128 Cyntia Karnes, “The Art and Science of Papermaking for Platinum Photographs,” in *Platinum and Palladium Photographs: Technical History, Connoisseurship, and Preservation*, ed. Constance McCabe (Washington, D.C.: American Institute for Conservation of Historic and Artistic Works, 2017), 128–143.

The Art and Science of Papermaking for Platinum Photographs

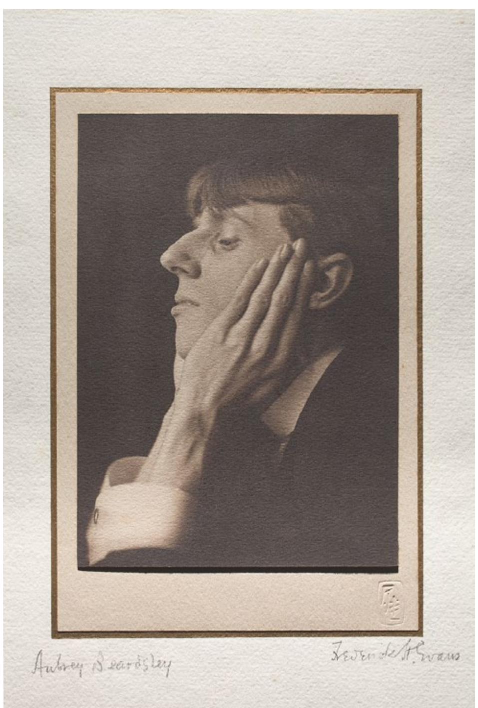
Cyntia Karnes

The luminous beauty of platinum and palladium photographs, with their wide tonal range and subtle gradations between light and dark, is largely dependent on the quality and characteristics of their paper substrate. The intimate mingling of metallic nanoparticles with paper fibers not only influences the viability and longevity of the image; it imparts a rich visual character to it that is immediately discernible (fig. 1). Early practitioners understood these principles well, their experiments driving the paper industry to meet the strict demands of a rapidly growing photographic market. While handmade paper was used and championed by many for its strength and purity, the introduction in the mid-nineteenth century of machine-made photographic paper achieved the same exacting standards on a large scale. This essay presents an overview of the specific material requirements of European papers used in the early practice of platinum and palladium printing and describes how their attributes were achieved in the papermaking process.

Paper Defined

Described simply, paper is a substrate composed of interlocking plant fibers, formed on a screen from a water suspension and dried. The fiber must be chemically and physically broken down into paper pulp before use, a process that promotes strong bonding between fibers in the dried sheet (fig. 2). Sizing agents are added to limit surface absorption and to improve strength and dimensional stability. Various filling agents, colorants, and finishing processes are also used to modify a sheet's characteristics to suit a specialized purpose.

Papers manufactured specifically for photographic use in the late nineteenth and early twentieth century—particularly those intended for single-layer print processes such as platinum and palladium—were made to high and precise standards. It was essential that they be composed of high-quality cellulose fiber, free of extraneous particles, and durable enough to withstand prolonged bathing in water, acidic processing chemicals, and the associated risks of abrasion and tearing while wet. Most critically, the cellulose pulp had to be chemically pure, without any metallic compounds, bleaching residues, free acids, or alkalis that could adversely react with photosensitive salts. Sizing agents had to be carefully formulated to allow uniform yet limited absorption of the sensitizer solution without compromising the white, or nearly white, color of the paper required to establish bright highlights in the image. Furthermore, the paper had to have uniform fiber distribution and thickness, and to remain dimensionally stable with repeated wetting and drying.



1a

Figure 1. Detail, Frederick H. Evans, *Aubrey Beardsley*, 1894.

1a. Frederick H. Evans, *Aubrey Beardsley*, 1894. Platinum print, illuminated in raking light, image 13 × 9.2 cm. National Gallery of Art, Paul Mellon Fund, 2007.29.19.

Cyntia Karnes, "The Art and Science of Papermaking for Platinum Photographs," in *Platinum and Palladium Photographs: Technical History, Connoisseurship, and Preservation*, ed. Constance McCabe (Washington, D.C.: American Institute for Conservation of Historic and Artistic Works, 2017), 128–143.

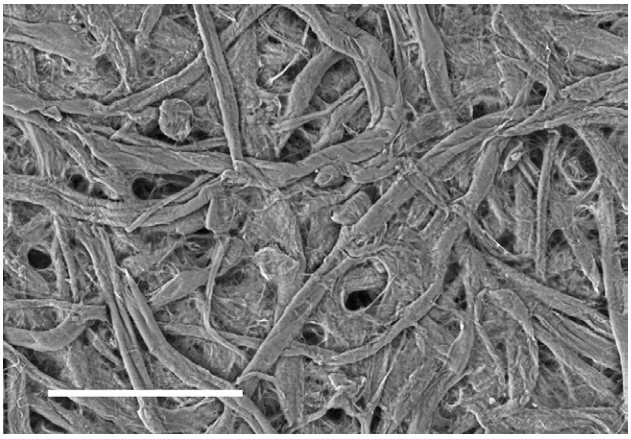


Figure 2. Backscattered electron scanning electron microscopy (BSE-SEM) image of paper surface from sample of Crane's 100% cotton bond paper, c. 1980. National Gallery of Art, Photograph Conservation Department. Image by Matthew L. Clarke. The fibers form a cohesive layer primarily through hydrogen bonding, enhanced by fiber processing methods. Scale bar = 200 µm.

Figure 3. Mold and deckle used in hand papermaking. National Gallery of Art, Paper Conservation Department. Copper wires aligned in parallel rows form a laid screen. Watermark and countermark designs are sewn to the screen at the corners.

Figure 4. Hand papermaking at the Basler Papiermühle, Schweizerisches Museum für Papier, Schrift und Druck, Basel, Switzerland. Image by the author. The papermaker is lifting the mold and deckle out of a vat filled with a slurry of paper pulp. After draining, a layer of pulp remains on the mold, seen at right with the deckle removed.

Figure 5. Handmade Whatman wove paper with watermark: "J Whatman 1908 ENGLAND." National Gallery of Art, Paper Conservation Department, Paper Sample Collection catalog number 1959.

5a. In transmitted light.

5b. In raking light. The diagonal texture is imparted by the weave of the drying felt.

Figure 6. Handmade Whatman laid paper showing laid lines (vertical) and chain lines (horizontal). National Gallery of Art, Paper Conservation Department, Paper Sample Collection catalog number 19.1.

