Z Badań nad Książką i Księgozbiorami Historycznymi 2020, t. 14, z. 3
The Studies into the History of the Book and Book Collections 2020, vol. 14, no. 3
www.bookhistory.uw.edu.pl
http://doi.org/10.33077/uw.25448730.zbkh

Anna-Grethe Rischel
Paper Conservator emerita
Environmental Archaeology and Materials Science
National Museum of Denmark
Anna-Grethe.Rischel@natmus.dk

A scientific description of specimens of Asian paper of known origin

Abstract: The fibres and technologies used in the production of 14 handmade paper samples of known provenance, collected during study tours to Nepal, Thailand and Japan in 1984, 1985 and 1988 illustrate the importance of the preparation process for the final quality of the paper. The detailed descriptions from field notes and observation of the time-consuming preparation process of the fibres from the Moraceae and Thymelaeaceae plant families in this article indicate the close connection between the preparation of the fibres and the technology used in the sheet formation and the drying process. A useful reference for known fibres, technology and provenance, these 14 samples serve in comparative analyses as an identification key for the fibres and technology of unidentified Asian papers.

Key words: Fibre preparation, sheet formation, traces of technologies, Asian papermaking.

„Z Badań nad Książką i Księgozbiorami Historycznymi" – Udział zagranicznych recenzentów w ocenie publikacji; Stworzenie anglojęzycznej wersji wydawniczej publikacji; Digitalizacja tomów archiwalnych rocznika w celu zapewnienia otwartego dostępu do nich przez Internet oraz wdrożenie i utrzymanie cyfrowej platformy redakcyjnej – zadanie finansowane w ramach umowy nr 653/P-DUN/2019 ze środków Ministra Nauki i Szkolnictwa Wyższego przeznaczonych na działalność upowszechniającą naukę.

Ministerstwo Nauki
i Szkolnictwa Wyższego

© Copyright by Uniwersytet Warszawski; CC BY-NC 4.0
https://doi.org/10.33077/uw.25448730.zbkh.2020.634

Introduction

Historical studies into Asian paper provide an introduction to and a theoretical understanding of the material and the technology used since paper was introduced as a writing support. If we combine these studies with observations of the surviving methods used by the papermakers and their choice of fibres, we discover new information about the history of paper in the link between the fibres and technology used, and the appearance and the quality of the paper. The inner bark layer or bast fibres from five plant species of the Moraceae and Thymelaeaceae families serves as raw materials for the selected 14 reference samples, collected along with numerous other paper samples on study tours in 1984, 1985 and 1988 in Nepal, Thailand and Japan. Field notes and observations of the actual preparation of the fibre material, the paper mould and sheet formation, as well as the drying process of the 14 new thin and thick, transparent and opaque, stiff and soft paper qualities are presented here. The preparation of the fibres and formation of the sheet has remained almost unchanged for centuries and the macroscopic observations, as well as the details discovered through microscopic analyses have shed light on the great variety of handmade paper qualities in these countries.

Sample No. 1, Sa SL 32. *Broussonetia papyrifera*, of the Moraceae family

AGR Sample No. 1: Sa SL 32; papermaker Cherit Lahpinkhah; field notes and observations; 8/11 1984 and 25/8, 1988
Provenance: Ton Paw village between Chiang Mai and Bor Sang, Chiang Mai Province, Thailand
Preparation: The fibres of the inner layer of bark derived from the paper mulberry tree *Broussonetia papyrifera*, of the Moraceae family is used by Cherit Lahpinkhah. In Thailand the paper mulberry tree is called *Ton Sa* and the paper *Sa*. The bundles of bark strips are gathered by local people and hill-tribe people in the Nan district of North-eastern Thailand, when the bark is most succulent. It is in this state that the layers are easiest to separate from the long twigs and branches to remove the dark outer bark layer. Dried, cleaned strips of bast, are sold to the paper makers and Cherit Lahpinkhah stores her bast in a well-ventilated barn in the shade.
The preparation begins with a twelve-hour soaking of the dried bast strips in water and rinsing three or four times in fresh water the next day before cooking in soda lye (Na_2CO_3) in a metal barrel for three or four hours. The mid-lamellae between the fibres will at this point be more or less dissolved and the soda lye will now have a dark brown colour because of the substances dissolved

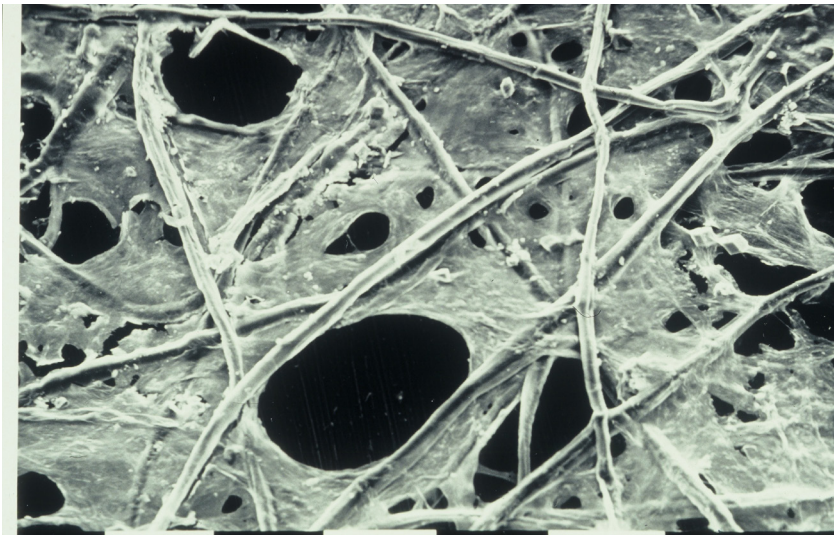
and extracted from the bast. Pieces of the outer layer of bark, such as knots or other impurities, are carefully removed by hand from the wet bast. Only the clean, light inner strips of bark are used for the pulp. The mechanical process and maceration, takes place in a Hollander beater with curved, blunt blades similar to the Japanese *naginata*. Here the strips of bast are turned heavily in water with a spoon of chloride per half an hour until individual fibres have completely dissolved into a mushy pulp. The pulp is stored in a large pot next to the vat, ready for use.

The paper mould and sheet formation: The interior measures of the mould correspond to the size of the untrimmed tissue-thin sheet of paper, measuring 55 cm × 48 cm. In Thailand a simple paper mould made of teak wood is used with a coarse woven textile fixed as a screen with bamboo spikes. Cherit Lahpinkhah uses a fixed, nylon gauze as a screen in her moulds, produced in the Ton Paw workshop and they tend to last for three years. The rather primitive Thai paper mould is reminiscent of the earliest known Chinese floating mould, but is here used as a dipping mould.

The sheet formation takes place in a rectangular cement vat, filled every morning with fresh water. For the production of 150 sheets of the tissue-thin quality only half a bucket of pulp is needed. The water and pulp are mixed in the bucket by hand, agitated at such a speed that the pulp foams and transforms into a homogeneous soup of floating fibres, stirred in the vat by a big paddle. From time to time during the sheet-formation process the mixing of fibres and water in the vat is repeated with a whisk or a paddle in order to keep the fibres afloat. The mould is only dipped in the vat once in a half-circular movement, lifted horizontally with the scooped pulp, shaken slightly and tilted vertically towards each of the four corners in order to encourage the drainage of water. The fibres are united in a thin layer on the fixed screen, and moulds with the newly formed sheets are left in pairs in the sun until dry. The sheets of paper are now ready for removal from the mould and use without further treatment.

Fig. 1. Drainage of *Ton Sa* tissue on mould with fixed screen, used as a dipping mould

Fig. 2. *Ton Sa* tissue paper is rich in amorphous substances between the fibres (Photo: Inger Søndergård. DTU)



Sample No. 2, Yoshinogami 93. *Broussonetia kazinoki*, of the Moraceae family

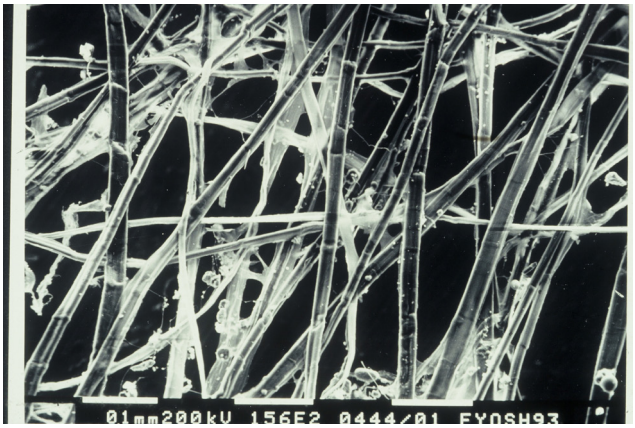
AGR Sample No. 2: Yoshinogami 93; papermaker Kazuo Konbu; field notes and observations; 9/9, 1988
Provenance: 295 Kubokaito, Yoshino town, Yoshino County, Nara Prefecture, 639-34, Japan
Preparation: The fibre, *kaji* in Kazuo Konbu's workshop does not originate from local paper mulberry trees, *Broussonetia papyrifera*, of the Moraceae family. The strips of bark are imported from the Kochi district on Shikoku Island, where another mulberry species, *Broussonetia kazinoki*, of the Moraceae family, is cultivated by papermakers and the local population in general. This plant is called *kōzo* and the highest numbers of *kōzo* plants in the country are found here, where the greatest amount of handmade paper is produced.
The bark from the *kōzo*-plant in the Kochi district is collected in the autumn. The one- or two-year-old twigs are cut just above ground level and gathered in large bunches. The dry twigs need to be steamed for a couple of hours in a copper vat covered by a large wooden barrel in order to remove the layer of bark in long strips. They are then rinsed and dried. The strips are collected in large sheaves and in this form they are sold to individual papermakers.
The preparation of the bast from the strips of *kōzo* at Kazuo Konbu's workshop begins with a 24-hour soaking in running water followed by drainage on a grating of bamboo. The outer, dark layer of bark is scraped off with a blunt knife before the bast is boiled in a lye of soda (Na_2CO_3) for four hours. At intervals the soda lye is stirred in order to ensure evenness of cooking. The bast is left to cool in the soda lye until the next morning, when the second drainage on the bamboo grating takes place. There then follows a sun and water bleaching of the strips of bast in cold running water in a large basin in front of the workshop, where amorphous substances and other water-soluble products released during the boiling are rinsed away. The strips of bast are turned at intervals in order to achieve a homogeneous natural bleaching.
Remnants of the outer layer of bark, knots and other coarse material are now carefully removed by hand from the strips of bast soaking in cold water. One more careful manual rinsing follows and the now dry bast is pressed together in firm round balls, ready for mechanical maceration. The wooden hammers in the electrically driven stamping machine turn the finely rinsed mass into a homogeneous pulp of individual fibres within an hour. The pulp is collected in nylon-lined baskets and rinsed and macerated for the last time in running water whilst pounded with a beater. Now only the pure fibres are left, resembling a white fleecy material with no hemicellulose.

