FINE PRINT

RAW MATERIALS FOR PAPERMAKING

by Simon Barcham Green

IT IS GENERALLY UNDERSTOOD that paper quality, particularly permanence, depends on the quality of the raw materials used in its manufacture. However, few people involved in the production of fine books, or indeed in the production of handmade paper on a workshop scale, have had sufficient training and experience to distinguish between the various qualities of materials available to them. Popular books and journal articles on papermaking abound with generalizations to the effect that handmade paper will last forever, or that the exclusive use of rags as raw material will lead, apparently automatically, to a better product. Unfortunately, the making of paper is not so simple, and if such misconceptions continue to go unchallenged, paper scientists and conservators should not be surprised that they have become widespread. To help dispel a few of these misconceptions, it is well to examine and summarize the raw materials actually used in papermaking and how they affect the character and permanence of a sheet of paper.

Papermaking fibres can be divided into two general groups: (1) virgin or primary fibres, converted directly from vegetable materials to paper; and (2) recycled or secondary fibres. The two main categories of secondary fibres are wastepaper and rags.

PRIMARY FIBRES

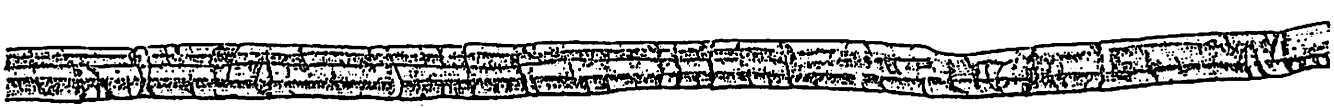
Oriental Bast Fibres. The best-known are gampi, kozo, and mitsumata, which are made from the purified inner bark of a variety of shrubs. These fibres, if properly prepared (a very lengthy and demanding process), yield exceptionally permanent papers. These fibres are not generally available to western papermakers, and since our direct experience of them in recent years has been negligible, I will leave a more detailed assessment of their qualities to more qualified people. It should be noted, however, that many Oriental handmade papers today contain a substantial proportion of wood pulp and even, in some cases, waste paper.

Cotton (*Gossypium* species, most commonly *hirsutum var. latifolium*). Cotton is the purest form of cellulose and is the most important high-quality fibre used in papermaking in the West. Cotton is part of the mallow family and carries its seeds in capsules, or bolls, each containing thirty to forty-five seeds covered with seed hairs of varying lengths. A large proportion of cotton is converted into textiles using the long (10–15 mm.) lint fibres while the smaller quantity of shorter fibres (2–5 mm.), called linters,[1] is used both in papermaking and for chemical conversion. Some paper mills pulp their own cotton linters, but most is produced as market pulp by mills specializing in that one stage of production: taking the raw materials, converting them to pulp, and offering the dried pulp for sale to anyone who wants to buy it.

Typically, cotton linters received at the mill contain 73% cellulose, 11% seed hulls, 8% water, 2% fat and wax, 2% ash, 2% protein, 1% pectins, and 1% sand. After chemical purification and cleaning, good market cotton linters pulp is 99% cellulose, of which 99.7% is alpha cellulose and only 0.3% the less desirable beta and gamma cellulose. This 99% figure excludes water, which usually makes up 10% of the total mass, although a moisture content of 30% is not uncommon because drying more fully can reduce the fibre's strength. Cotton is not an exceptionally strong fibre and is best used in association with other fibres unless a soft, compliant paper is required, such as that often used for etchings.

Flax (*Linum usitatissimum*) is a bast fibre like kozo; i.e., the useful material lies in the inner bark and makes up only about 5% of the total mass of the plant. The initial stages of purification involve retting: bundles of the plant stems are left to soak in stagnant ditches or slow-running streams; biological decomposition softens the bark, making it relatively easy to strip off to reach the underlying bast layer. Further chemical treatment removes lignins and other non-cellulose materials. Traditionally, bleaching was achieved by repeated washings in clear streams combined with the effects of sun drying, not unlike the methods used for Oriental fibres.