6a. In transmitted light. Scale bar = 1.5 cm.

6b. In raking light. Scale bar = 1.5 cm.

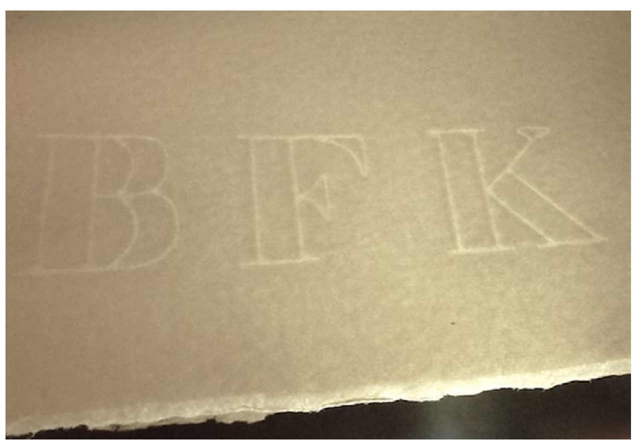


Figure 7. BFK Rives wove paper from *Papier de Rives*, a paper sample book from Blanchet Frères & Kléber dated 1895, seen with transmitted light. Collection of the University of Delaware Library, Newark, Delaware. Image by the author. The sample shows a watermark and false deckle edge from a cylinder-mold papermaking machine.

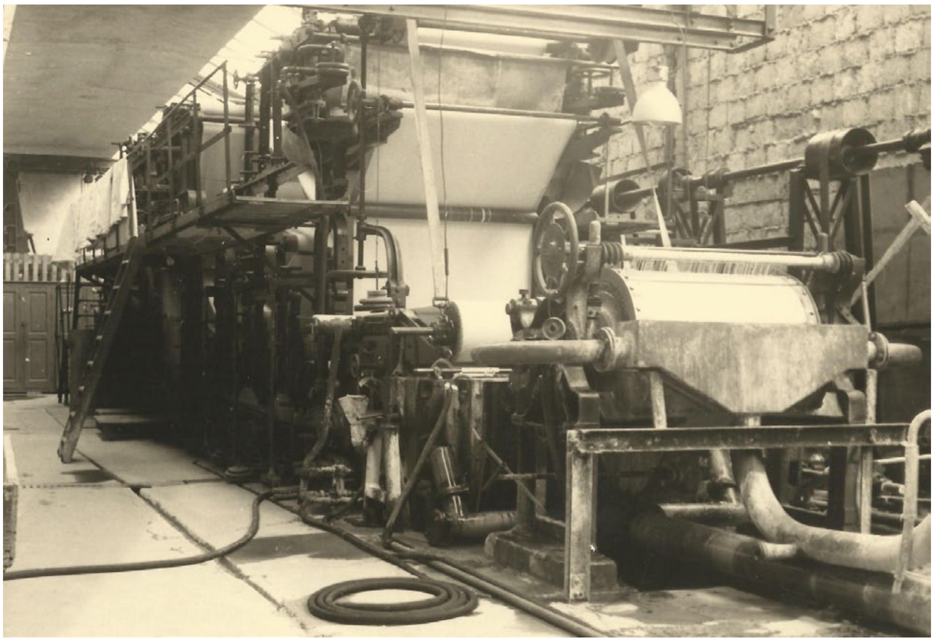


Figure 8. Cylinder-mold papermaking machine at the BFK Rives mill in Rives, Isère, France, installed between 1878 and 1889. Image courtesy Carole Darnault, private collection. The pulp collects on the cylinder at right using internal suction, after which the paper web passes through the woolen felts to remove moisture. Note the faint line across the cylinder that forms the tear wire, used to separate the roll into sheets while still damp, and to prepare them for hand-sizing and loft-drying.

Sheet Formation

Paper may be formed by hand or fabricated mechanically using either a cylinder-mold or Fourdrinier papermaking machine. Papers made by any of these methods were used for hand-sensitized platinum prints, but the fine handmade paper from the English firm of James Whatman was particularly valued for this purpose, continuing a tradition of use with the calotype negative and salted paper processes.[1] Other handmade papers recommended specifically for platinum processes include Zanders, Ingres, Unbleached Arnold, Imitation Creswick, and O. W. Paper.[2]

Handmade papers are formed on a rigid wire screen, called a mold, surmounted by a separate wooden frame, known as a deckle (fig. 3). The mold and deckle are dipped into a vat of watery paper pulp and then lifted out to settle the fibers across the screen as the water drains from below (fig. 4). After sufficient draining, the deckle is removed and the wet pulp is transferred from the mold by pressing it onto woolen drying felts. Following a series of pressings to remove free water, handmade papers are suspended in a drying loft with controlled heat and air circulation to minimize distortion and dimensional change. Once dried, features related to the construction of the mold (such as a watermark) or the drying process become particularly visible in transmitted and raking light (fig. 5). Most platinum and palladium prints were made on wove paper, named for the finely woven metal screen on which it is formed.[3] The Whatman mill was the first to introduce wove paper, which had a uniform texture ideally suited to capture subtle details and tonal transitions. Conversely, paper made on a screen composed of parallel rows of wire, known as laid paper, was less commonly used for platinum printing because its ridged, linear pattern often interfered with the image (fig. 6).[4]

The refined qualities of handmade paper could be produced at greater speed by forming the sheet on a cylinder-mold machine in combination with hand-drying methods. In fact, cylinder-mold papers mimicked the physical attributes of handmade paper so effectively that some manufacturers and vendors sold them as such, possibly to assure buyers of their superior quality (fig. 7).[5] The cylinder mold consists of a long, hollow drum covered with a laid or wove screen, often with an attached watermark design. As the cylinder turns, partially submerged in a vat of pulp, internal suction draws out the water, and the pulp settles on the screen. Rubber or metal straps at either end of the cylinder block the flow of pulp, forming two irregular edges similar to those created with a deckle. The remaining two edges are formed by a wire spanning the length of the cylinder, creating a thinner area of pulp deposition, which was used to tear the roll into separate sheets (fig. 8).

True mass-production of specialized paper for photographic use—known in the industry as raw stock or plain paper—was made possible by the Fourdrinier paper machine, which enabled much higher yields and superior control over sheet consistency.[6] The industry was dominated by two firms, which colluded in 1898 to control the market in Europe and North America: Steinbach & Company in Malmédy, Belgium (then part of Prussia), and Blanchet Frères & Kléber in Rives, France (BFK Rives).[7] Both mills had manufactured paper for albumen and other

Cyntia Karnes, "The Art and Science of Papermaking for Platinum Photographs," in *Platinum and Palladium Photographs: Technical History, Connoisseurship, and Preservation*, ed. Constance McCabe (Washington, D.C.: American Institute for Conservation of Historic and Artistic Works, 2017), 128–143.

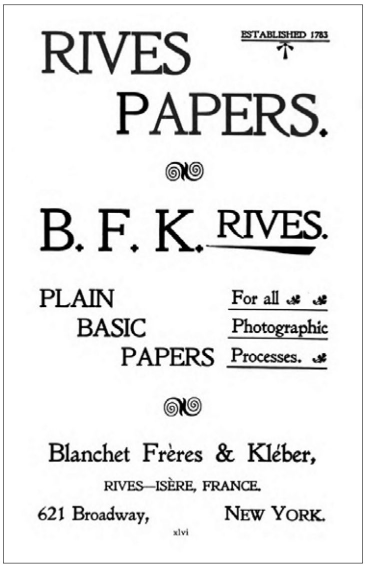


Figure 9. BFK Rives advertisement for plain basic papers. From *The American Annual of Photography and Photographic Times Almanac*, vol. 14, *1900* (New York: Scovill & Adams, 1900), xlvi.

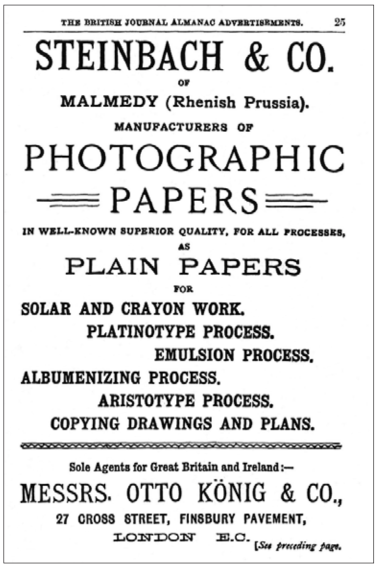


Figure 10. Steinbach & Company advertisement for plain paper. From *The British Journal Photographic Almanac and Photographer's Daily Companion, 1895* (London: Henry Greenwood, 1895), 25.

photographic processes since the mid-nineteenth century, moving into the production of specialized papers for platinum work in partnership with William Willis Jr. (1841–1923) and Alfred Clements for their Platinotype Company products.[8] By the 1880s, both mills sold their papers to other commercial producers or directly to photographic supply houses for hand-sensitizing (figs. 9, 10).[9] It is unclear, however, exactly what material distinction there is between base stocks supplied for different processes, with the possible exception of those intended for ephemeral use or for gelatin silver, which came to dominate production at BFK Rives by the 1890s.[10]

Mills producing raw stock on a Fourdrinier refined their processing methods to assure buyers that, in the words of one contemporary, "machine made papers can be produced superior in every respect to hand-made sorts even as regards strength."[11] In the Fourdrinier machine, the pulp slurry is fed from the headbox onto the "wire," a continuously revolving metal screen that distributes the pulp with a shaking motion as it travels toward the drying rolls (fig. 11). The Steinbach mill used a narrow wire screen at slow speed to produce a strong paper with a less pronounced grain direction.[12] After the web of paper passes a suction box, which removes most of the water, a dandy roll gently compresses the surface and creates a watermark. The Steinbach paper was marked with "Steinbach, Malmedy" along either edge of the paper web.[13] The BFK Rives mill did the same, using numbers to denote its raw stock (fig. 12).[14] A series of rollers and felts continue to remove water and compress the surface until the paper reaches the drying cylinders. Papers made on the Fourdrinier have a much stronger grain direction than handmade or cylinder-mold-made papers. Slow, methodical control of the drying process minimized this property and ensured papers would remain reasonably dimensionally stable during sensitizing and processing.[15]

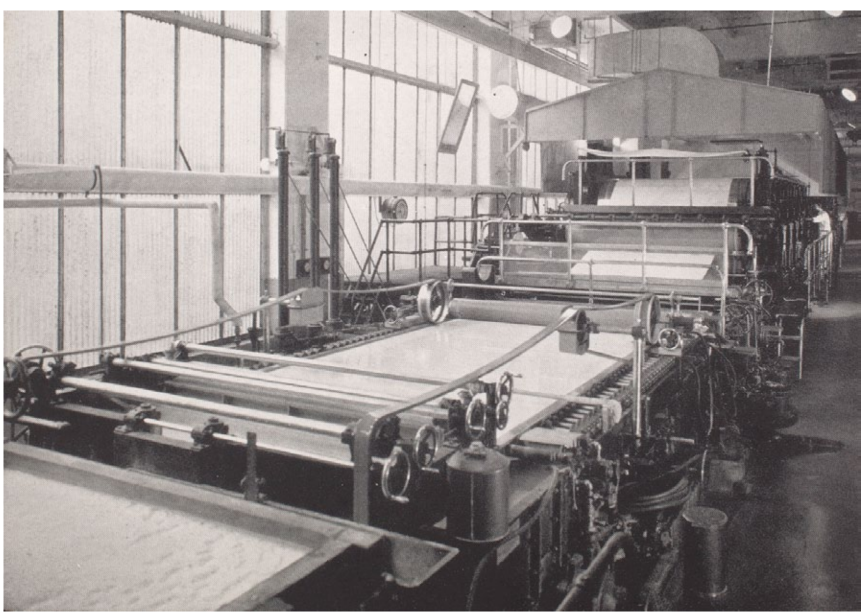


Figure 11. Fourdrinier papermaking machine. From *Kodak Photographic Papers for Professional Use* (Rochester, N.Y.: Eastman Kodak Company, 1941), 4. The screen supporting the paper pulp, called the "wire," continuously shakes back and forth to distribute and settle the fibers into a continuous "web" of paper.

 Cyntia Karnes, "The Art and Science of Papermaking for Platinum Photographs," in *Platinum and Palladium Photographs: Technical History, Connoisseurship, and Preservation*, ed. Constance McCabe (Washington, D.C.: American Institute for Conservation of Historic and Artistic Works, 2017), 128–143.