The paper mould and sheet formation: The classic tripartite Japanese paper mould is used at Kazuo Konbu's workshop. The inner dimensions of the mould do not correspond precisely to the dimensions of the paper samples because it is divided into halves. The length may therefore only be estimated to approximately 100 cm and the width is 24.4 cm. A removable flexible screen, tied with twisted silk threads and bamboo splints, forms the bottom of the paper mould and is supported by transverse ribs. The screen is fixed during the formation of the sheets by the deckle, hinged to the reverse edge of the paper mould.

Fibres and water are mixed and pounded until they nearly foam together in the deep, steel-lined wooden vat by heavy movements to-and-fro of a large reed. A measure of viscous plant mucilage is added that immediately changes the pulp into a viscous consistency. This mucilage, known locally as *utsugi-nori* or *neri*, is an aqueous extraction from the inner layer of the bark of twigs from *Hydrangea paniculata*, of the Hydrangeae family. The mucilage prevents the fibres from clumping together and sinking in the vat. During the sheet formation the drainage of water through the woven screen is delayed by the mucilage, giving the papermaker time to spread the fibres evenly on the screen. The pulp is scooped up once and spread by dint of gentle shaking to-and-fro of the mould in an even layer.

The mould is then placed on a tilted board over the vat, the deckle opened and, by means of the flexible bamboo screen, a tissue-thin layer of fibres is released directly onto a wooden drying board. After carefully removing the screen from the board, it is placed in the sun for final drying of the paper. The usual Japanese procedure of pressing or smoothing the paper with a bristled brush on the drying board is not carried out here.

Fig. 3. *Yoshinogami* tissue paper with fewer amorphous substances compared to Sample No. 1 (Fig. 2)



Sample No. 3, Misugami G 118. *Broussonetia kazinoki*, of the Moraceae family

AGR Sample No. 3: Misugami G 118, Papermaker Kazuo Konbu; field notes and observations; 9/9, 1988
Provenance: 295 Kubokaito, Yoshino town, Yoshino County, Nara Prefecture, 639-34, Japan
Preparation: Kazuo Konbu has chosen, as do most other Japanese papermakers, to concentrate on the demanding, crucial preparation of the pulp and the forming of the sheet, and to leave the cultivation and the collection of the strips of bark to other people. At his workshop similar imported kōzo fibre material is used as in Kazuo Konbu's workshop for both his *misugami* paper (Sample No. 3) and his *yoshinogami* paper (Sample No. 2), but it results in two different paper qualities. This is caused by different preparation of the raw material for Sample No. 3. Here shorter soaking, drainage, less rinsing of the fibre after boiling, the addition of filling and a different sheet formation are employed. By selecting reference material from paper of similar fibre, but different technologies we learn through comparative microscopic and macroscopic analyses, the way traditional Asian paper production, unchanged for centuries, makes it possible to produce so many different paper qualities through changes and variations in the technology employed.
The preparation of the Kochi bast of the strips of *kōzo* begins with a 12-hour soaking in cold running water, either in a river, held in place by stones or in a large cement basin in front of the workshop, followed by drainage on a grating of bamboo. The outer dark layer of bark is removed manually from the wet strips with a blunt knife, if this has not already been done during the steaming of the dry twigs before the rinsing and drying processes on Shikoku Island. The boiling takes place in a copper vat filled with a soda lye (Na_2CO_3). Here the material is carefully stirred several times during the three-hour cooking process to ensure the evenness of the cooking, and the bast is left to cool in the soda lye until the following morning. The drainage and a short rinsing take place on the bamboo grating in front of the workshop. The bast is then transported to the big basin or to the river, where a thorough rinsing and sun and water bleaching takes place in cold running water. This process lasts for three days and nights and the strips of bast are turned at intervals in order to achieve a homogeneous natural bleaching. Dark fragments of the outer layer of bark remaining after the cooking process and additional rinsing are now carefully removed by hand from the strips as they float in cold water. It is an extremely time-consuming, but necessary process in achieving a regular quality of paper free from black spots. The manually cleaned strips are finally pressed together in compact round balls ready for the mechanical process. The wooden hammers in the electrically driven stamping machine turn the rinsed

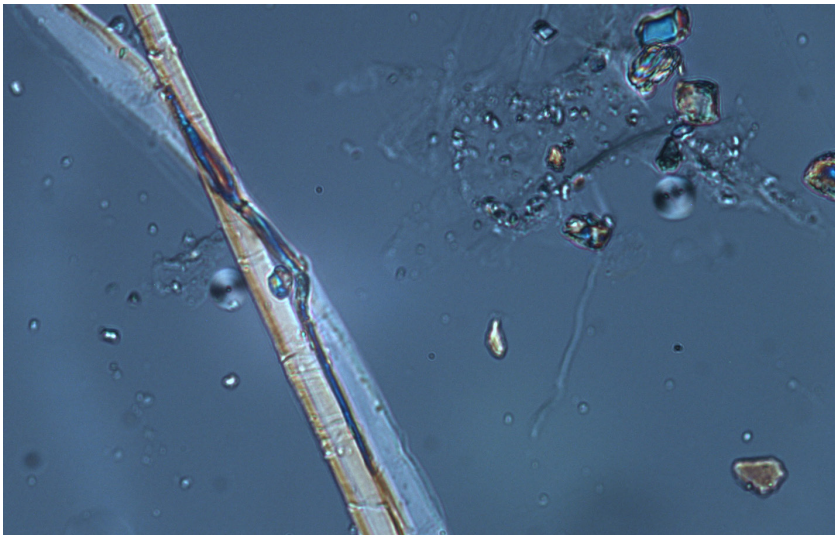
mass to an even pulp of individual fibres in one hour. They are then collected once more in nylon-lined baskets, rinsed and manually macerated by pounding for the second time for the removal of remnants of amorphous substances.

The paper mould and sheet formation: No definition of the inner length of the paper mould is possible because the sheet is trimmed. It is, however, more than 64 cm and at most double that. The inner width of the mould is 25 cm. The removable flexible screen is secured with twisted threads and bamboo splints, and the screen is supported by transverse ribs at the bottom of the mould. During the forming of the sheet the mould is connected to long bamboo poles mounted at the ceiling to facilitate the papermaker's movements of the heavy mould. Fibres and finely pulverised filling are mixed together to a uniform pulp through vigorous movements. The filling consists of crushed oyster shells or *gofun* as it is called in Japan. A large amount of viscous *neri*, *Hydrangea paniculata*, of the Hydrangeae family, is added to the pulp in a way similar to the sheet formation process of Yoshinogami 93 (Sample No. 2). As the pulp thickens, the stirring movements begin to produce a dull sound and the pulp is ready for the sheet formation.

The paper mould is dipped for the first time in a half-circular movement and lifted evenly on a horizontal axis with the portion of scooped pulp. The viscous consistence makes it possible for the papermaker to distribute it while the pulp slowly deposits the fibres. Pulp is usually scooped several times, and the paper maker manipulates the distribution of the fibres by virtue of his deft side-to-side movements of the mould, where the pulp moves from edge to edge, and he finishes the forming of the sheet by returning the surplus pulp into the vat. Two round wooded bars across the vat support the mould, when the deckle is opened. The bamboo screen with the new layer of fibres is lifted by the papermaker, turned over and released onto the tilted wooden drying board or stack of already formed sheets of paper. The bamboo screen is carefully rolled back, replaced in the mould and fixed by the deckle. The round bars are pushed aside and the mould is ready for the next sheet.

Before the next sheet of paper is released, a string is placed along one of the long edges of the former sheet in the stack. This string is intended for use in the later separation of the sheets, positioned directly on top of each other. After exerting light pressure on it, the stack is moved to the large press, where it is exposed to increased pressure. When the sheets are semi-dried, they are carefully separated from each other with the separating string. They are flattened with a long-bristled brush on a heated metal plate, where they dry within few minutes. The finished sheets of paper are then loosened and bundled together.

Fig. 4. Small starch grains show that the *neri* mucilage is added as an aid to sheet formation



Sample No. 4, Sa KT 30. *Broussonetia papyrifera*, of the Moraceae family

AGR Sample No. 4: Sa KT 30; Papermaker Cherit Lahpinkhah; field notes and observations; 25/8, 1988
Provenance: Ton Paw village between Chiang Mai and Bor Sang, Chiang Mai Province, Thailand
Preparation: The fibre in Cherit Lahpinkhah's workshop is exclusively the bark of the paper mulberry tree, *Broussonetia papyrifera*, of the Moraceae family, also for her local production of *Khoi* paper.
Papermakers in Thailand have in the past used the bark from the *Khoi* tree, *Streblus asper* Lour., for the production of *Khoi* paper, called *Ton Khoi* in Thailand. *Streblus asper* Lour. belongs to the Moraceae family similar to the paper mulberry tree that in Thailand is called *Ton Sa*.
There is a natural growth of *Khoi* trees in the surrounding mountainous regions, but collecting the strips of bark from the wild growing trees is time-consuming and preparing the pulp is complicated. It is necessary to soak the long *Khoi* twigs and steam them in weak lime to loosen the bark from the twigs. An additional manual fine rinsing of the bark strips was at least as time-consuming as the Japanese manual sorting of boiled and rinsed *kōzo* bast. Khoi bast was nevertheless for centuries chosen as the writing material for folding books in the monasteries and for legal documents of importance because of *Khoi* paper's naturally high

resistance to insect attacks in the tropical climate and its consequent durability. Cherit Lahpinkhah uses the bark from *Ton Sa* trees, as do other papermakers today in Thailand and Burma. The trees are cultivated in many regions, such as the Nan-district in north-eastern Thailand, where Cherit Lahpinkhah buys her material. She uses a shaded and well-ventilated barn as a store for the dried bundles of cleaned inner layers of bast that have been separated from the twigs without steaming and manually rinsed for remnants of the outer layer of bark when they are collected.

The preparation of the pulp begins at the workshop with the soaking of the strips in water for 12 hours. The following morning the now brownish water is poured away and the 5 cm to 6 cm-wide strips are rinsed thoroughly in three changes of water in large vats. The boiling of the strips takes place in a large metal barrel filled with lye of ash. The bast usually softens to a state when, after an hour of cooking, it can be pounded by hand. It is again rinsed in three changes of water and manually rinsed strip by strip for dark, rough fragments and fibres of the outer layer of bark and knots. The complete disintegration into individual fibres occurs after one hour's manual pounding with wooden mallets on a large block of wood. Water is added at intervals to the pulp in order to keep the right moisture during the pounding process.

The paper mould and sheet formation: The inner dimensions of the paper mould correspond to the size of the untrimmed sheet of paper, 78 cm long and 54.5 cm wide. Four pieces of bamboo are combined simply to make the mould, where a piece of woven cotton gauze fixed with bamboo pegs functions as the bottom and the screen of the mould.

In the production of *Khoi* paper Cherit Lahpinkhah uses a low rectangular zinc tray on the table as a vat. It is filled with fresh water every morning. The fixed textile screen is moistened with water before the woven mould is placed in the zinc tray, where it floats with the textile screen just below the surface of the water. A portion of hand-pounded pulp is poured into the water inside the floating mould, where it disperses and is distributed by hand by the papermaker to achieve an even layer. The surface of the layer of pulp is then smoothed with a plastic tube, before the mould with the thick layer of fibres is lifted evenly on a horizontal axis.

The new sheet of paper is left in the mould in the sun until it is dry, when it is ready to be detached from the textile screen. No pressing takes place of the thick, dry sheet of paper. As an after-treatment the *Khoi* writing paper is sized with rice water and glazed with stone. The sheets are generally used in monasteries for folding books, where several sheets are glued together into a long tape of a certain length and folded. Two qualities of *Khoi* paper are produced at Cherit Lahpinkhah's workshop: one with a smooth surface for writing and one with a more uneven and rough surface, used as a fabric for fine dresses.

Cherit Lahpinkhah learned the method for making *Khoi* paper with the floating

mould from her mother, and this method is in many ways in agreement with the classic production of genuine *Khoi* paper that until 1985 prevailed in the Bangsue area north of Bangkok. The designation *Khoi* paper at Cherit Lahpinkhah's workshop and other papermakers' workshops in Thailand, Burma and China now applies only to the technology used and not to the use of the traditional bast from the inner layers of bark of the *Ton Khoi* tree, *Streblus asper* Lour. of the Moraceae family. The *Khoi* paper of paper mulberry fibres from Cherit Lahpinkhah's workshop will most likely be less resistant to insect attacks and therefore less durable than original *Khoi* paper.

Fig. 5. *Khoi* floating mould technology is used, but paper mulberry fibres are chosen instead of *Khoi* fibres

Sample No. 5, Kōzo T 124. *Broussonetia papyrifera*, of the Moraceae family

AGR Sample No. 5: Kozo T 124; papermaker Sadashige Kikuchi; field notes and observations; 14/9, 1988
Provenance: 2050 Takase, Nomura town, Higashiwa County, Ehime Prefecture, 197-72 Japan.
Preparation: In Sadashige Kikuchi's workshop a mixture of various explicitly local species of the paper mulberry tree is used with the collective name *kaji*, *Broussonetia papyrifera*, of the Moraceae family. The workshop is situated on Shikoku Island, the main centre for the cultivation of paper mulberry and *mitsumata* plants in Japan.

During my visit no further information was given about the collection or preparation of the layer of bark. One or two–year-old twigs are usually harvested in the autumn and cut just above ground level and gathered in large bunches for steaming in a copper vat. The layer of bark may be loosened and removed in long strips after steaming for approximately two hours. The dark outer layer is scraped with a blunt knife either during the steaming process or after the soaking. The inner strips of bark, the bast strips, are rinsed in running water and hung out to dry, and are stored thus until use.

The strips of bast are soaked for 24 hours in a cement basin with running water in front of the workshop before they are cooked in a mixed solution of soda (Na_2CO_3) and caustic soda (NaOH). Seven kilograms of soda and nine kilograms of caustic soda are used to cook 80 kilograms of bast strips. Caustic soda is stronger than sodium carbonate and it is so efficient that the subsequent removal of remnants of the outer layer of dark bark and rougher fibres is less time consuming. Formerly a thick solution of lime lye would have been used in Togawa for steaming, followed by two or three days of sun and water bleaching for *togawa-senkashi*.

Once the bast strips have been cooked in the copper vat and cooled in the lye, they are transferred to the basin, where they are thoroughly rinsed in running water for between 48 and 72 hours. At intervals the material is turned over in order to achieve as even a sun and water bleaching as possible. If the paper needs to be absolutely white, as in the case of that used for sliding doors, Sadashige Kikuchi bleaches the strips of bast further in NaCl, combined with acetic acid (CH_3COOH) in order to achieve the optimum pH value for the bleaching process.

After a thorough rinse in running water the strips of bast are collected in baskets and taken to the workshop, where the time-consuming fine sorting of the material takes place. All remnants of rougher, dark fibres and residual fragments of the dark outer layer of bark are manually removed from the moist bast on a table. In other workshops the first sorting tends to take place in baskets or vats, where the strips lie in running water. During the second sorting the bast is dry. Sadashige Kikuchi's method is a mixture of these two techniques. No further information was given regarding the additional maceration of the cleaned strips that resulted in the loosening of the original fibre structure. It tends to be done in a stamper or in the *naginata*, the Japanese Hollander beater.

The paper mould and sheet formation: The inner length is estimated to approximately 130 cm and the width to approximately 63 cm. The deckle is divided into six sections, each 43 cm × 37.7 cm. The bottom of the double paper mould consists of two removable, flexible screens, where one screen is tied with twisted silk thread and bamboo splints and the other with twisted silk thread and grass culms. The double screen for the production of *senkashi* paper (double

paper) is supported by transverse ribs in the mould to which the deckle is hinged. In order to aid the papermaker's work while forming the sheet the large, heavy mould is connected by strings to two long bamboo poles to the ceiling. The rather coarse pulp is mixed with water in a rectangular vat by dint of the temporarily mounted single reed with long teeth. Viscous plant mucilage is added in the form of *utsugi-nori*, extracted from the inner layer of bark of *Hydrangea paniculata*. The pulp and mucilage are mixed together to a homogeneous heavy soup of fibres with the reed. The mucilage ensures the fibres float without forming lumps, and the reed is replaced by the mould before the sheet is formed.

The heavy mould with the six-part deckle, used for making *uwa-senkashi* paper is dipped slanting into the vat and lifted at horizontal axis having scooped a portion of pulp. It is spread evenly over the double screens with the papermaker's deft, rhythmical movements of the mould to-and-fro. Pulp is scooped once more, and this second scoop is spread across the top of the first layer of fibres. When the second scoop is evenly spread and the thickness of the sheet is satisfactory, the surplus pulp is discarded into the vat. The two round-sectioned sticks, positioned across the vat are now pushed into the centre as support for the mould until the next sheet is formed. The deckle is thrown back and the farthest bamboo screen with three sheets is lifted and positioned precisely with the layer of fibres downwards on top of the three corresponding sheets on the grass screen in front of the paper maker.

The six thin sheets are now placed together as three thick double sheets in the mould. The bamboo screen is removed from the sheets and replaced in the mould, while the grass screen that supports the three double sheets is lifted, turned and placed with the double sheets downwards on the tilted table next to the vat. The grass screen is carefully rolled off and repositioned in the mould, now ready for the next sheet, when the deckle is closed and the round-sectioned sticks pushed sidewards. Before the next three double sheets are put in place, a separation thread is placed along the long edge of the first sheets.

When the sheets are formed, a light pressure is applied to drain the stack of paper during the night. The following morning the stack is moved to a large press, where the drainage continues under heavy pressure until the stack is finally removed from the press. The still moist sheets of paper are picked up one by one and flattened with a long-bristled brush on a wooden drying board or on a heated metal plate.

Drying on the metal plate indoors is the quickest method. No further bleaching of the double papers takes place unlike with the sheets of paper drying in the sun on wooden boards. The sheet of paper that has been dried slowly is softer and less sensitive to changes in humidity than a sheet of paper that has been dried quickly. The papermaker's choice of drying technique may therefore determine the character and quality of his paper.

Fig. 6. Couching the sheet of paper with the help of the removable, flexible screen on the paper stack.

Sample No. 6, Lokta T 12. *Daphne bholua*, of the Thymelaeaceae family

AGR Sample No. 6: Lokta T 12; Papermaker Prem Bahadur Lama; field notes and observation, 29/10, 1984 & 8/10, 1985
Provenance: Goulche village, Bagmati Zone, Sindhu-Palchowk District in Himalaya, Nepal
Preparation: The bark for the production of the paper comes from the *lokta* trees that Prem Bahadur Lama cultivates at an altitude of 2600 m in a mountainous region, two-day's journey by foot from Goulche. *Lokta* is the local name for both *Daphne bholua* and *Daphne papyracea,* both of the Thymelaeaceae family. They are so similar that they are easily confused. *Daphne papyracea*, however, normally grows in West- and Central Nepal and *Daphne bholua* in East Nepal.
The collection of the bark for a year's production takes place between March and June, when the plants are at their juiciest and the bark therefore easily loosened with a longitudinal cut and removed in long strips from the twigs. The dark and coarse outer layers are immediately separated from the white inner layers and discarded on the ground, while the inner layers of bast fibres are collected in bunches and taken down to Goulche. Here paper production takes place in the autumn in the open on the river bank.
The papermaking process begins with one night's soaking of the dry strips of bast in cold running water, held in place by stones on the river bank. The following morning remnants of the outer layer, knots and other irregularities are removed

with a blunt knife, while the strips float in water. Lye of ashes is prepared at the same time in a basket. The basket is filled with ashes and wet with water that trickles through the ashes and the porous basket into the container below. If the lye of ashes is insufficiently strong, the process is repeated. The lye is thereafter mixed with water in a large iron drum, positioned in an open fire on the river bank.

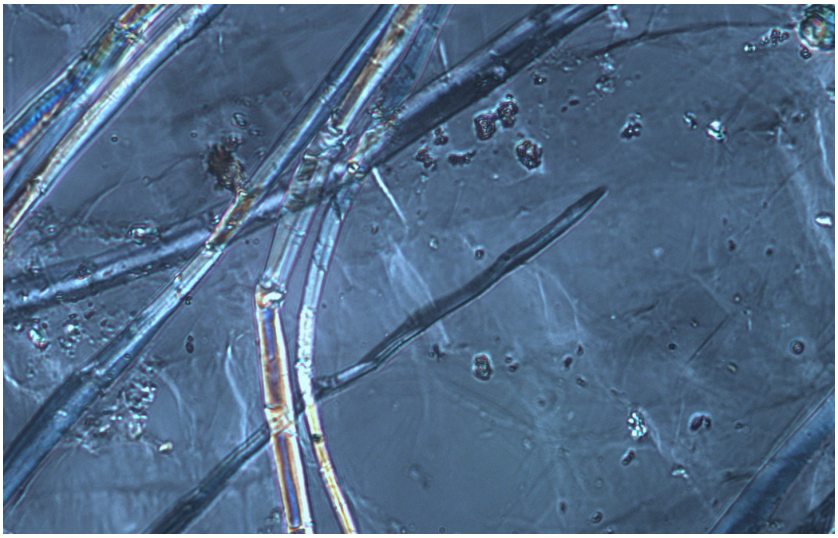
The strips of bast from the inner layer of bark are added to the boiling lye of ashes, careful stirring of which takes place at intervals. After between six and eight hours of cooking and a brief rinsing, followed by brief draining of the now brownish mass on a flat rock, it is ready for the mechanical maceration on the rock. Here the bast is rhythmically pounded with wooden mallets for one or two hours by the papermakers. A little water is occasionally added to keep the fibres at the right levels of moisture during the pounding process. The fibres are then gathered in large round balls in sizes suitable for mixing the pulp.

The paper mould and sheet formation: The inner measurements cannot be given with any degree of certainty because all four edges of the sheet would be trimmed. It is, however, larger than 50 cm × 42 cm. The screen that forms the bottom of the floating mould without the support of transverse ribs consists of a coarsely woven white textile, stretched on the mould and fixed with wooden rivets. This simple Nepalese mould is reminiscent of the earliest known Chinese paper mould in a similar way as the Thai mould used to produce paper Sample No. 2 Sa SL 32 and Sample No. 4 Sa KT 30.

The current in the river in Goulche is too strong for a floating mould and therefore two rectangular basins, fenced with stones, are constructed on the river bank. The mould is placed in the basin, where it floats with the coarsely woven textile screen just below the surface of the running water. A measure of the pulp is mixed with water in an oblong container with a beater the shape of a split twig. The papermaker pours a scoop of beaten pulp between spread fingers into the floating mould, where the fibres mix with the water in the mould and disperse by energetic rotating movements of both hands for approximately half a minute. The fibres are now dispersed in a cloudy, though relatively even layer. The mould is lifted and kept at horizontal axis, while the water quickly drains away through the textile screen, leaving the new sheet of paper on the fixed screen of the mould. Here the paper dries in the sun and wind until the sheet can be loosened. No pressing or other after- treatment is necessary. Drying the paper in the mould means that a good many floating moulds are needed at the workshop for a daily production. The thick sheets of paper need a whole day to dry if it is made by one big pouring of pulp into the floating mould. It is, however, also possible to produce a thick sheet of paper from two thinner sheets that dry much quicker. They may then be glued together to form one thick sheet.

Fig. 7. Pounding of the boiled *lokta* bast mass with mallets
(Photo: Paper maker Prem Bahadur Lama, 1984)

Fig. 8. Separated fibres of varying widths from Lokta T 12 specimen



Sample No. 7, Gampi CLLG 95, *Diphlomorpha sikokiana*, of the Thymelaeaceae family

AGR Sample No. 7: Gampi CLLG 95; papermaker Takenobu Tanino; field notes and observations, 17/9, 1988
Provenance: 1492 Najio in Shiose, Nishinomiya town, Hyogo Prefecture 669-11, Japan
Preparation: Takenobu Tanino uses the bark from *gampi* trees, *Diphlomorpha sikokiana*, of the Thymelaeaceae family for the production of *gampi* paper in his workshop. *Gampi* is a wild-growing tree with dark brown bark. There exist seven or eight different species of *gampi* trees, of which *Diphlomorpha sikokiana* is the favourite for papermaking. It has, however proved impossible to cultivate *gampi* trees, and the number of wild-growing *gampi* trees is rapidly decreasing. This makes collection of the bark difficult and increases the price of *gampi* paper, the most valued of the Japanese paper.
The bark is collected between February and May, at which time the approximately 1.50 m tall trees are most succulent. It is therefore easiest in this period to loosen and peel off the bark from the long twigs. No steaming or separation of the outer- and inner layers takes place at this stage. The preparation of the pulp begins at the workshop with soaking the bark strips in water for 24 hours. The dark outer bark may be loosened without steaming and removed with a blunt knife. The rinsed strips of inner bast are then boiled for four hours in a soda solution (Na_2CO_3) in a copper vat, where the material is left afterwards to cool overnight.
The following day the strips are thoroughly rinsed in running water and the remaining dark, coarse fragments of bark manually removed. Mechanical maceration takes place in the *naginata*, where the decocted mass turns into a viscous pulp of short, thin fibres after an hour's beating by the curved *naginata* blades. The pulp is stored in a cool place until use.
The paper mould and sheet formation: The mould is a plainer model of the traditional Japanese paper mould. The inner length of 58 cm. is similar to the untrimmed length of the sheet and the inner width of 41 cm. is similar to the sheet. Takenobu Tanino uses a rectangular mould consisting of three parts, where the bottom of the mould supports with transverse ribs the detachable flexible screen, secured with threads twisted around the bamboo splints as illustrated in photo Fig. 16. He makes his own screen of bamboo from his garden and uses flax yarn as twisted chain threads in the screen. It is covered by two layers of woven silk, on the surface of the screen an old, coarse silk material and on top of that a new, closely woven smooth silk. The silk hinders the loss of fine *gampi* fibres through the screen of laid lines of bamboo splints and results in a smooth paper surface free from imprints of the laid lines and chain lines.

Takenobu Tanino alternates during the formation of his sheet between two screens, supported by transverse ribs at the bottom of the mould. The third part of the mould, the deckle, is not hinged to the mould, but only fixed during the forming of the sheet by Tanino's thumbs. The deckle is also used between the forming of the sheets to stir the pulp in the vat, thus avoiding precipitation of the clay particles added as fillers to the pulp. The clay is extracted from caves west of Najio and a stock of the clay is kept in Takenobu Tanino's garden. There is no hanging system for the paper mould with strings connected to long bamboo sticks attached to the ceiling as it is practised among Japanese papermakers that usually work in a standing position.

Takenobu Tanino carries the total weight of the heavy paper mould during the formation of the sheets of *gampi* paper. Water, *gampi* pulp, finely pulverised local clay pigments and five measures of plant mucilage are mixed by stirring the pulp with the deckle in the low, rectangular vat, positioned on two heavy cross beams on the floor. Takenobu Tanino's plant mucilage is an aqueous extraction of the inner bark from twigs of *Hydrangea paniculata*, of the Hydrangeae family. During the very forming of the sheet he sits with his legs under the low wooden vat in a countersink in the floor. The paper mould is only supported by a round-sectioned bamboo cane along the vat and the front edge, when the finished sheet of paper is couched and another bamboo screen placed in the mould. On the right side of the vat a tilted wooden board and a horizontal board are found for the placing of the sheet of paper.

When the pulp is satisfactorily mixed by the deckle in the vat, the first screen is placed in the mould and fixed by the deckle. The paper mould is dipped in a semi-circular movement in the vat and lifted at the horizontal axis with the scooped portion of pulp that is distributed over the screen gently agitating the mould. The process is repeated three times so that a layered laminate of *gampi* fibres is created. Eventual rough fibres are removed from the sheet with tweezers. The deckle is tilted into the vat and the mould is again supported by the round-sectioned sticks, while the first screen is raised and positioned on the tilted board with the fibre layer on top of the first sheet of *gampi* paper upwards. The second screen is placed in the mould and fixed by the deckle. Before the sheet is formed Takenobu Tanino turns the first screen around and place the first sheet of paper on the horizontal wooden board. After the second scooping of the second sheet, a little water is poured over the first screen on the horizontal wooden board. After the last scooping of the second sheet and the positioning on the tilted board the first screen is carefully removed from the first sheet of *gampi* paper and again placed in the mould. Takenobu Tanino is now ready to form the third sheet of paper, while the first put aside sheet lies with the front side downwards on the horizontal wooden board and the second sheet still lies on the second screen with the front side upwards on the diagonal board.

This technology is only used in Japan for *maniai-gami* paper (*gampi* paper with a filling of clay). Takenobu Tanino's method differs in many ways from the traditional Japanese *nagashi-zuki* method. He uses no temporarily added reed for mixing the pulp, plant mucilage and eventual filling together with his loose deckle. He sits when he forms the sheet carrying the full weight of the paper mould. The pulp of *gampi* fibres is only distributed with minuscule shaking movements during the drainage of water, thus resulting in the random direction of the fibre. Takenobu Tanino's sheet formation corresponds to the earliest Japanese sheet formation, called *tame-zuki*. His slow couching of the new sheet of *gampi* paper in two steps before the screen is removed differs from the one-step method that tends to be used by other Japanese papermakers. The stack of wet sheets is left under light pressure overnight, and the following day it is further pressed for surplus water in the large press. The sheets may now be loosened one by one and smoothed out on a diagonal drying board. With a short-bristled brush covered by a piece of silk the sheets on the drying board are at first smoothed from the centre towards the edges with two strokes at the top and thereafter with two strokes at the bottom. The centre is then smoothed in the same way, after which the drying board is taken outside with sheets of paper on both sides to dry slowly in the shade.

Fig. 9. Separated *gampi* fibres with fillers of pulverised clay particles and a needle shaped crystal illustrates the addition of *neri* mucilage

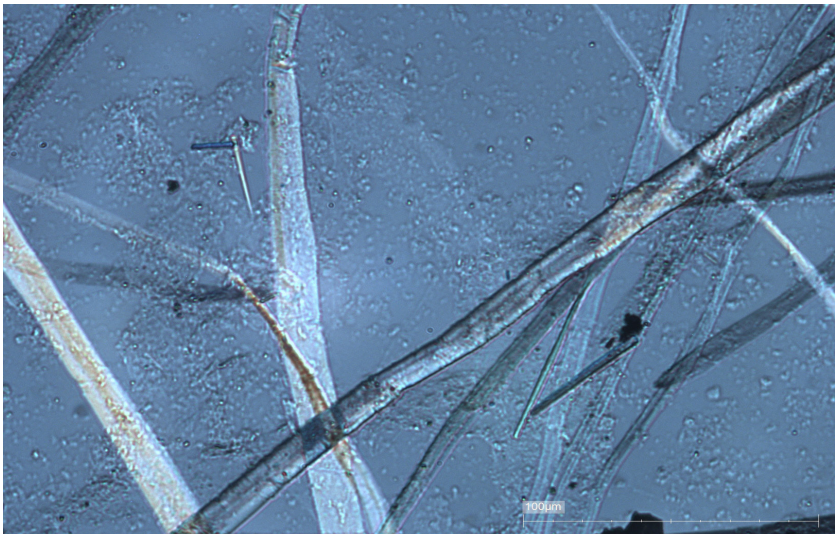


Fig. 10. Final couching of *gampi* sheet of paper on the horizontal stack

Sample No. 8, Mitsumata CL 123. *Edgeworthia papyrifera*, of the Thymelaeaceae family

AGR Sample No. 8: Mitsumata CL 123; papermaker Kazuo Ueda; field notes and observations, 17/9, 1988
Provenance: 2518 Kamiyokono, Tsuyama village, Okayama Prefecture 108-01, Japan
Preparation: Kazuo Ueda uses the bark from the *mitsumata* tree, *Edgeworthia papyrifera*, of the Thymelaeaceae family for his paper. *Mitsumata* trees are cultivated in a similar way to the *kōzo* trees for the production of paper. The tree branches are traditionally collected late in the autumn and early in spring from trees at least three years old. The twigs are gathered in bunches and placed in front of the workshop in the cold river water, where they may be kept until needed for further treatment. They are then steamed for two hours or so in a copper vat in order to loosen and remove the outer bark in long pieces before rinsing and drying it. No further information was given at the workshop about the method of collection and preparation of the bark or about the soaking of the strips in water before the removal of the outer layer.

Together with five other *mitsumata*-producing papermakers Kazuo Ueda established a co-operative workshop on the river, where a huge water wheel is used to operate the machinery. The separation of the outer bark and the inner bark is a purely mechanical process here. The dark outer bark is scraped and rinsed away with the help of a screen-rinsing machine in the workshop next to the *naginata*. It is later used for blending the boiled and softened inner bark into a pulp of individual, separated fibres. The strips of bast are rinsed in running water after the screen-rinsing and gathered in large sheaves, hung to dry in the sun in front of the workshop.

The regional occurrence of chalk coarse lye of lime ($Ca(OH)_2$) mean that it is used at Kazuo Ueda's workshop to break down the middle lamellae cementing fibres. The steaming of the inner bark takes place in an out-door copper vat. The steaming process continues until the strips are soft and easily malleable.

Nothing was mentioned of the cooling or rinsing of the steamed mass, but it most likely takes place in the river running through the village and passing the workshop. Coarse fibres and irregularities are probably manually removed and discarded in the water before mechanical maceration, which takes place in the collective *naginata*, where the original fibre structure is broken up by rotation between the curved blades. The *naginata* needs to be adjusted precisely to avoid crushing the pressure-sensitive short *mitsumata* fibres. The same applies to maceration of *gampi* fibres in the *naginata*.

The paper mould and sheet formation: A basin full of pulp and water is added to the steel-lined wooden vat and more water is added and mixed thoroughly with an electric engine rotating and beating the fibres. A bucket of water, in which crushed roots from the *tororo-aoi* plant, *Hibiscus manihot*, of the Malvaceae family soak in a coarse-woven nylon bag, stands next to the vat. The viscous extraction of plant mucilage from the crushed roots is released through a tap at the bottom of the bucket. Before it is collected in another bucket on the floor, it is strained one more time through a nylon bag. Two ladles of *tororo-aoi* is poured into the vat and mixed with the pulp, which immediately becomes a heavy viscous pulp. Together with the mucilage filling of finely ground clay is added to the pulp and thoroughly mixed with an electric engine before the formation of the sheet begins. The engine within the vat is at intervals used to avoid deposition of the added filler.

The paper mould is dipped in the vat four times per sheet in total and every time a portion of pulp is scooped, the mould is shaken rhythmically horizontally three times to-and-fro causing the pulp to flow over the screen. When the fibres are distributed in an even four-layered laminate with a dominant fibre direction parallel to the chain lines, the surplus pulp is discarded back into the vat. The deckle is opened and a small fold or double edge is made at the front edge of the screen, intended for a later separation of the moist sheets in the stack. Kazuo Ueda lifts

the bamboo screen with the new sheet of paper and turns it around for placing on an inclined table next to the vat. Two guiding sticks at the edge of the table help to the correct couching on the pile of the paper sheets already put aside. Light pressure is applied to the finished stack of *mitsumata* paper until the following morning, when the drainage is intensified by the electric press.
When the stack is semi-moist, it is possible for Kazuo Ueda's wife to separate and one by one loosen the sheets carefully by help of the double edge tool and flatten them on wooden drying boards with a long-bristled brush. There is room for several sheets at a time on the drying boards placed outside for a slow drying in the shade.

Fig. 11. Scooping *mitsumata* pulp with the hinged dipping mould

Sample No. 9, Local Kōzo SB 125. *Broussonetia kazinoki*, of the Moraceae family

AGR Sample No. 9: Local Kōzo SB 125; papermaker Yasuo Kobayashi; field notes and observations, 5/9, 1988
Provenance: 2851-1 Kadoide, Takayanagi town in Kariha region, Niigata Prefecture, 945-15 Japan
Preparation: The bast fibre in Yasuo Kobayashi's workshop comes from the mountainous region around Takayanagi, where the papermaker grows paper mulberry trees on three acres of land on a slope to the east. The bushy paper mulberry trees, *Broussonetia kazinoki*, of the Moraceae family, with broad leaves reach a height of about 1.20 m in September. All side branches and twigs are trimmed in November and April in order to be sure of twigs with few knots, thus making it possible to remove the bark in continuous strips

of the twigs. Yasuo Kobayashi collects material for the year. In November twigs between 1 m and 2 m in length are harvested, now between 2 cm and 3 cm thick. They are cut just above ground level and gathered in bundles that need to be steamed for two hours or so before the bark can be removed from the twigs. The strips of bark are rinsed, before being dried and gathered in bundles for storage in the barn until use. The entrance to the barn is on the first floor because of the snow during the winter completely covers the ground floor and doors to the houses.

By cultivating their own raw materials, Yasuo Kobayashi and eight other papermakers in the region secure homogeneous fibres of the same species and age. If fibres of different ages, and therefore of different levels of coarseness, are mixed, it is impossible to achieve a sufficiently homogeneous paper quality. Fibres from different paper mulberry species will also result in an uneven paper quality.

There was some confusion about the paper mulberry species that Yasuo Kobayashi grows. During our visit both *kōzo* and *kaji* plants and their Latin names were mentioned. Misunderstandings may occur because *kaji* is the local name of *Broussonetia papyrifera* of the Moraceae family and *kōzo* the local name of *Broussonetia kazinoki* of the Moraceae family. The confusion was primarily caused because Yasuo Kobayashi uses his own *kōzo*, *Broussonetia kazinoki*, and Kochi *kōzo* for various other paper qualities in his workshop.

Preparing the dried strips begins with 72 hours' soaking and sun and water bleaching in running water. This is followed by removal of the dark outer layer by scraping it with a blunt knife. The boiling takes place in the centre of the workshop in the copper vat, where the twigs were earlier steamed. The strips of bast are boiled in a 15% soda solution (Na_2CO_3), but a milder solution is used for strips of bast from plants younger than one year. Remains of lye on the bast material would need a thorough rinsing in running water in order to avoid future attack on the paper by insects. Then, the removal of black residue of bark takes more time. Yasuo Kobayashi therefore chooses soda because more impurities are removed from the strips of bast and that makes the paper less vulnerable to insect attacks. The boiling process lasts five hours and is followed by a thorough rinsing in running water of the now soft mass of strips and by careful removal of coarse fibres, remnants of the outer layer and other impurities.

During the winter Yasuo Kobayashi utilises the huge amount of snow to bleach the boiled cleaned strips. They are placed in the snow for two weeks when the weather is good. The mechanical treatment takes place in an electrically driven stamper with a rotating wooden block and in the *naginata*, where the mass is finally rotated by the curved blades for half an hour's maceration.

The paper mould and sheet formation: The inner length of the mould and that of the untrimmed sheet is 92.5 cm. and the width is 62.5 cm. The bottom

of the mould with transverse ribs consists of a removable flexible screen, tied with twisted silk threads and bamboo splints and treated with persimmon juice. The juice makes the screen more water-proof. On top of the screen a finely woven piece of silk is fixed in order to reduce the impression of the screen structure and thus resulting in a smoother surface. The transverse ribs at the bottom of the mould support the removable flexible screen, fixed by the deckle during the formation of the sheet. The deckle is hinged to the mould that is connected with strings to long balancing bamboo poles to the ceiling when the sheet is formed.

A suitable portion of the pulp, now similar to wadding, is mixed in the steel-lined vat with water by help of a double reed. Yasuo Kobayashi stirs the mixture vigorously with a reed until it is a foaming soup of pulp before the plant mucilage from the crushed roots of *tororo-aoi*, *Hibiscus manihot*, of the Malvaceae family, is added. The pulp immediately becomes more viscous and the movements of the pulp in the vat begin to make deeper noises. The crushed *tororo-aoi* roots have been soaked in cold water the night before, and the presence of gelatinous threads between the paper maker's fingers indicate that the filtered extract is now ready. During winter the *tororo-aoi* extract may be used for an entire day without losing its strength and viscosity, but in warm weather its effect diminishes within between 15 and 20 minutes and results in a thin pulp. Winter is considered as the best season for papermaking.

When the double reed is removed, the paper mould is prepared for use and connected with the cord drive to the ceiling that eases the papermaker's movements of the dipping mould. The removable flexible screen is moistened before the sheet formation begins. A measure of pulp, scooped by the mould, flows in small waves over the screen forwards and backwards and from side to side thanks to Yasuo Kobayashi's deft rhythmical movements of the mould. The process is repeated and the surplus pulp is returned to the vat, when the distribution of the fibre and the thickness of the sheet is satisfactory. The paper mould is now supported by two round-sectioned sticks, positioned across the vat and after half a minute's drainage the deckle is opened, the screen lifted with the new sheet of paper and placed with the sheet upwards on a slant table. Here it rests for another minute before the screen is turned around and the sheet of paper placed on the dampened horizontal board. The screen is rolled back and placed in the mould, now ready for the next sheet, when the deckle is closed and the round-sectioned sticks pushed aside. Before the second sheet of paper is couched on the horizontal stack, a narrow nylon ribbon is laid down at the long edge of the sheet in the stack. This ribbon facilitates the later separation of the still moist sheets during the drying process. Two vertical guiding sticks in front of the board mark precisely, where the wet sheet would be couched.

When all the sheets are formed, the bamboo screen is thoroughly rinsed and

dried. The paper stack is covered with a nylon net and the mould placed on top of the pile, resulting in a light pressure on the sheets to drain them during the night. The following morning the stack is moved to the screw press, where the pressure is considerably increased and thereby also the speed of drainage. After some time in the press, it is possible to remove the sheets one by one from the pile by help of the separation threads and to flatten them on a drying board with a long-haired horse-hair brush. If there is too little sunshine for drying outdoors, the paper stack is buried in the snow until there is sufficient sunshine to dry and bleach.

Fig. 12. Mixing pulp and mucilage with the reed before the formation of the sheet takes place

Sample No. 10, Lokta L 10. *Daphne bholua*, of the Thymelaeaceae family

AGR Sample No. 10: Lokta L 10; papermaker Prem Bahadur Lama; field notes and observations, 29/10, 1984 & 8/10, 1985
Provenance: Goulche village in Bagmati-zone, Sindhu-Palchowk District, Nepal
Preparation: The bast for a year's production is gathered in spring. The *lokta* trees that Prem Bahadur Lama cultivates on the high-lying, north-facing slopes in the mountains are most succulent at this time. *Lokta* is the local name for *Daphne bholua*, of the Thymelaeaceae family. The bark is removed

with a lengthwise cut from the branches. The outer layers are left there and the strips of the light inner bark are collected and transported down to the workshop in Goulche. Here the preparation begins with a night's soaking in running cold water for the dry strips of inner bark. The next morning the softened strips are cleaned with a blunt knife in the river of the remnants of the dark outer bark and knots. Boiling takes place in coarse lye of ashes and the mass is regular stirred over a period of between 6 and 8 hours. Fresh lye of ashes is occasionally added until the right consistency of the now brownish coloured mass of the strips of bast has been achieved. A brief rinsing in running water is then followed by draining the bast on a flat rock. Here the mechanical maceration takes place and two papermakers process the half boiled bast under intensive pounding with wooden mallets for between 1 and 2 hours. Water is added at intervals to maintain the necessary moisture. The original fibre structure is then completely softened and the pulp of individual fibres is ready for use.

The paper mould and sheet formation: The inner length of the mould is 74 cm. and the width 52.2 cm.; a similar size to the untrimmed sheet of paper. The bottom of the mould consists of a screen of open-woven linen textile, spiked to the wooden frame with wooden nails. This plain type of mould could be modelled on the earliest floating moulds used by Chinese papermakers, when the knowledge of paper production in the first millennium reached Nepal.

The pulp is mixed with water and mixed together in a narrow container with a kind of beater in the shape of a forked branch that is rapidly rotated by a cord drive. After this process the papermaker pours a measure of diluted pulp into the mould, floating with the textile screen just below the surface of the water in a small basin. Here the papermaker mixes the pulp and the water with a rapid rotation of both hands for half a minute, thus distributing the fibres in a fairly even layer. The mould is lifted at the horizontal axis just above the surface of the water, where it is kept still while the water quickly drains through the fixed textile screen into the basin. The mould with the new sheet is then positioned almost vertically on the river bank with sufficient sun and wind to dry the thin paper.

The sheet cannot be removed from the mould until it is dry. This procedure therefore requires many moulds because a new sheet cannot be formed with the floating mould until the former one is removed.

Fig. 13. Manual distribution of the pulp of *lokta* fibres within the floating mould (Photo: Paper maker Prem Bahadur Lama, 1984)

Sample No. 11, Local Kōzo LGB 102. *Broussonetia kazinoki*, of the Moraceae family

AGR Sample No. 11: Local Kozo LGB 102; papermaker Yasuo Kobayashi; field notes and observations, 5/9, 1988
Provenance: 2852-1 Kadoide in Takayanagi town, Kariha County, Niigata Prefecture, 945-15, Japan
Preparation: As with Sample No. 9, the bark comes from the Takayanagi region, where Yasuo Kobayashi like eight other regional papermakers grows his own local *kōzo* plants, *Broussonetia kazinoki* of the Moraceae family. The collection of the raw material for paper making takes place in winter. The twigs, between 1 m and 2 m in length, are cut just above ground level and collected in bundles. They are placed vertically in the copper vat and steamed until the bark has contracted so much at the ends that it is easily loosened and with a lengthwise cut removed from the twigs. After the separation the strips are rinsed and dried for storage in the barn until use.
The preparation continues with soaking for several days in running water at the same time as the sun and water bleaching. The dark outer bark is removed from the strips with a blunt knife, but the greenish layer between the outer and inner bark is only partly removed. The strips of paper (Sample No. 11) therefore consist of some added green middle-layer bast to the white inner layer of bast, resulting in a white paper with a greenish tint. The boiling of the bast from the one-year-old twigs takes place in a 15% soda solution (Na_2CO_3) and takes

five hours. The soft strips are then rinsed and bleached in a solution of sodium chloride ($NaClO_2$), followed by a second thorough rinsing in running water. Careful removal of impurities, coarser fibres and other irregularities most likely takes place in water at this stage of the process, but no details were given. The mechanical maceration begins in the electrically driven stamper and is finished in the *naginata* in order to ensure that all fibres have been completely removed from their original structure.

The paper mould and sheet formation: The inner length of the mould or rather of the deckle is 114 cm. and the width 59 cm. The measurements are identical with the dimensions of an untrimmed sheet of paper. As mentioned above in connection with Sample No. 9, the screen is tied with twisted silk threads and bamboo splints, impregnated with persimmon juice and covered with a closely woven piece of silk. The mould is connected by means of strings to two long balancing bamboo poles attached to the ceiling. During the formation of the sheet the screen is secured by the hinged deckle and supported by the transverse bars at the bottom of the mould. Pulp and water are mixed together in the vat with the double reed until the pulp is a homogeneous fibre soup. Plant mucilage from the crushed roots of *tororo-aoi – Hibiscus manihot*, of the Malvaceae family, is added and thoroughly blended with the pulp with the double reed before it is removed. The paper mould is dipped repeatedly and pulp is scooped and distributed with rhythmical to-and-fro and side-to-side movements of the mould in a laminate of several layers with stratified perpendicular fibre directions, similar to plywood. The direction of the fibre parallel to the chain lines of the screen, however, dominates because the mould is moved to-and-fro more than side to side and because the directions of the fibre in the first and last of the three to five layers are parallel to the chain lines. When a satisfactory distribution and thickness of the sheet is achieved, the surplus pulp is thrown back into the vat. The new sheet of paper rests on the screen for half a minute in the mould, now supported by two round-sectioned sticks athwart the vat and half a minute with the front up on the drying board. Yasuo Kobayashi then turns the screen around with the front down and places the sheet on the stack. The screen is carefully removed and the separating thread placed along the long edge of the paper.

After a night of light pressure exerted on the stack of sheets, it is further drained under greater pressure. With the help of the separating threads the sheets are lifted one by one and smoothed out by a long-bristled brush on heated stainless-steel plates. The temperature of the plate is adjusted to the thickness of the sheet of paper, and for the paper quality of Sample No. 11 the temperature is 50° Celsius. After between 3 and 4 minutes drying the paper sheet may be detached from the plate. Rapid drying results in a somewhat harder, stiffer paper quality than paper dried slowly on a wooden board in the shade.

Fig. 14. Filtering mucilage extraction from *tororo-aoi, Hibiscus manihot*, of the Malvaceae family

Sample No. 12, Kōzo Mino 88, *Broussonetia kazinoki*, of the Moraceae family

AGR Sample No. 12: Kozo Mino 88; papermaker Kozo Furuta; field notes and observations, 8/9, 1988
Provenance: 1914 Warabi in Mino town, Gifu Prefecture, 501-37, Japan
Preparation: Kozo Furuta prefers the bast from *kōzo* trees, *Broussonetia kazinoki*, of the Moraceae family, from the region north of Tokyo to the bast from the local *kōzo* trees. The further north one goes, the finer and thinner are the fibres because of the cooler climate. The total process of collecting the *kōzo* twigs and steaming, separating the layers of bark and twigs, as well as the outer and inner layers of bark are thus already done when Kozo Furuta receives the bundles of dried strips of inner layers of bark. In the workshop in Mino the work begins with the strips' being soaked in water overnight and continues the following day with the boiling of the bast in a large copper vat in a solution of soda (Na_2CO_3). The mass is regularly turned and stirred during the cooking in order to achieve a homogeneous treatment of the material. The boiling process ceases, when the strips of bast are softened so much that they may be mashed by hand. Not until the following day, when the material has cooled down in the copper vat are the strips gathered in baskets and taken to

the stony river in front of the workshop. Here the boiled strips float in the cold, fresh water for three days and are thus rinsed and bleached by the sun and water. During this process the strips are turned over at intervals.
Now follows the careful sorting of the fibre in water. This takes place indoors in a long building, where the baskets with the strips of bast are placed in a groove in the floor filled with water. Five women are engaged with discarding all coarser fibres, knots and other impurities, an activity essential in order to achieve the perfect result of pure white paper free from blemishes. The women kneel for hours on the floor along the groove to complete this time-consuming, meticulous stage. The cleaned bast is collected in large balls that, once dry, are manually cleaned once more. The bast balls are moistened with a little water one by one and mechanically macerated by pounding on a large wooden board with two hand-held mallets with carved patterns. The bast is at intervals moistened with a little water and after an hour of pounding becomes a soft mass of finely separated fibres. They are once more taken in nylon-lined baskets to the river and placed in the water at the bank, where the bast in the baskets is macerated through heavy manual mixing.
The paper mould and sheet formation: The inner length of the mould, or rather of the deckle, is 92 cm. and the width is 64 cm. The measurements are identical to the dimensions of the untrimmed sheets of paper. The bottom of the mould with the transverse ribs consists of a removable flexible screen, tied with twisted silk threads and bamboo splints. During the formation of the sheet the screen rests on the transverse bars at the bottom of the mould. The deckle is connected to the paper mould by hinges on one of the long edges, and the mould is connected by a cord drive to two long bamboo poles to the ceiling. The screen is produced in the town by Kozo Furuta's brother. He is one of the few screen makers in Japan still to practise this special handicraft. The tying, or weaving, of the screen begins with the production of approximately 2.000 thin bamboo splints. These splints are equally rounded along whole length by passing them through a metal plate with tiny holes. The bamboo splints are shorter than the screen and therefore additions are needed at intervals. At those places the chain lines reviled in paper made with such screen are twofold positioned with short mutual distances. The production of the bamboo splints and the bamboo screen with the twisted silk threads takes between four and five days.
Pulp and water are thoroughly mixed in the rectangular vat by vigorous movements to-and-fro of the temporarily mounted reed. As soon as the thin soup of fibres is homogeneous, a portion of plant mucilage is added. At Kozo Furuta's workshop a watery extraction of the crushed roots of *tororo-aoi*, *Hibiscus manihot*, of the Malvaceae family, is used. After the removal of the reed, the moistened bamboo screen is placed in the mould, where it is fixed by the deckle when closed. The paper mould is dipped twice to

scoop the pulp and the mould is each time shaken quickly and rhythmically to-and-fro twice and once from side to side, thus maintaining the constant rippling of the pulp. The fibres settle parallel to the chain lines because of the papermaker's guiding movements of the mould. The last surplus remnant of pulp is discarded into the vat before the mould is supported by the two round-sectioned sticks positioned across the vat.

The deckle is opened and the bamboo screen lifted and turned with the layer of fibres facing down for couching the new sheet of paper on the tilted wooden board next to the vat. The screen is carefully lifted, thus leaving the wet sheet of paper with the clear imprint of the screen structure of chain lines and laid lines. A separating string is placed along the long edge of the sheet. When the last sheet of paper is couched, the stack of paper is drained under light pressure overnight. The following morning the drainage process continues under greater pressure until the sheets are sufficiently dried but moist enough to be separated with the help of the strings between the sheets. Each sheet is loosened and flattened with a long-bristled brush on a wooden drying board. Sheets are mounted on both sides of the boards that are placed outside in the sun and at intervals turned. Here the sheets remain until dry. They are then loosened, folded or piled and trimmed.

Fig. 15. Careful sorting in water of the *kōzo* fibres before the mechanical maceration

Fig. 16. Production of screens of bamboo splints and twisted silk threads

Sample No. 13, Tengujoshi T 107, *Broussonetia kazinoki*, of the Moraceae family

AGR Sample No. 13: Tengujoshi T 107; papermaker Sajio Hamada; field notes and observations, 13/9, 1988
Provenance: 541 Kashiki, Ino town, Agawa County, Kochi Prefecture, 781-21, Japan
Preparation: Sajio Hamada uses the bast from the local *kōzo* trees, *Broussonetia kazinoki*, of the Moraceae family, that are cultivated all over Kochi on Shikoku Island. A video about the production of *tengujo* paper showed the way one-year-old twigs are harvested in November and steamed in standing bunches in a copper vat. The vat is covered by a reversed wooden barrel that holds the steam in the barrel. When the bark is saturated with vapour and softened, it may be removed in one piece from the twig with a lengthwise cut. The dark and the green outer and middle layers are scraped off with a blunt knife and the bright inner layer is rinsed and collected in bundles that are then hung to dry. The next step in the process is to soak the dried strips overnight in running water. The following morning a solution of soda (Na_2CO_3) and slaked lime ($Ca(OH)_2$) is mixed together in the copper vat, where the strips are boiled for four hours with regular stirring in order to achieve a homogeneous mixture. Once the mixture has cooled, the bast is transported in large baskets to the stone-hinged basin by the river. Certain that the strips will not float away they are cleaned

here for water-soluble substances by rinsing in running water for between 1 and 3 days. Little by little the strips are gathered in large balls that are drained by pressing and rinsed once more when dry.

The paper mould and sheet formation: The inner length of the deckle is approximately 158 cm. The inner width of the deckle is 54 cm., similar to the width of the sheet of paper. The traditional loose-lying flexible screen is tied with twisted threads and bamboo splints. A closely woven piece of silk is mounted on top of the screen in order to achieve an even surface free from an imprint of the screen structure of chain lines and laid lines. Transverse ribs at the bottom of the mould support the removable screen during the formation of the sheet. The deckle is hinged to one of the long edges of the large mould, connected with strings to two long balancing poles attached to the ceiling.

The formation of the sheet begins as usual by mixing the pulp and water together with the temporarily mounted single reed that beats quickly backwards and forwards in a deep rectangular vat. The formation of *tengujo* paper takes between 3 and 4 minutes per sheet, and in order to keep the fibres floating and evenly distributed in the pulp a rather generous amount of plant mucilage is added to the pulp from the crushed roots of *tororo-aoi*, *Hibiscus manihot*, of the Malvaceae family. Pulp and mucilage are thoroughly mixed with the reed that is afterwards removed. The mould is dipped three or four times into the now viscous pulp, where the mucilage contributes to a delayed drainage during the long formation process. The first time only a small portion is scooped into the mould and Sajio Hamada maintains a steady rhythmical movement to-and-fro six times and three times from side to side. The second portion of pulp is scooped and Sajio Hamada increases his movements like a crescendo, throwing the pulp to-and-fro like waves in the surf. The fibres gradually settle in layer upon layer, and the third scoop of pulp is once more distributed with diminishing rhythmical movements, a diminuendo. This stage concludes by discarding the surplus pulp back into the vat.

The mould is then supported by the two round-sectioned sticks positioned across the vat, while the deckle is opened. The front edge of the screen is bent back, thus forming a double edge approximately 1 cm. wide along the paper's edge. Sajio Hamada lifts the screen with the newly formed laminate of fibres, turns it over and places the sheet of paper on the large tilted table next to the vat. The screen is carefully rolled off the wet sheet and replaced in the mould, now ready for the next sheet. The finished paper stack is drained under light pressure between two wooden boards overnight. Pressing evenly on a surface of this size is difficult and the pile of the still-wet sheets is cut into two halves before the final part of the pressing process. The two halves are placed on top of each other in a high stack that is again lightly pressed until the sheets are suitably moist for careful separation into single sheets. The drying process

takes place on a metal plate heated by wood, where the sheets are smoothed out with a long-bristled brush. It is a quick drying process that takes place in the shade.

Fig. 17. Sheet formation of *tengujoshi* paper

Sample No. 14, Kōzo Uda CL 12. *Broussonetia kazinoki*, of the Moraceae family

AGR Sample No. 14: Kōzo Uda CL 12; papermaker Michiharu Kubo; field notes and observations, 9/9, 1988
Provenance: 188-1 Kubokaito, Yoshino town, Yoshino County, Nara Prefecture, 639-34, Japan
Preparation: It is uncertain whether Michiharu Kubo received the dried, rinsed *kōzo* bast strips, *Broussonetia kazinoki*, of the Moraceae family, from the Kochi district on Shikoku Island as the other papermakers in the town, or whether she used the bast from the local *kaji* trees, *Broussonetia papyrifera*, of the Moraceae family. The bast could be imported *kōzo* bast of a similar species as that used by Kazuo Konbu at his workshop in Kubokaito (Sample No. 2 and 3). There the collected one-year-old twigs are steamed for two hours before the bark may be loosened in long strips. The dark outer layer of bark is scraped off strip after strip with a blunt knife, followed by a short rinse before drying and storing the cleaned material.
No details were given regarding the preparation of the pulp at the workshop, but some conclusions may be drawn from the tools in the workshop. The outdoor

copper vat is clearly used for the boiling of the strips after they have been soaked in water. Boiling the bast in Kubokaito either takes place in a soda solution (Na_2CO_3) or in a mixture of lye of soda (Na_2CO_3) and slaked lime ($Ca(OH)_2$). The traditional and most likely treatment after boiling is that the mass cools in the copper, followed by three days of rinsing in running water and sun and water bleaching. A careful rinsing in water of impurities and coarse fibre fragments follows. Boiling in lye of ashes, like in Nepal and Thailand, is almost unthinkable in Japan today. The *naginata* in the workshop clearly indicates that the mechanical maceration of the boiled, rinsed, bleached and sorted bast takes place by washing in water between the curved blades of the *naginata* rather than by stamping or manual pounding with wooden mallets.

The paper mould and sheet formation: The inner length and width of the deckle are 145 cm. and 32 cm. respectively, similar to the untrimmed dimensions of a sheet of paper. The bottom of the dipping mould with the transverse ribs consists of a removable, flexible screen, tied with twisted silk threads and reeds of grass. When the sheet is formed the screen is fixed by the hinged deckle, and the forming of the sheet with the heavy mould is made easier by two pliant bamboo poles attached to the ceiling, connected to the mould by strings.

The rectangular vat is steel-lined similar to the *naginata*. Pulp, water and finely pulverised local clay are mixed together in the vat with vigorous movements of the temporarily mounted single reed into a foaming homogeneous soup of fibres. A measure of *utsugi-nori* or *neri* of plant mucilage from the inner layer of the bark of branches from *Hydrangea paniculata*, of the Hydrangeae family, is added to the vat and mixed with the pulp before the reed is removed from the vat.

With the paper mould Michiharu Kubo scoops pulp only twice and each time a tiny tilt of the mould, kept rather low just above the surface of the pulp in the vat means that the pulp passes over the screen one time to-and-fro. When the sheet is formed after the second scooping, the mould is supported by two sticks positioned across the vat. The deckle is opened and a narrow double edge is made by a small fold along the front edge of the sheet. The screen is lifted and turned with the new sheet of paper downwards for placing on the horizontal wooden board with two guiding poles next to the vat. The screen rests for a moment before it is rolled off the wet sheet of paper and replaced in the mould, ready for the next sheet. One wet sheet is placed directly on the previous one with no other separation than the small double edge.

The finished stack rests under light pressure for a night of slow drainage, which is intensified in a large wooden press the next day.

The addition of plant mucilage to the pulp leads to a greater force of internal attraction between the fibres in the single sheet than between the fibres from the two neighbouring sheets in direct contact with each other. A double edge fold

or a separation string is sufficient for the papermaker to know where to separate the still-wet sheets, when the water content of the paper stack is suitable for the drying process and for transferring them one by on to an electrically heated metal plate.

Fig. 18. Separated *kōzo* fibres with fillers of clay particles and needle-shaped crystals from *neri* mucilage

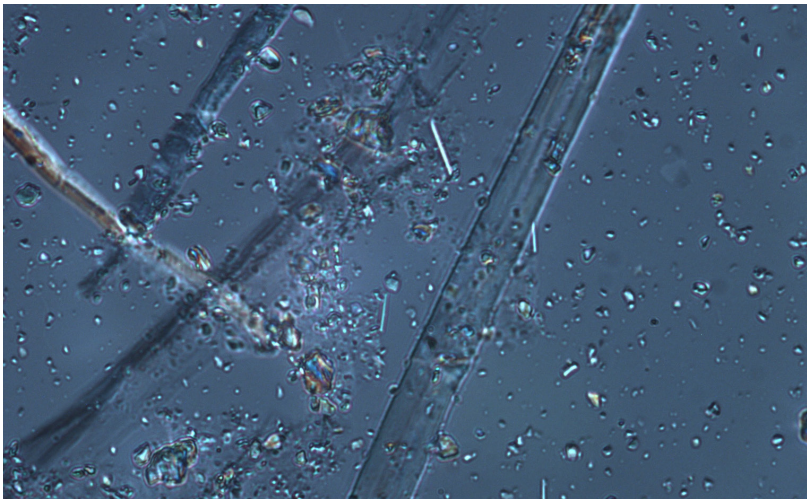
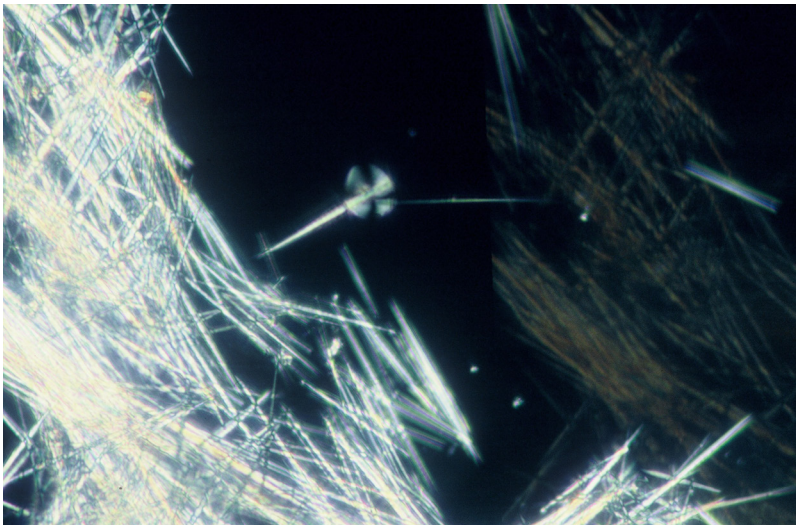


Fig. 19. Small starch grain, mixed with needle-shaped crystals from the inner layer of bark of *Hydrangea paniculata*, of the Hydrangeae family. Extraction from this plant, *utsugi-nori* or *neri*, is used by Japanese papermakers as mucilage



Conclusion

Dr Julius von Wiesner, Professor of Botany in Vienna, founded the scientific analysis of paper in 1886. He built his analysis on optical microscopic observation of paper specimens, chemical tests and identification of the fibres through comparative analysis of his botanical reference material from plants. This optical macroscopic observation of new Asian hand-made paper of known origin create, together with microscopic observation of the specimens, a valuable reference for future case-studies of paper documents and works of art made of paper. It shows how important it is to combine the identification of both the raw material and the technology used to obtain valid historical information.

Macroscopic information for possible identification of the origin of paper and its condition is to be found in the paper itself through examination of the traces of the technology. The macroscopic analysis consists of documentation and registration of the whole piece of paper, including its morphology, surface, hue, fibre distribution, quality and impression of the screen and the drying process. Combined with a microscopic analysis of tiny paper specimens, information is collected regarding the condition and origin of fibres, the presence or absence of amorphous substances, starch grains and crystals, thus documenting the technologies and fibres used. The reference material of 14 samples of paper described here serves in comparative analyses as a useful key to pinpoint the possible provenance and date of anonymous Asian hand-made paper documents from the evidence of the technology and fibres used.

Bibliography

Catling D. & Grayson J., *Identification of vegetable fibres*, London 1982.

Harders-Steinhäuser M., *Mikroskopische Untersuchung einiger früher ostasiatischer Tun--huang-Papiere*, Das Papier, April/M 1969, Heft 4-5, pp. 210-212, 272-276.

Ilvessalo-Pfäffli M., *Fiber Atlas, Identification of Papermaking Fibers*, 1995, pp. 292-304.

Rischel A-G, *Natural plant sizing agents in Oriental papers and the importance of re-sizing such papers after washing*, Conference Papers Manchester 1992, The Institute of Paper Conservation. pp. 222-227.

Rischel A-G, *Analysis of fibers used for oriental papermaking compared to botanical descriptions, aiming at establishing an identification key* Cultures of Silk Road and Modern Science, Vol. 2, Scientific Analysis, Conservation and Digitization of Central Asian Cultural Properties, Osaka 2005, pp. 21-30.

Rischel A-G, *Through the Microscope Lens: Classification of Oriental Paper Technology and Fibres*, Looking at Paper evidence & interpretation, Symposium Proceedings, Toronto 1999, pp.179-188.

Trier J., *Ancient paper of Nepal*, Jutland Archaeological Society Publ. Vol. X 1972.

W.F. Tschudin, *Älteste Papierbereitungsverfahren in Fernen Osten,* Sonderdruck aus Textil-Rundschau Heft 12, 1958, pp. 1-11.

Wiesner J., *Mikroskopische Untersuchung alter Ostturkestanischer und anderer Asiatischer Papiere nebst histologischen Beiträgen zur mikroskopischen Papieruntersuchung*, Denkschriften der Kaiserlichen Akademie der Wissenschaften Wien 1902, pp. 1-50.