The History and Treatment of the Papyrus Collection at The Brooklyn Museum

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The Brooklyn Museum possesses one of the most important collections of papyri in the United States. The collection is a rich source for study and publication by Egyptian scholars and papyrologists, yet it was not until 1990, in preparation for a storage upgrade and for reinstallation of new Egyptian galleries, that the collection was reviewed for the first time by the conservation department. This situation is not surprising considering the scarcity of conservators specializing in papyrus. At The Brooklyn Museum this material became the responsibility of the paper conservation department from necessity and through an interest, on the part of the paper conservators, to undertake the study of papyrus and to discover whether certain paper conservation techniques could be successfully adapted to the conservation of papyrus.

The initial phase of conservation, begun in 1990, was a search of the conservation literature and various publications in order to compile a comprehensive bibliography and article file on the history, manufacture, scientific investigations and research and the reported treatments of papyrus. A second phase of conservation was obtaining papyrus stalks and making sheets in order to become familiar with the material and its manufacture and also to provide samples for experimentation and testing of various conservation treatments. The third phase involved investigations into appropriate housing for exhibition and storage and the final phase of conservation was the examination, analysis and treatment of papyrus from the collection.

A papyrus sheet is a laminate structure composed of fibers running vertically in one layer and horizontally in the other layer. This is what gives papyrus it's characteristic grid pattern when viewed in transmitted light. The sheets are made from the triangular, inner pith of the Cyperus papyrus L., a sedge plant, which often reaches 9-18 feet in height. In antiquity, the plant grew abundantly along the banks of the Nile River, in marshy areas. At present the plant grows indigenously in the area of the upper Nile in the Sudan and along the Ciane River near Syracuse, Sicily. Recently it has been cultivated near Cairo.

After the stalk of the plant is cut its green outer rind is removed exposing a soft, white pith. The pith material is composed mainly of cellulose (54-68%) and lignin (32-24%); the proportions are based on variables such as age, manufacturing process and environmental effects [Weidemann and Bayer 1983, 1230]. A magnified cross-section view of the pith reveals parenchyma cells surrounding vertical fibrovascular bundles and hollow air ducts. The fibrovascular bundles transport food and water from the roots to the flowerhead and give rigidity to the structure. The hollow air ducts provide buoyancy to the stalk. In transmitted light it is the vascular bundles which appear as the dark perpendicular lines and the parenchyma cells which form the translucent matrix.

THEORIES OF MANUFACTURE OF PAPYRUS

It is surprising that a detailed record of the process by which the Egyptians transformed the pith of the papyrus plant into sheets has never been found. The Roman naturalist Pliny the Elder describes papyrus making in his Natural History XIII,[Hendricks 1980] and [Lewis 1974] but his account is obscure and open to several interpretations and many believe he did not actually see the process first hand.

The most commonly held theory on the manufacture of a papyrus sheet is as follows: strips were cut longitudinally along the pith either parallel through the triangular shape or along the sides of each triangular face. The strips were then laid down on a smooth surface, parallel to each other and slightly overlapping. Then a second layer of strips are laid on top of and perpendicular to the first. This laminate sheet was then rolled and/or pressed.

A second, more recent theory of the ancient manufacture of papyrus sheets was derived from an interpretation of Pliny's description of the process. The pith was not cut into strips but was peeled continuously down to its core [Hendricks 1984, 31]. Two of these peeled layers were then pressed together perpendicular to each other to form a single sheet. According to Wallert, these different manufacturing processes (strip vs. peeling) result in distinct and characteristic surface textures which are sometimes visible with a scanning electron microscope and, at times, with a stereo microscope [Wallert 1989].

Disagreement surrounds the nature of the bond between the two perpendicular layers. Pliny describes the "muddy water" of the Nile River as having the "effect of glue" but all research to date discounts this point. Wiedemann and Bayer believe the addition of a starch adhesive between the layers was common in ancient papyri manufactured before 300 BC and they have identified with microscopy a starch layer between the papyrus laminates in over 50 microtome cuts of ancient samples [Weidemann and Bayer 1983, 1222]. However, no such use of starch has yet been found in any papyri of the Graeco-Roman period [Cockle 1983, 149]. Hepper and Reynolds have postulated the bond is inherent in the cell sap of the pith which is composed of vegetable gums (arabans and galactans) with adhesive-like properties [Hepper and Reynolds 1967, 156-57]. A persuasive argument is made by Ragab that the main reason for bonding between layers is physical rather than chemical and occurs during pressing [Ragab 1978]. The ovoid parenchyma cells, which surround both hollow air spaces and vascular bundles, when cut have a cupped shape. When the two strips of papyrus are pressed together, the parenchyma tissue on the surface of one strip is forced to merge into the hollow air spaces on the surface of the other strip forming a dovetail-like join. Upon drying, these interlocking tissues undergo appreciable shrinkage and form a tight bond, assuring adherence of the strips.

EXPERIMENTAL PAPYRUS MANUFACTURE AT THE BROOKLYN MUSEUM

In addition to studying the published literature on the subject, the conservation lab obtained papyrus stalks from both the Brooklyn and the New York Botanical Gardens and performed a variety of experiments in order to better understand the nature of the material and its structure and to prepare for treating the collection. The following summarizes our findings.

1. The pith can be cut into translucent, thin strips and, though it is difficult to achieve uniformity of thinness along the strips, with much practice a certain uniformity was probably achieved. Interestingly, in transmitted light an uneven translucency could sometimes be seen in many ancient papyrus sheets.

2. It is possible to successfully peel the pith into layers but again, it is difficult to achieve uniformity of thinness along the peeled layer; there are some gaps and holes as well as thicker bumps. With much practice uniformity was probably achieved. The resulting papyrus sheet in transmitted light looked remarkably similar, upon first glance, to papyrus sheets made from strips.

3. We know that no adhesive is necessary to form a sheet but that heavy pressing (we used a screw press) is critical. All papyrus sheets formed in the lab with no adhesive but heavy pressing resulted, upon drying, in smooth, intact sheets. On the other hand, papyri formed without adhesive but only light pressing or air drying resulted, upon drying, in shrinkage across the grain to form individual, unattached strips, rather than sheets. These unattached, shrunken strips were rewetted and placed in a screw press and upon drying they formed a smooth intact sheet. This indicates that heavy pressing plays a large role in achieving good sheet formation.

4. The intact sheets which were formed with pressing and no adhesive could not be easily separated when later immersed in water; after soaking for four days, the horizontal and vertical layers remained reluctant to part. This indicated the use of moisture treatments on ancient papyri should not cause unwanted separations.

5. It was also noted that when the above mentioned soaked sheets were allowed to air dry (rather than pressed) there was considerable distortion of the sheet and several areas of delamination. This indicated that all wet treatments should be followed by pressure drying.

6. Adhesive (starch paste) was used to paste layers together to form sheets: some were pressed until dry and others were not. With the papyri which were not pressed, the adhesive alone was not strong enough to restrain the shrinkage of the fibers and the resulting disruption of the sheets. The papyri which were pressed until dry formed smooth, intact sheets. This seems to indicate that starch adhesive plays a minor role in achieving good sheet formation.

7. Beating or hammering of the wet strips when forming the sheet caused distortions which remained after pressing; rolling of wet strips did not cause this distortion. Sometimes these types of distortions were noted in ancient papyri and may have been caused in this way.

8. A papyrus sheet made of a single layer of strips when pressed forms a smooth intact sheet for writing but is less flexible than a double layer cross-laminated papyrus when rolling into a scroll.

9. Prior to pressing, the color of the pith and resulting sheets changed from bright white to yellow brown to dark brown by increasing the soaking time and rolling of the strips. Basile believes the aluminum sulfate found in natron, a salt present in the Nile waters composed primarily of carbonates and bicarbonates of soda, prevents the papyrus from darkening and that this fact was known in ancient times [Basile 1972,902]. Opinions in the literature are that a freshly made ancient papyrus sheet was of a white, light yellow tone [Cerny 1947, 6-7]. Interestingly, sheets formed in the lab which had a yellow/tan tone were bleached to a bright white by exposure to sunlight in a window for a period of several months.

Given the lignin content of papyrus this was a surprising result.

Much additional research is needed to answer the questions concerning ancient manufacturing techniques; it is possible various methods were used throughout the nearly 4000 years of papyrus manufacture. By whatever method the sheets were made, the height and width of a sheet adhered to set dimensions which varied in different dynastic periods [Cerny 1947]. It is thought that these sheets may have been made in factories [O'Casey and Maney 1973, 16] which also produced rolls by attaching sheets together with starch. An adhesive was necessary in these cases because the attached sheets were already dry, but these joins are often barely discernible. Approximately 20 sheets to a roll was most common. There were at least six different qualities of papyrus produced in the Ptolemaic period and described by Pliny. Scribes usually wrote on the horizontal or recto side of a roll. This side was always the side rolled inward, the vertical side forming the outside of the roll [Cerny 1939, XVII] and the rolling began from left to right.