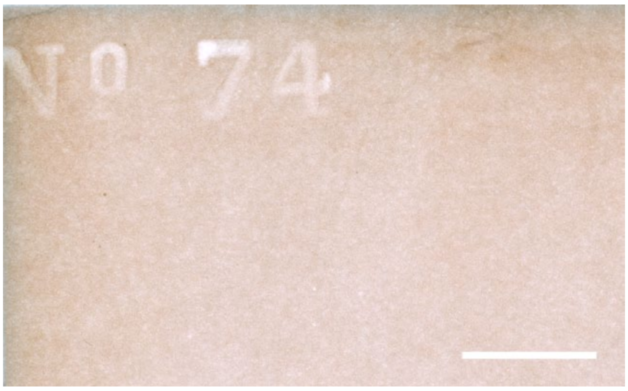


Figure 12. Partial watermark in BFK Rives paper no. 74, seen in transmitted light. National Gallery of Art, Photograph Conservation Department. Note the uneven displacement of fibers to the edges of the mark caused by the pressure of the dandy roll on the wet web of paper as it passes through the Fourdrinier machine. Scale bar = 1 cm.

Fiber Stock

Linen and cotton rags are widely cited in period trade literature as the best source materials for fine drawing or writing papers and photographic raw stock. Linen rag is composed of flax fiber containing a high percentage of crystalline cellulose, a pure form that resists chemical attack.[16] Cotton rag has long but somewhat weaker filaments that add bulk and softness to linen papers. Reports from 1892 note the predominance of cotton over linen in Whatman papers.[17] In contrast, a 1903 analysis of the Rives and Steinbach papers found a ratio of 85% flax (bast fiber from linen rag) and 15% new cotton.[18] Recent analysis of fiber content in three platinum and twelve *faux platinum* prints, dated 1888–1912, found that most supports were composed entirely of linen and cotton rag, with an increasing predominance of cotton toward the latter half of the nineteenth century and into the twentieth century.[19]

After fermentation and treatment with caustic lye, rag fibers were broken down into pulp in a series of mechanical processes, culminating with a Hollander beater. The sharp blades of the Hollander tended to cut fibers rather than grind them, and mills adjusted their operations to improve fibrillation of the fibers, necessary for the production of durable paper.[20] For example, the Steinbach mill beat its pulp for up to ten hours, and the BFK Rives mill collected and reused miniscule "waste" fibers from the pulp stock.[21] Magnified images of fibers from photographic paper made in both mills, published in the early twentieth century, show a mix of cut and frayed fibers of varying lengths.[22] Evidence of similar processing methods was also observed in recent analysis of papers used for platinum and *faux platinum* processes (fig. 13).[23]

The Hollander beater and the vast amounts of water used to grind the pulp are both potential sources of metal contamination in paper. Manufacturers expended considerable energy avoiding, removing, or neutralizing iron and other metallic compounds that caused disfiguring spots in the paper.[24] The BFK Rives mill minimized metal contamination by replacing iron parts in its machinery with harder alloys of bronze or steel, lining its Hollander with glazed tile, and installing a stone bedplate made of lava.[25] The Steinbach and BFK Rives mills utilized nearby sources of pure mountain water, but impurities remained a constant hazard. The Rives mill, in proximity to iron mines in the region, captured particulates by routing water into long covered sluices and filtering it in gravel traps and troughs lined with thick cloth.[26] Additional measures taken by mills to remove metal particles from the pulp included the use of magnets in the beater and chemical methods that employed peroxides, persulfates, or sulfuric acid to form soluble metal salts that could be washed away.[27]

Chronic scarcity of papermaking rags drove the industry to search for other sources of cellulose fiber. By 1923 the director of an American initiative to produce photographic papers noted that "the imported French and German photographic stocks are made from linen with a small percentage of sulphite and soda pulps."[28] The Rives mill is reported to have introduced wood pulp into its photographic papers in 1910.[29] Analysis of historic gelatin silver papers indicates that wood pulp began to be widely

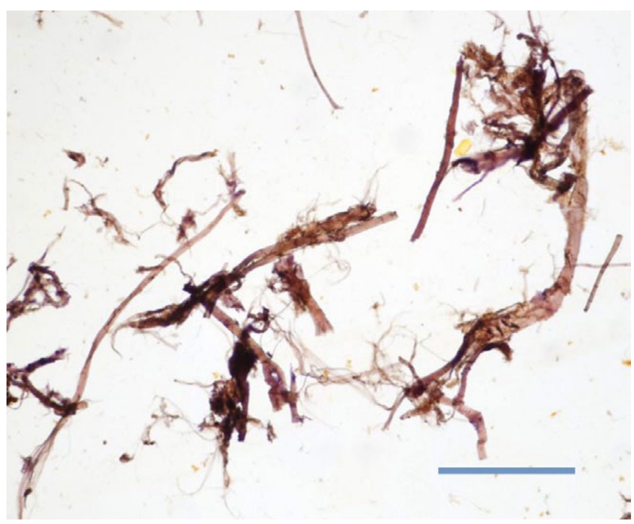


Figure 13. Magnified view of cotton and bast fibers of varying size with cut and frayed ends in photographic paper. From a platinum print by Henry Troth, *Syria, Jerusalem, Gossip, Algerian Quarter* (1909). Library of Congress, Prints and Photographs Division, PH Filing Series no. 5. Image courtesy Jennifer McGlinchey Sexton and Paul Messier. Scale bar = 300 µm.

Cyntia Karnes, "The Art and Science of Papermaking for Platinum Photographs," in *Platinum and Palladium Photographs: Technical History, Connoisseurship, and Preservation*, ed. Constance McCabe (Washington, D.C.: American Institute for Conservation of Historic and Artistic Works, 2017), 128–143.

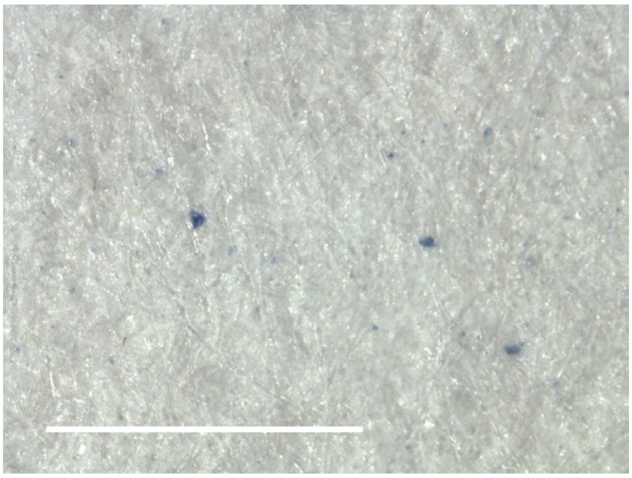


Figure 14. Magnified view of blue handmade Whatman paper showing smalt particles. From the 1931 sample book, *J. Whatman Papermakers: A Short History and Appreciation* (Springfield Mill, Kent, UK, 1931). National Gallery of Art, Paper Conservation Department, Paper Sample Collection catalog number 19.1. Scale bar = 0.5 mm.

incorporated by this date, with the amount of wood relative to rag increasing throughout the 1920s and 1930s.[30] The extensive use of straw has also been observed in gelatin silver photographs dated circa 1898–1932.[31] Wood pulp, straw, and other grasses require extensive chemical processing to remove colored compounds, silica, and lignin, a process that risked contamination of the pulp.[32] The use of these fibers in significant amounts appears to have been limited to gelatin silver processes in which the barium sulfate subbing layer would protect image salts from harmful components. One researcher of photographic paper stated that papers with a layer of baryta can contain up to 40% chemical wood pulp, but those "which serve directly and continuously as the carriers of photographic pictures, should be manufactured only from the best rag pulp."[33]

Additives

Inorganic compounds known as filling, bulking, or loading agents were mixed with paper pulp to make the finished sheet more smooth, white, and opaque. These materials added weight, improved dispersion of the pulp, and optimized machine performance. In the opinion of one early researcher of albumen photographic paper, raw stock could contain 5–10% filler without causing undue harm to image formation.[34] Despite this statement, additives were generally kept to a minimum. Inorganic particulates interrupt fiber-to-fiber bonding, thereby compromising paper's resistance to acidic chemicals and prolonged washing. Certain mineral fillers, such as Cornish clay (kaolin), were also a well-known source of metal contamination, particularly iron.[35] Furthermore, contemporary researchers and practitioners have observed that alkaline compounds in modern papers can have a negative impact on platinum image formation.[36]

Historical analysis of gelatin-sized papers used for hand-sensitized platinum prints, such as Whatman, Hollingworth, and Arnold, found only trace mineral content.[37] Somewhat higher amounts were found in an 1874 analysis of machine-made albumen stock: BFK Rives paper contained an average of 2.5% inorganic material, and Steinbach contained an average of 0.64%.[38] Another analysis the same year, of "the new raw paper" by BFK Rives, reported the presence of calcium oxide and trace amounts of silica and kaolin.[39] Later testing in 1903, however, found 3–4% ash in Steinbach and Rives papers, with some measuring as high as 9–14%, consisting of kaolin (aluminum silicate) and barium sulfate.[40]

By limiting the use of additives, included partly to enhance paper brightness, mills relied on other methods to produce paper white enough to reveal image highlights. Standard bleaching of the pulp, using chlorine followed by an antichlor such as sodium thiosulfate, risked leaving residues harmful to photographic processes. If bleach was used, as it apparently was at the Rives mill, extensive washing was critical.[41] The preferred way to ensure white paper was through the careful selection of rag stock that had previously been bleached and thoroughly washed before being woven into textiles. Blue coloring agents, in the form of pigments, dyes, or fibers, were commonly added to pulp in small amounts to mask yellow tones in unbleached rag stock or induced over time by gelatin or the degradative action of residual bleach on cellulose.[42] The Rives mill offered photographers a variety of colored papers, although pale blue and yellow tones appear most common for platinum printing.[43] Smooth, blue-toned papers were recommended for small images with bright highlights, while yellow-toned papers were promoted as ideal for softening or harmonizing larger images.[44] Photographers working with platinum processes were advised to use papers toned with smalt (cobalt blue) instead of ultramarine blue, since the latter was known to turn yellow in the acidic clearing bath.[45] Recent analysis has in fact confirmed smalt's presence in some supports used for platinum photographs (fig. 14).[46]

Sizing

Papers suitable for platinum printing were usually prepared with a sizing agent to close the surface, improve dimensional stability, and add mechanical strength.[47] Most important, sizing slowed absorption of the sensitizer, allowing its even distribution across the paper and concentrating it near the surface. Sizing, therefore, ensured long, clean tonal values by facilitating the exposure of the iron-platinum salts to light (where revealed by the negative) and their subsequent reduction to metallic nanoparticles, while also promoting the clearance of unexposed, soluble salts in the clearing and washing baths. It had the added benefit of physically protecting the paper's otherwise vulnerable surface during sensitization and processing, which might cause abrasion or lifting of paper fibers.

Period trade literature broadly characterized English handmade papers as gelatin sized, and Continental machine-made papers as either starch or rosin (or resin) sized. In fact, sizing practice was much more complicated than this description might imply. While gelatin has historically been used as a surface size for both handmade and cylinder-mold-made papers, it was also applied to "high-class" papers made on a Fourdrinier machine.[48] Application may have followed the addition of rosin directly to the pulp, commonly used alone to size machine-made papers.[49] Both gelatin and rosin relied on the addition of alum to transform them into water-resistant materials.[50] The BFK Rives and Steinbach mills incorporated starch with alum-rosin to size their photographic raw stock.[51] Starch was also applied at the mill as a surface coating for alum-rosin-sized papers to ensure water-resistance and a smooth surface.[52] To add to this confusing array of possibilities, photographers would sometimes apply their own secondary sizing agents to paper to reinforce the surface or adjust the final image tone.[53]

In developing their line of Platinotype Company papers, William Willis Jr. and Alfred Clements partnered with both the Steinbach and BFK Rives mills to customize alum-rosin-sized papers for platinum printing in a range of tones and surfaces.[54] Gelatin-sized paper had been rejected for its failure to produce platinum prints with clean, pure whites.[55] This fault may not have been due to the use of gelatin per se, but rather the result of its reaction to the hot-development process used in Willis's early trials. Gelatin swells at elevated temperatures, potentially trapping image material and impeding the removal of residual sensitizer during clearing and washing; the highest temperatures recommended for development may even cause dissolution of the gelatin film and the loss of image material.[56] The quality of gelatin used for sizing would also have been critical to successful platinum image formation.[57] Gelatins of lower quality incorporated clarifying agents that would have affected the viability and longevity of the print.[58] While high-quality gelatin had long been used to size fine papers, it is uncertain how consistently this practice was observed throughout the industry.[59] The Whatman mill, for example, had on occasion procured fine leather and parchment scraps for sizing special runs of printing paper, but there is no indication that the same efforts were extended for sizing the company's drawing papers, recommended for platinum printing.[60]

Papers sized with alum-rosin have been known to darken and become brittle over time, particularly in the presence of ferrous ions, so their use for platinum printing is initially surprising.[61] Studies noting poor aging characteristics, however, have not adequately examined the variables in materials and processing that have been known to contribute to paper deterioration.[62] The remarkably good condition of many platinum photographs on alum-rosin-sized paper may be partially attributed to high-quality sizing materials used under controlled conditions of temperature and pH, the use of supplemental sizing agents, and the beneficial influence of platinum photographic practice.

Rosin, an amber-colored mixture of acidic compounds extracted from conifer wood, could be distilled and filtered to reduce acidic and oily compounds before use with fine grades of paper.[63] The conditions under which rosin was added to the pulp had a significant impact on sizing efficiency and paper permanence. Recipes for sizing photographic stock indicate that the rosin was saponified, usually with sodium carbonate, and adsorbed onto the cellulose with alum.[64] "Potash alum" (potassium aluminum sulfate) was preferred, as it contained little to no iron or free sulfuric acid, unlike the "papermaker's alum" (aluminum sulfate) commonly used for machine-papermaking in the late nineteenth century.[65] Excessive amounts of alum were added to create acid conditions necessary for sizing efficiency, especially in mills using water with a high mineral content.[66] Although uncomplexed alum is normally a cause of deterioration in paper, it may have been removed from platinum prints in the washing and clearing baths due to its solubility in water.[67] Sizing theory during the

 Cyntia Karnes, "The Art and Science of Papermaking for Platinum Photographs," in *Platinum and Palladium Photographs: Technical History, Connoisseurship, and Preservation*, ed. Constance McCabe (Washington, D.C.: American Institute for Conservation of Historic and Artistic Works, 2017), 128–143.

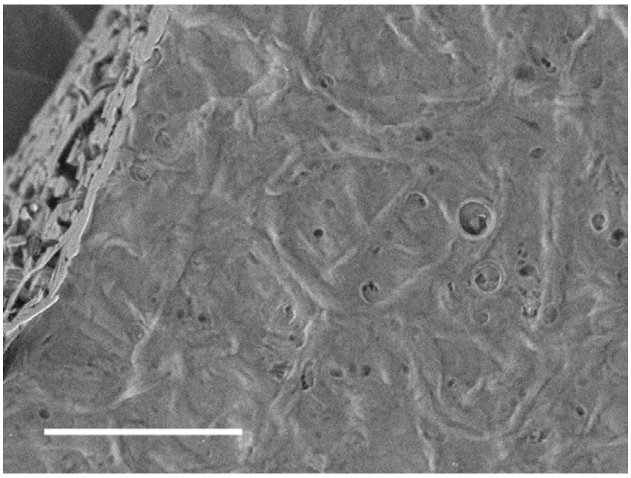


Figure 15. Backscattered electron scanning electron microscopy (BSE-SEM) image of the parchmentized surface of Crane's 100% cotton paper, c. 1980. National Gallery of Art, Photograph Conservation Department. Image by Matthew L. Clarke. The paper (same as shown in fig. 2) was modified with sulfuric acid to dissolve the cellulose and produce a parchmentized surface. Scale bar = 200 μm.

platinum era proposed that certain conditions, such as the excessive use of alum, actually interrupted the chemical bonding of rosin soap to cellulose by initiating the formation of a free acid rosin dispersion.[68] The dispersion, composed of a finely divided rosin particulate, melted in the steam-heated drying rolls to reinforce the surface and add strength to the paper.[69] Starch also strengthened the size, as the water-swollen granules burst under the heat and pressure of the drying rolls, releasing an adhesive film.[70] Secondary sizing layers used in platinum printing may also have served as a physical barrier against any chemically reactive impurities, a particularly important practice when hand-sensitizing papers that had not been specifically marketed for platinum work.

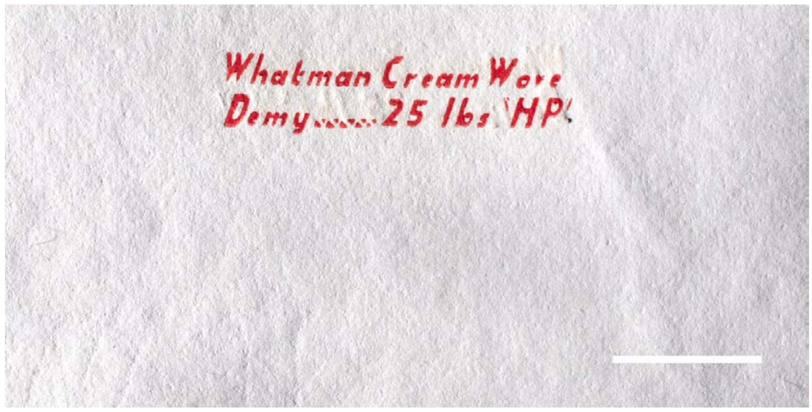
Surface Finishing

Paper could be chemically modified to improve mechanical resistance, close the surface, and impart sheen in a process known as parchmentization. This process was generally done before sizing and other surface finishing treatments, although it could even be performed after photographic development.[71] Sulfuric acid converts crystalline cellulose to a gelatinous, amorphous state, creating a translucent appearance and a hard, closed surface similar to that of animal parchment (fig. 15).[72] Acid treatment had the simultaneous benefit of dissolving any metallic particles in the paper that would be injurious to platinum and palladium chemistry.[73] The degree of translucency and surface reflectance in treated paper is controlled by the acid concentration, duration of exposure, and initial moisture content.[74] The Rives mill offered parchmentized papers in a number of sizes and weights, in white or blue tones, partnering with the Platinotype Company in 1906 to produce its range of surface-parchmentized Japine papers.[75]

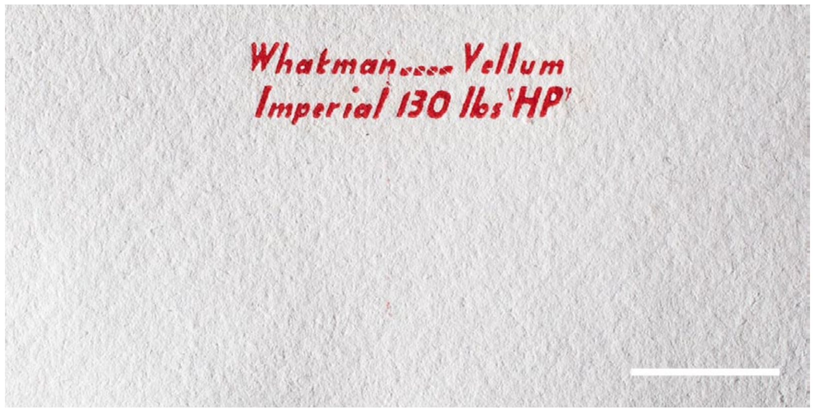
Drying procedures could also be regulated to impart surfaces ranging from very smooth to highly textured, to create a particular aesthetic effect. By the platinum era, the Whatman company sold its handmade wove papers in three surfaces: cold-press (also called "Not," i.e., "not hot-pressed"), rough, and hot-press (fig. 16).[76] Cold-press surfaces had a "natural surface with a slight grain," imparted by the first pressing between brushed woolen felts. Rough-surface papers were "coarse" and had a "larger and open grain" due to a final pressing between highly textured felts. Hot-press papers were "perfectly smooth," from pressing between metal plates, sometimes heated.[77] Within these categories, there was still a great deal of variation in surface texture, depending on the thickness of the paper and the woven pattern or nap of the felt. Significant textural variation may be evident within the sheet as well, as the side closest to the screen during sheet formation is usually rougher than the side first deposited onto the felt for drying. For this reason, some manuals recommended applying sensitizer to the smoother "felt side" of the paper to better reveal fine details and crisp highlights. Smooth surfaces were recommended for smaller formats, while rougher papers were deemed suitable for larger images such as landscapes, as their surface undulations generated internal shadowing that harmonized and softened the scene.[78]

The rough- or cold-press textures of handmade and cylinder-made papers were reproduced on the Fourdrinier with textured or brushed felts held taut between rollers. Some German mills omitted the felts, relying on the finely woven wire screen and pressure from rollers to impart a smooth surface.[79] The BFK Rives mill sold its raw stock in three surfaces: *non-satinè* (cold-press), *à grain* (rough), and *glacé* (hot-press).[80] Highly polished surfaces were produced by repeatedly passing the paper through the "affectionate squeeze" of the calenders (a stack of highly polished metal rollers) to create a compact, hard surface that could withstand "the rough treatment to which it must be subjected by the photographer."[81] Other mills used metal rollers to impress patterns or texture into the surface. A "linen surface," with a woven texture, was impressed into raw stock by passing it through steam-heated embossing rolls.[82] One unusual paper cited for platinum printing was "pyramid-grain paper," a drawing paper with an embossed

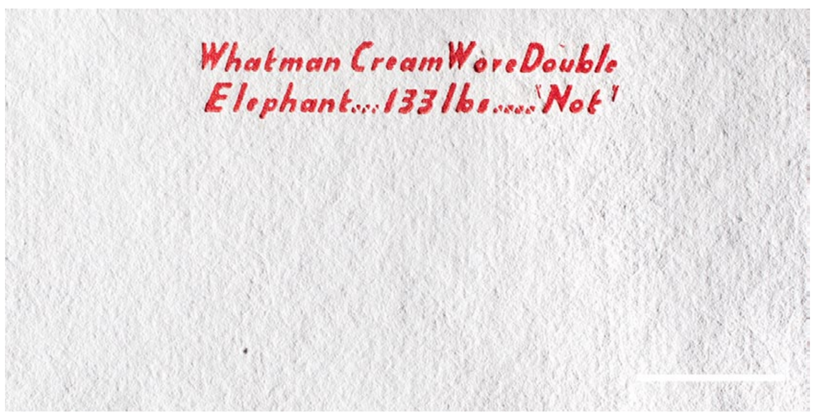
Figure 16. Comparison of handmade Whatman papers showing variations in surface texture, from the 1931 sample book *J. Whatman Papermakers: A Short History and Appreciation* (Springfield Mill, Kent, UK, 1931). National Gallery of Art, Paper Conservation Department, Paper Sample Collection catalog no. 19.1. Note that the hot-press paper illustrated in figure 16a appears significantly different from the hot-press paper illustrated in figure 16b due to the greater thickness (weight) of the latter and to the use of a heavily textured felt as it dried. Scale bars = 1 cm.



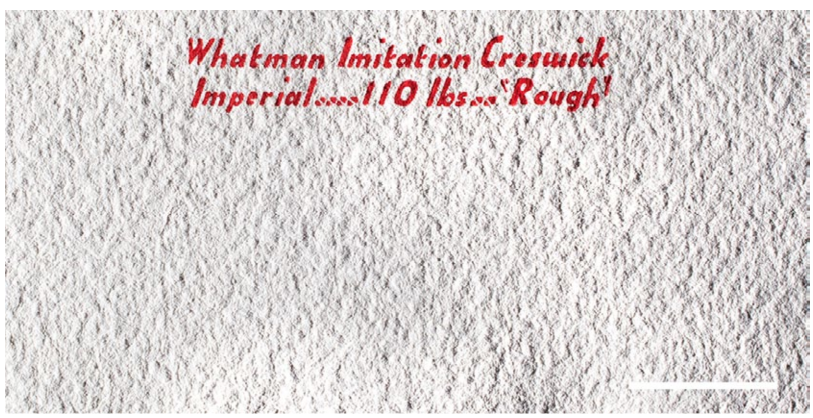
16a.Thin (25 lb.) wove paper with a hot-press surface.



16b. Heavy (130 lb.) "vellum" paper with a hot-press surface.



16c. Heavy (133 lb.) wove paper with a "Not," or cold-press, surface.



16d. Heavy (110 lb.) Imitation Creswick wove paper with a rough surface.

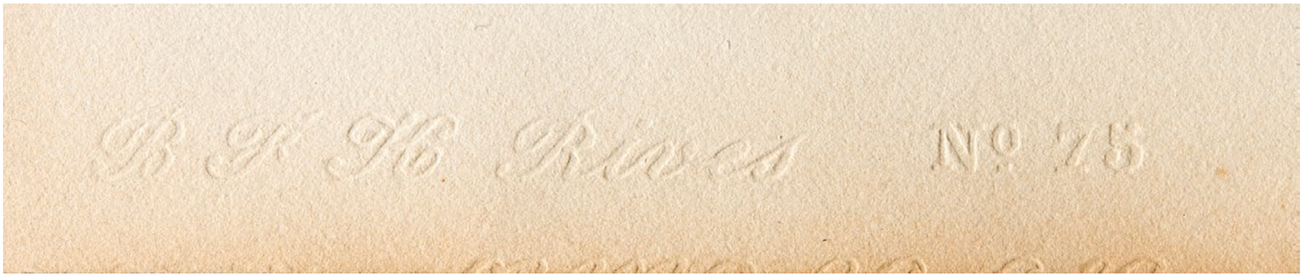


Figure 17. BFK Rives no. 75 embossed watermark on verso of platinum print by F. Holland Day, *Nude Youth with Laurel Wreath and Staff*, c. 1906. Library of Congress, Prints and Photographs Division. Image courtesy Adrienne Lundgren. The stamp is repeated in reverse, trimmed at the edge. The embossing indicates the use of a *typographe* roll, used to create a false watermark in Fourdrinier machine-made paper.

tooth available in three grades.[83] The BFK Rives mill blind-stamped its paper along edges with a *typographe*, a cylinder that impressed a "watermark" on the paper surface (fig. 17).[84] Individual sheets cut to standard sizes on the "slitter" were similarly stamped with a watermark by pressing them between embossed zinc plates.[85]

It is important to note that the surface quality of any paper may be further modified by wet processing, mounting, rolling, or burnishing, all of which may make it difficult to ascertain exactly how the paper might have appeared in its original state.[86]

Conclusions

When William Willis announced his platinum process in 1878, the centuries-old art of making paper by hand had evolved into an industrial science with fully mechanized production. The development of specialized papers for photography in the mid-nineteenth century incorporated the formative principles of fine papermaking that extolled the use of purified cellulose from rag stock and high-quality sizing agents, while adding ingenious methodologies to refine processing methods and reduce harmful contaminants. These innovations enabled the mass-production of fine papers that allowed the platinum image to form unblemished and to resist harsh chemical processing and the ravages of time. The mills of BFK Rives, Steinbach, and Whatman were instrumental to the development of the photographic arts, inspiring experimentation with handmade and machine-made papers in a myriad range of textures, colors, weights, and sheens. By the turn of the twentieth century, the art and science of papermaking had become intimately united with the art and science of platinum printing, ensuring the lasting impact of many of photography's most beautiful images.

Acknowledgments

Deep appreciation and thanks to Marian Dirda, Constance McCabe, and Sarah S. Wagner, conservators at the National Gallery of Art in Washington, for sharing their extensive knowledge and many informative texts. Thank you also to Bruno Kehl, keeper of the Steinbach Paper Museum in Malmédy, Belgium, for sending several hard-to-find articles, and to Carole Darnault, lecturer in history, Grenoble, France, for providing primary source information and images from the BFK Rives mill. I am grateful to the following people who provided crucial images and/or analysis for this research: Matthew L. Clarke, conservation scientist at the Freer Gallery of Art and Arthur M. Sackler Gallery; Adrienne Lundgren, photograph conservator at the Library of Congress; Christopher Maines, scientist at the National Gallery of Art; Jennifer McGlinchey Sexton, conservator of photographs at Paul Messier LLC; Paul Messier, head of the Lens Media Lab at the Institute for the Preservation of Cultural Heritage, Yale University; Caroline Minchew, research assistant at the National Gallery of Art; and Sylvie Pénichon, photograph conservator at the Art Institute of Chicago.

Notes

1. Fairbanks Harris et al. 2006, 108; Hyejung Yum, "A Study of Early Photographic Paper" (unpublished manuscript for the Advanced Residency Program in Photograph Conservation, Rochester, N.Y., 2009), 4. In trade manuals discussing platinum processes, the venerated Whatman name was invariably associated with handmade paper, although its watermark was also used in papers made by machine until 1859 (at the former Whatman-owned Turkey Mill), after which it was sold under the name of the new owners, the Hollingworths, a paper also recommended for working in platinum.

2. Scolik 1893, 659; Clark 1890, 41–42; Engelmann 1904, 24. Zanders paper was made by J. W. Zanders in Bergisch-Gladbach, Germany; Ingres, by the Arches mill in Vosges, France; Unbleached Arnold, by Arnold & Foster in Kent, England; Imitation Creswick, by the Whatman mill; and O .W. Paper, short for Old Watercolor Paper, by Hayle mill in Maidstone, Kent.

3. Wove papers are also called *velin* or "vellum" in paper and photographic trade literature. The term "vellum" has also been used to refer to partially parchmentized paper, hot-press (or glazed) paper, and heavyweight, smooth Japanese papers.

4. Similar parallel lines may be visible in Japanese papers commonly used by the Pictorialists. These lines, called *sunome*, are created by a *sugeta*, a flexible screen made of bamboo in a hinged frame. A woven cloth placed on top of the screen prevents the formation of lines in the dried sheet.

5. Blanchet Frères & Kléber 1895; Picard 1891, 118. Sometime between 1878 and 1889, the Rives mill began operating a cylinder-mold machine alongside its Fourdrinier machines. Some paper specimens sold as handmade (*à la cuve*) in the sample book have false deckle edges with well-defined inner edges typical of papers made on a cylinder-mold machine. However, the features in paper most useful for distinguishing handmade and cylinder-mold-made papers, such as watermarks and deckle edges, are generally trimmed off in the final print.

6. Kaefer 1981,7; Darnault 2000, 122; Wilson 1882. The BFK Rives mill used a Fourdrinier machine (M4) for making specialized photographic paper, confirmed by Carole Darnault, personal communication, September 2, 2015, and March 7, 2016.

7. "Photographic Supplies" 1901. It should be noted that Steinbach advertised its "Saxe" raw stock, but the term has occasionally been incorrectly attributed to the BFK Rives mill in the trade literature. Other major manufacturers of machine-made raw stock observed in period trade literature include Schleicher und Schüll in Düren, Germany, Felix Schöller in Burg Gretesch, Germany, Gustav Röder and Company in Marschendorf, near Vienna, Austria, and C. Schauffelen in Heilbrunn, Germany.

8. