi
和紙、麻→楮、三椏、雁皮に発展



d if information about its raw materials
own.
紙の復元は可能

Mulberry 桑

Pteroceltis tatarinowii Straw 青楡・藁

Bamboo 竹







Kozo 楮

Mitsumata 三椏

Gampi 雁皮

Writing brush

haracteristics of astern paper

Derived from plants
植物由来





Chinese paper is represented by Xuan paper, which is made from Pteroceltis and straw
中国紙の代表格は宣紙、
青楡と藁が原料。



There are numerous bamboo papers as well
竹紙も数多い

Bast fibers from plants
植物から作る靭皮繊維

毛筆 東洋紙の特徴



Mostly Moraceae and Thymelaeaceae plants
多くはクワ科、ジンチョウゲ科植物