Writing implements were made from a particular type of rush which was feathered to produce brushes [Lucas 1962, 364-65], while reeds were sharpened to make pens [Cerny 1947,12]. The inks were made of pigment and gum ground together and formed into small, solid cakes [Lucas 1962,362]. The brushes and ink were often held in palettes made of wood or ivory; many of the palettes in TBM's collection have residual black and red ink still visible in the cake receptacles. The most common writing ink was carbon black or soot bound with gum. Although mention is made in the literature of iron gall and sepia also being used, examples of these have not been found in TBM collection. Rubrics, text written in red ink to distinguish chapter headings, opening words and the beginning of new sections were composed of red ochre and gum. A variety of pigments, also thought to have been mixed with gum, were used for creating vignettes.[1]

THE BROOKLYN MUSEUM COLLECTION OF PAPYRI

The Museum's collection comprises over three hundred individual documents and is well represented by examples of Egyptian, Greek and Coptic papyri as well as a few fragments of Latin, Arabic and Pahlevi. The oldest papyri dates from the IV and V Dynasties (approximately 2400 BC), but the majority of the collection is from the Late Period through the Ptolemaic Period (1100-30 BC). A large number of the papyri are devoted to religious aspects of Egyptian civilization such as magical texts and the Books of the Dead. There are also papyri which represent aspects of the non-religious, everyday life such as medical texts and legal documents.

Some of the papyri exist only as very small piles of fragments, others are intact as rolls (some well over 20 feet in length) but are inaccessible to scholars and the public because their deteriorated condition prohibits their unrolling, study or exhibition. The majority of the papyri, however, upon entering the collection in the 1930's and 1940's, were flattened and cut into shorter sections from the original rolls, and sandwiched, often randomly, between glass and sealed with tape. These glass sandwiches were stacked in large, heavy drawers located in an uncontrolled climate area of the Museum until 1990, when they were moved to the Museum's newly renovated, climate controlled storage.

The general condition of the papyrus collection in The Brooklyn Museum is poor as a result of age, improper previous treatment, questionable housing methods, and poor climate control. Most of the condition problems found on the papyri were similar to those often seen with works on paper. For example, previous restorations such as Western paper backings and repairs made with many small pieces of pressure-sensitive tapes were noted. Inherent problems included deterioration of the papyrus from the corrosive action of copper-containing pigments and flaking paint. Staining and resinous-like accretions were found on the surfaces of many pieces. Environmental factors influence the condition of papyrus as well. Fluctuations in humidity contributed to the growth of mold and to salt migration on the surface of many papyri stored within glass sandwiches. Evidence of insect damage was observed with associated losses in the papyrus. Several pieces have symmetrical losses which span the sheet, indicating the damage occurred while the papyrus remained rolled. In a few cases, inactive egg casings were found as well as insect impressions in the paint layer.

PRESERVATION: REHOUSING AND TREATMENTS

Rehousing

The paper conservation laboratory was responsible for treating and preparing fourteen papyri in preparation for the reinstallation of new Egyptian galleries. Before treatment was begun, however, a new housing system to replace the glass sandwiches was developed. Working with the curators to determine the research and handling needs of the collection, a framing system was designed to accommodate easy viewing, handling and exhibition of the papyri.

The papyrus is placed within a 2-ply ragboard inlay or window which follows the contour of the papyrus but does not come closer than 3/16" to its edge. The papyrus is secured to the window at various points with small, toned strips of Japanese tissue and wheat starch paste.

The window and papyrus rest against a 4 ply ragboard and this package is sandwiched between two pieces of Plexiglas[2], the top being ultraviolet filtering. This sandwich is sealed with polyethylene tape and placed within a specially designed Plexiglas box. The two ply window will create a small space between the glazing material and the papyrus, and the rag boards will act as an absorbing material for any off-gassing of the papyrus as it ages. This system allows for easy exhibition and handling and will serve as a storage housing as well.

Treatments

Many traditional conservation methods were successfully applied to treat the papyri. Conservation techniques employed include consolidation, solvent treatment, joining and repair, aqueous treatments such as blotter washing and humidification, stain reduction and enzyme treatments. The use of facings and the vacuum suction table were found inappropriate. Bleaching and float washing have not yet been tried.

A. Consolidation

Consolidation of the pigment layers, especially the more thickly applied paint, and papyrus surface fibers was often necessary before further treatment was begun. Paint layers were generally quite friable and appeared to have little binder. As mentioned, according to Lucas, gum was predominately used for binding inks and pigments. Paint surfaces varied greatly but many examined were found to be poorly ground and often chunks of undispersed pigments were seen under magnification. In certain cases where Egyptian blue (a calcium-copper silicate) had been applied, only granules of pigment were observed with little of their "paint" quality remaining.[3] Much testing was done to find the appropriate consolidant which would act as a sufficient binder without darkening the paint or the papyrus support. A number of consolidants were tested in the paper lab including Klucel G (hydroxypropyl cellulose) in ethanol, B-72 (ethyl methacrylate/methyl acrylate copolymer) in diethylbenzine, methyl cellulose in both water and ethanol, gelatin, and funori, a mucilage made from seaweed. Only funori adequately secured the paint without darkening the paint or papyrus.[4]

B. Tape Removal

Many fragments had been adhered with numerous small pieces of pressure-sensitive tape before they had been placed inside glass sandwiches. While this "conservation" method may have saved many small fragments from being lost, removal was necessary due to the non-archival nature of the adhesive and because many of the joins held with the tapes were not perfectly aligned. Acetone was found to dissolve the adhesive on most tapes while leaving the carrier undissolved. By flooding the tapes with the solvent and slowing evaporation with a mylar cover for approximately 10-15 minutes, the tapes and adhesive could be mechanically removed. In a small proportion of papyri a second type of pressure sensitive tape was encountered which did not successfully respond to acetone. Ethanol and toluene were employed to swell the adhesive, which then had to be removed with tweezers or cotton swabs soaked in solvent (applied over a lens tissue). None of the solvents employed appeared to have any effect upon the papyrus or the paint layers.

C. Joining and Repairs

Joining and alignment of fragments was easily accomplished using the microscope and a light box. The numerous patterns created by the fibers (vascular bundles) provided a guide for exact alignment of the fragments. It was possible to determine losses as small as the width of a single fiber when joining the edges of two fragments. The light box and the microscope were also useful in identifying fragments which had previously been joined in error by scholars who were unable to detect their exact positions without the aid of a microscope. Fragments with vertical fibers joined on the horizontal side of the sheet were identified as restorations previously placed within the papyrus as "filler" pieces. Although adjustments and realignments changed each join only slightly, when carried out over an entire papyrus it resulted in recognizable visual changes. An example of this is a vignette from Thebes which dates from October 14, 651 BC and measures approximately 12" (H) X 46" (W). In the early 1950's, the fragments of this scroll had been positioned and joined with tape by scholars. The papyrus, in this joined form, was published in 1962. Using a microscope, however, we were able to correct alignment of many parts of the vignette, such as the bottom of garments, the tops of heads and other prominent design lines.

Repairs were made using toned, handmade sheets of Kozo tissue and dilute wheat starch paste. These repairs were sufficient to hold the fragments in place. Their reversibility is facilitated by cut rather than feathered edges. The tiny hairs of feathered edges tended to pull the papyrus fibers and necessitated using more moisture, while the smooth edged tissue tended to grab less when removed.

D. Humidification and Aqueous Treatments

With humidification and aqueous treatments papyrus rapidly absorbs moisture, swells and then tends to rapidly loose moisture. With humidification papyrus becomes temporarily more flexible and when fully wetted is quite malleable. Fragments which were so warped they skewed the proper alignment and attachment to each other were successfully coaxed into their original shape and brought into alignment with use of ultra-sonic vapor. Because papyrus so rapidly absorbs moisture, it easily becomes saturated if ultra-sonic humidity is applied for too long.

Discoloration within papyrus easily moves with the application of water. It was observed that papyrus fragments which were over-humidified or wetted but not fully "washed" usually darkened in tone, but that wetted fragments which were thoroughly washed between blotters lightened in tone. The difference, we assume, is that overall wetting and thorough washing provides a means for diffusion of the discoloration. For this reason it was found best to either fully saturate the papyrus, when possible, and allow thorough overall washing on blotters to occur, or to judiciously limit the amount of moisture applied to only light ultra-sonic humidification. In fact, washing between wet blotters has been very successful; discoloration moves quickly into the blotters, without disturbance of inks. Some papyri with text and drawings in black and red inks have been blotter washed for several hours. A papyrus with painted vignettes was also blotter washed but with Gore-tex cut-outs protecting the painted areas while allowing the papyrus to wash. Brittle, lifting fibers on the surface of the papyrus are often found to reattach following washing and pressing. Blotter washing was also sufficient to allow removal of paper backings attached with animal glue.

As noted local washing and even heavy humidification can cause darkening and tidelines, therefore tests were undertaken to reduce local stains on the vacuum suction table. Water had difficulty penetrating the thickness of the papyrus sheet and tended to run along the fibers of the papyrus rather than down through the sheet. This localized washing was uneven and caused mottling of the sheet.

E. Enzyme Treatments

The application of an enzyme was used to facilitate the removal of a backing attached with a starch based adhesive. This was undertaken when it became evident that water alone would not successfully dissolved the backing adhesive.5 A 0.01% solution of alpha amylase6 in deionized water was brushed onto the backing during blotter washing of the papyrus piece. The piece was kept under a warm lamp to allow the enzyme to work within its optimum temperature range. After approximately 25 minutes the backing was mechanically removed and blotter washing was continued in order to remove excess enzymes, adhesive residues and discoloration.

F. Facings

The technique of applying temporary supports or facings to the recto of fragile, fractured papyri prior to removing backings or mounts has been reported in the literature [Walker 1988] and [Fackelmann,M. 1985]. Several mounted papyri examined in the lab appeared to be candidates for facing. Several facings were tested on the papyrus samples manufactured in the lab. A Japanese machine made paper, RK-0 from Paper Nao, was used for the facing tissue and the adhesives tested were BEVA (a proprietary adhesive) flocked onto tissue; Lascaux 360 (a butyl acrylate/methyl methacrylate copolymer dispersiion) in water at various dilutions; and 10% B-72 in acetone. After drying, the faced samples were immersed in the appropriate solvents to remove the tissue and adhesive. They were then assessed for any textural changes, adhesive residues or loss of medium. Similar tests were carried out on several, small, ancient non-placeable, papyrus fragments. Although B-72 proved to be the quickest and easiest adhesive to reverse, we came to the conclusion that in removing the facing the papyrus was subject to more manipulation than when using a wet blotter alone as its support. The wetness of the blotter actually held hair-like fibers on the papyrus in position during removal of a lining and the blotter could be removed from the face of the papyrus with little disruption or pulling.

CONCLUSION

Seven separate pieces have been treated for installation in the new Egyptian galleries and seven additional pieces will be treated for rotation.7 We find it remarkable, as examination and treatment of the papyrus collection continues, how appropriate paper conservation methods are in the treatment of papyrus. The program of conserving this collection is just beginning and improvements and refinements are expected as our expertise increases. Additionally, many challenges remain such as the treatment of several intact, uncut scrolls over 20 feet in length. These works pose a whole new set of questions concerning their treatment, housing, storage and exhibition.

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valuable information, and he allowed us to view and examine papyrus layers using the SEM.

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NOTES

1 With the polarizing microscope and SEM/EDS analysis performed by Mark Wypyski at The Metropolitan Museum of Art, we found evidence of orpiment, Egyptian blue, yellow ochre, iron oxides and calcium carbonate on papyrus samples in TBM collection.

2 Plexiglas was chosen as the sandwiching material for several reasons: it has ultraviolet filtering capacity, it is light weight and it has a tendency not to break when handled or dropped. It does impart static electricity, however, and shatterproof glass with ultraviolet filtering capacity has begun to be used directly above the papyrus in most packages. We do not anticipate frequent opening of the Plexiglas sandwiches but, if necessary, a trained conservator would be in charge of this operation.

3 It was surprising to find in our examination of several papyri pieces that deterioration of paint layers and the papyrus below was often associated with Egyptian blue, a pigment considered to be fairly stable and to age well.

4 Preliminary testing at the National Archives indicates that many of the elements found in sea brine such as bromine, chlorine and iron, to name a few, are also present in the seaweed which is cooked to make funori. Further testing in this area is needed. Presoaking of the seaweed prior to cooking might diminish the presence of some of these elements.

5 The fact that some ancient papyri did have a layer of starch between the laminates was taken into consideration. Blotter washing alone could possibly dissolve a starch layer and use of alpha amylase certainly would. Although we did not believe loss of an adhesive would cause separation of the papyrus laminates, it would remove evidence of the sheet manufacture. This was weighed against the fact that the correct alignment of fibers could not be undertaken without removing the backing, which could not be safely removed without the use of a starch specific enzyme.

6 Alpha amylase Type IIA from Bacillus species. Sigma Chemical Company, St. Louis, MO 63178. Conservation literature usually recommends an optimum pH of 6.5-7.5 and an optimum temperature range of 37-40 C.

7 We have recommended 12 months at 5 footcandles for those works which have not previously been exhibited in the Museum. After deinstallation these works may not be exhibited for 2 years.

Antoinette Owen, Conservator of Paper
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