1. The word linters is always in the plural and, ironically enough, is derived from the Latin adjective *linteus* meaning "of linen."



Most flax is used for spinning and weaving linen, and thus it is extremely difficult to obtain market flax pulp. Linen (a term normally but not always restricted to the woven flax fibre) is also virtually impossible to obtain in reasonable quantities with continuity and reliable quality. At present we at Hayle Mill are using flax in small production quantities to determine how virgin flax pulp compares to manila. Though the latter is a stronger fibre, there continues to be a considerable interest in flax primarily because of its attractive "flaxen" color, which is compatible with mediaeval papers requiring repairs, and for its tough surface, which is ideal for calligraphy and book covers.

Manila (*Musa textilis*—also called manila hemp or abaca) is used mainly for cordage and also as a textile fibre locally in the Philippines, the only area where it is cultivated on a large scale. The plant consists of a cluster of sheathing leaf stalks rising to a height of four to six meters. Three grades of fibre are obtained from different layers of the stem. The tupoz layer from the inner leaf stalks is the finest and is used for papermaking. The finest quality manila is the strongest papermaking fibre in use in the West, being several times stronger than cotton and exceeding flax in most properties. Most manila is processed in papermills and is mainly used to make fine tissues, including Hayle Mill's range of machine-made conservation tissues.

There are only a small number of market pulp producers of manila. Prior to pulping, the fibres are combined in strands two to four meters in length, but as the process continues, the length is normally reduced to less than ten millimeters, depending on requirements. Heavy initial beating is needed to reduce the fibre length to manageable proportions, and considerable care is needed to avoid an excessively wet "stuff." Manila is usually used in combination with cotton linters to give a range of different strength characteristics.

Hemp (*Cannabis sativa*) and *jute* (*Corchorus capsularis*) are mainly used as cordage fibres, but they are also suitable for papermaking. Hemp was one of the earliest fibres used for papermaking in the Orient; jute is similar to it but usually coarser. Both are now uncommon as papermaking fibres, especially in Western countries, where the cultivation of hemp is illegal because of its connection with drugs, although the best papermaking and textile varieties have a narcotic content so low as to be not worth extracting.

Raw manila, hemp, and jute have quite a significant lignin content which must be removed by fairly strong chemical treatment. While such treatment would be unacceptable for cotton, these three fibres are stronger in all respects and any damage caused by vigorous processing will still leave them stronger than cotton.

Woodpulps. Practically all types of trees can and have been used for papermaking. Coniferous softwoods are the most common varieties, but in recent years a number of hardwoods have also been heavily cultivated. Notable among hardwoods is eucalyptus, which has now been planted very widely in the South American tropics and can be harvested in ten to fifteen years (typical northern conifers can take seventy years).

Woodpulps can be classified according to the method of treatment: mechanical, chemical, or semi-chemical. Mechanical, or groundwood, pulps are literally whole trunks (less bark) ground to a very fine particle size prior to bleaching (if required) and beating. All the non-cellulose impurities are retained and will lead to rapid deterioration of the paper in both color and strength. The mechanical pulping method is cheap and gives a very high yield.

Chemical woodpulps are produced by "cooking" wood chips under pressure in a variety of chemicals. Usually this is a continuous process under automatic control. A modern pulp mill can process 400,000 metric tons per year and will generate much of its own power from bark and other waste, while an auxiliary plant will recover useful chemicals from the waste liquors. Chemical woodpulp is superior to mechanical pulp in all respects but it is not so pure as cotton, flax, or manila.

Semi-chemical woodpulp combines a preliminary softening up with chemicals followed by mechanical pulping and is intermediate in most respects. High-alpha woodpulp is chemical pulp which has had extra purification and which has a higher than normal level of alpha cellulose (the purest type of cellulose). Since it is the impurities that cause deterioration, paper with a very high alpha cellulose content is, in principle, more permanent than that made from ordinary woodpulp. However, the chemical treatment is very harsh and usually reduces strength to unacceptable levels. In recent years there has been a tendency to call any high-quality chemical pulp "high alpha," whereas in the past this term would usually indicate at least 95% alpha cellulose.

Some of the best pulps are made from western redwoods, notably western red cedar and sequoia. Properly treated, they are very strong and reasonably permanent. However, terms such as "redwood linters" (implying some relationship with cotton) are meaningless and misleading. Two other misleading but legal terms are "pure cellulose" and "wood-free" which invariably mean 100% chemical (as opposed to mechanical) woodpulp. The main advantage that the best non-wood fibres have over woodpulp is greater permanence, because woodpulps are available that are as good, and often better, in every *other* respect.

Straw, Bagasse, Sisal, and Esparto Grass are a few of the various types of annual fibres widely used for papermaking. Traditionally straw is associated with short fibres, weakness, poor opacity, and a lot of debris. Its advantage is cheapness. Improved methods of pulping straw have led to better quality machine-made papers, but straw still cannot be used for handmade paper. Esparto has many good characteristics, notably a silky feel that is very desirable in note papers, but it is no more permanent than most chemical woodpulps. Bagasse is the fibre left over after sugar cane has been crushed and is important for papermaking in sugar producing countries. Sisal is made from a type of agave (century plant); neither fibre is of adequate quality for fine papermaking.

Recycled or Secondary Fibres

Rags. It may not be immediately apparent that rags are a source of *recycled* fibre, yet it was this fact that made rags the dominant raw material for European papermaking until the early nineteenth century. Since the introduction of papermaking to Europe, all raw materials had tended to be in short supply, but rags formed the most attractive economic option.

Naturally, worn out linen or (later) cotton rags were much cheaper than fresh new fibre. An entire industry emerged based on the collection of old clothing by "rag and bone men." Some other types of vegetable fibres were also available secondhand, notably hemp and jute in the form of old ropes.

The invention of woodpulp initiated the decline of the rag merchants, but until the mid-twentieth century they were protected by the huge growth in papermaking generally. After the Second World War, however, rising labor costs for sorting and the introduction of synthetic fibres caused a virtual collapse of the trade. Ironically, rags are now a feasible raw material in the Western papermaking only for larger users who buy off-cuts in bulk directly from textile mills (thus insuring they know just what they are getting), or for very small hand workshops whose demands for rags can be satisfied by family and friends. One practical alternative for American users is offered by Cheyney Pulp and Paper Company (Franklin, Ohio 45005), which makes a variety of cotton rag half-stuffs,[2] some of which are suitable for handmade papers. It is important to specify non-fluorescent material made from white rags (not bleached blue jeans) and to bear in mind that half-stuff at 50% moisture content in time invariably develops mildew, which is difficult to kill chemically with safety; if it is not killed, the paper will of course be contaminated.

At one time, dozens of different grades of rag were available to the papermaker. Among the more important and interesting linen types were: best linen cuts (i.e., new linen off-cuts direct from textile mills and made from the best quality flax); French linen (regarded in some quarters as the finest quality); canvas (a much coarser material, sometimes adulterated with cotton); and firehoses (an extra heavy linen canvas guaranteed to play havoc with beating tackle). A feature of all flax fibres is the attractive off-white shade which in older rags becomes grimier in character.

The best quality cotton rags were "new white pieces." Typical sources were offcuts from new uniforms (also called drills), from new bed sheets, and the like. "Fines" were used cotton rags and were subdivided into No. 1 Fines, No. 2 Fines, "Outs," etc. In later years, sorting by merchants became very bad and so-called No. 1 Fines could include old crocheted table cloths, very beautiful but containing thousands of tiny hard knots that would not disperse. "New light prints" were factory off-cuts from colored shirts, sheets, curtains, etc., and were either bleached or used for colored papers. "Old (used) light prints" were generally used for making cheaper papers. Among the worst qualities of recycled rags were old hospital sheets. Often blood-stained, damp, and infected, they could spontaneously ignite from the heat caused by their decomposition. The spread of the Black Death has sometimes been blamed on the collection of rags from the dead, the concept of infection being unheard of in those days.

It is important to emphasize the distinction between rags and virgin fibre pulps, as the word "rag" has great emotive significance for some paper users. Unfortunately, the debate on the relative merits of these two classes of materials is confused from the start by the misuse of the word by some papermakers. A "rag" is a piece of woven material, and the term cannot be applied to a virgin fibre that has never seen a loom. But in the English-speaking world "100% rag" often means 100% cotton linters, and "rag content" may mean 20% cotton and 80% woodpulp!

It may be of some interest to summarize briefly by means of a chart the relative merits of rags and the various high-quality pulps of primary fibres:

	Rags	*Cotton Linters*	*Flax*	*Manila*
1. Paper production	Dependent on type, give good formation; may be adulterated with artificial brightners, synthetic fibres, etc. For best results require extensive and careful chemical treatment, including washing out the chemicals (few workshops trouble to do this).	Successful beating needs care and experience.	Very difficult to beat successfully; slow draining, can be difficult to form well.	Very difficult to beat; slow draining; difficult to form well.
2. Characteristics of paper produced	Have a degree of character due to faults such as extraneous colored fibres and other impurities (e.g., possible dirt). Considered "folksy," ecologically sound.	Soft and lacking in character; very pure and white; limited strength.	Excellent character, especially surface, handle, and tone; strong.	Excellent character; very strong (better than flax or any rag).
3. Quality Control	Variable in classification, color, strength, etc.	Quality controlled by pulp mill; very reliable.	Quality controlled by pulp mill.	Quality controlled by pulp mill.
4. Price	Cheap when available.	Moderately priced.	Expensive.	Very expensive.
5. Availability	Difficult to obtain.	Readily obtainable.	Very difficult to obtain.	Limited availability.

2. "Stuff" is papermaking fibre that has been fully beaten and is ready for making into paper. "Half-stuff" has been partially beaten and drained to a higher consistency for re-use in a number of ways. It is convenient for small manufacturers to buy half-stuff, as it reduces the time required for beating.

From the chart it can be seen that cost is the only real advantage of rags when they can be obtained with satisfactory quality and character (and the latter is a matter of taste and application). Cotton linters have limited strength and are therefore rarely used alone. Various blends of cotton with manila or flax will yield book papers with a variety of properties. However, different printers will have different requirements: one will give emphasis to durability, wanting a sheet with good fold endurance and tear strength, whereas another may seek a softer sheet because it is easier to print dry. Such properties are incompatible, so it is best to offer a range of different papers: for example, among Hayle Mill papers Langley is considered to have good durability while Hayle or Tovil represent softer papers. When using rags, similar decisions have to be made: fines or old light prints offer softer qualities whereas strong types such as linen produce a harder, more durable sheet.

Wastepaper. Although most handmade papers consist of at least 95% vegetable fibre, the many different plants that can be used as a fibre source vary considerably in quality, as we have seen. It is certainly no longer safe to assume that only the finest materials are used in handmade papermaking. I feel that it is not unfair to lay part of the blame for this change at the feet of academically and ecologically inclined paper enthusiasts. These enthusiasts, often printers and printmakers (some highly regarded in their own fields), have published several books on the subject of hand papermaking in the past decade, most of which advocate the use of wastepaper at some point in their text, but few of which even touch on the questionable permanence of such papers. There is the idea that handmade paper, especially if made from waste paper, is ecologically sound. Recycling of waste paper, an admirable concept and one in which the papermaking industry has made great progress, has become confused in the public mind with the craft of making paper by hand. The truth is that the large paper corporations are far better suited than hand papermakers to organize the collection, classification, and purification of waste paper. It is now possible to make a wide variety of machine-made paper from waste, but unless the wastepaper itself is made from fine materials, the product of this recycling will inevitably be of an impermanent nature.

Water

After fibre, water is the most important papermaking material and yet the one that is most often overlooked. For many ephemeral applications the quality of the water is not too important, but if permanence of the paper is sought, then first-class water under the mill's control is essential. What are the points to look for? Essentially the fine papermaker will strive to obtain water of exceptional purity as evidenced by absence of iron, copper, chlorine, turbidity, microorganisms, and other contaminants. A neutral or slightly alkaline pH is essential: water must not be acidic. "City water" (including piped water to rural areas) is usually unsuitable due to the high degree of chlorination, the likelihood of contamination by iron or copper pipes, and fluctuations in composition caused by the water supplier's switching among a number of sources. If water contains harmful impurities it needs treatment before it can be used, but in some cases treatment is impossible, in which case the location must be ruled out as a site for fine papermaking irrespective of the quality of other materials used.

Hard spring water is ideal for papermaking, and it can surely be no coincidence that all the fine mills in Britain had the benefit of a location in a limestone area with reliable springs. At Hayle Mill we test about thirty factors in our water. Typical results include a pH of 7.3, hardness of about 450ppm calcium carbonate (with 22ppm of magnesium carbonate), iron and copper contents of less than one part per hundred million, no free chlorine and no microorganisms. Not every mill can be so fortunate. The calcium carbonate content (which helps protect the finished paper against deterioration caused by atmospheric acids) is certainly a bonus.

Sizing

The sizing of paper is a very complex subject, but many techniques are not applicable to handmade papers. The résumé that follows can cover only a few main principles. Methods of sizing generally fall into two categories:

Tub sizing involves dipping the paper, after drying, into a bath or tub of a suitable size. Although several materials can be used for tub sizing, the only one of importance to fine papermakers is gelatin, made from animal skins and bones. Gelatin sizing works by filling the pores of the paper, thus preventing the rapid entry and spread of aqueous solutions. Gelatin will absorb water slowly, enabling the paper to be damped and the inks to be absorbed into the surface without feathering. It also adds to the strength of any paper, allowing the use of weaker fibres while achieving the same toughness and rattle as stronger fibres. The main problem with gelatin sizing is that it involves a great many additional operations, which can not only double the costs of production but also increase the chances of damage due to improper handling.

Only the finest quality gelatins should be used for sizing good paper; i.e., those types usually designated for edible or photographic purposes. A curious fact about gelatin sizing is that the best results can usually be obtained only in acid conditions with a pH of less than five. Furthermore, traditional sizing almost invariably involved either papermakers' alum (aluminum sulphate) or potash alum, both acidic compounds. Yet these traditional papers have often survived for centuries in first-class condition despite their high acidity. Paper conservators have yet to explain this apparent anomaly, but it seems likely that the gelatin itself protects the paper from the harmful effects of acids and especially alum.

Internal sizes are added to the papermaking "stuff" before the sheets are formed. Thus the cost is limited to the cost of the size. By controlling the rate of addition of the size, it is possible to vary the degree of sizing. Most internal sizes are basically water-repellent and have little effect on the strength or handle of the paper. This is useful because it allows the papermaker to control these characteristics by fibre selection and beating quite independently of the actual degree of sizing, or water resistance.

Tragically, for many years the vast majority of paper has been internally sized with rosin (derived from the sap of

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Paper Fibres, continued from page 43.

trees) and papermakers' alum. Rosin, unlike gelatin, does not protect the fibre from the effects of alum and acidity; indeed, it increases the harm that is done. Compounding the deterioration of paper caused by the use of impermanent wood pulps, rosin sizing has caused a disaster in the preservation of mankind's records from which it will take centuries to recover. Books, prints, and documents on deteriorating paper can only be conserved by means of tedious techniques involving washing, de-acidification, and resizing. As yet, few governments allocate sufficient resources to conservation to keep pace with the problem. Rosin continues to be the most common sizing system, and although recent developments in papermaking processes permit its use in near neutral pH conditions, very few rosin sizes can be regarded as acceptable from a permanence point of view.

Fortunately for posterity, there are many advantages to the commercial papermaker in operating in slightly alkaline conditions. The Hercules Powder Company began to investigate the use of alkyl ketene dimers for sizing as early as 1938. Alkyl ketene dimers are organic compounds produced by extensively modifying natural tallows. They work by attaching themselves to hydroxyl groups projecting from the cellulose molecule. Essentially each fibre is therefore coated with an imperceptibly thin layer of water-repellent size. By reducing the amount of size added, this coating is partly eliminated to allow a controlled degree of absorption of moisture by the paper. On the basis of this research, Hercules developed and introduced its Aquapel size in 1957. In many cases, the use of this size is accompanied by the addition of calcium carbonate fillers, which act as buffers and can help give quite a high degree of permanence even to papers made from woodpulp. (Calcium carbonate addition is not necessary if it is already present in hard water.) Hercules now provides a number of different types of Aquapel for different papermaking conditions, but all can be used without any acidity and therefore have no harmful effects on the longevity of the paper. Papermaking is a conservative industry, however, and many papermakers have yet to be convinced of the merits of alkaline sizing.

Summary

I hope this discussion leaves the users of handmade paper a little more knowledgeable and able to ask pertinent questions. No papermaker should resent questions about the materials he uses (though he is still entitled to trade secrets, such as precise proportions of materials). I also hope it leaves one cautious and wary of descriptions such as "rag content" and "wood-free," concerned that even "all rag, acid-free" may not mean permanent, and anxious still to get long-lasting paper. I have tried to emphasize that in making paper, each imperfect component can only have a negative effect on permanence. Thus neutral to alkaline sizing conditions will not render permanent those papers made with mechanical woodpulp or wastepaper. Choosing the finest linen rags will be to no avail if the water is full of harmful impurities. Quality is subtractive, not additive, which is why the "rag content" pa[illegible] well contain 100% woodpulp rather than so[illegible] thought needs to be exercised before any material is added to a papermaking recipe. This is why we tend to be conservative in adding anything to paper: the simpler the mixture of components, the less risk there is of any unforeseen complications.

The two figures on page 40 are enlargements of paper fibres, courtesy of Mr. Simon Green. Top: cotton linters x 500; bottom: manila x 500.

FURTHER READING

An excellent book on cotton linters is published by one of the leading European suppliers of cotton linters pulp: *Temming-Linters (Technical Information on Cotton Cellulose)*, by Temming and Grunert. Price and availability not known; inquire of Peter Temming AG, Stadstrasse 2-14, Glückstadt D-2208, West Germany.

Much of interest in papermaking fibres has been published in trade magazines and is thus widely disseminated. Two very worthwhile articles by Thomas Collings and Derek Milner were recently published in volumes 3 and 4 of *The Paper Conservator*: "The Identification of Oriental Paper Making Fibres" and "The Identification of Non-Wood Papermaking Fibres, Part 2." Back numbers are available for £5 each from the Institute of Paper Conservation, P.O. Box 17, London WC1N 2PE, England.

Recent Press Books, *continued from page 57.*

taking up too the mottling of the stones: a princely finishing.

Here, all told, is an example of cultural nationalism turned to one of its happiest uses: as the guiding light, and literary storehouse, of a private press; the dissemination of a heritage in print without dissipating or losing its native spell. The shades of Gregynog are made glad. M.C.L.

HIGH LOFT
Seal Harbor, Maine 04675

Yourcenar, Marguerite. *Suite d'Estampes pour Kou-Kou-Haï.* 1980. 25 x 17 cm. (10 x 6¾), 30pp. 3 colored woodcuts by Nancy McCormick. Centaur type on handmade Fabriano Ingres. Bound in maroon Roma paper over boards, leather spine, label by Gray Parrot. 20 copies, cased, with extra set of prints, signed, $185 (out of print); 180 copies, $43. (See illustration, page 63.)

THIS SLENDER AND ELEGANT BOOK, a tender series of sketches for the author's Pekinese, Kou-Kou-Haï, becomes a reflection on the nature of life, spirituality, worship, omnipotence, ownership, love, and death; a tribute from one bit of life to another.

Colored calligraphed versal capitals open the nine sketches, and three bi-colored woodcuts are interspersed through the text, creating a balance of spareness and luxuriousness. Impeccably printed; beautifully designed and bound. The accompanying four-page English translation from the French, laid in, is unpretentious yet shows the same care for design and typography. P.C.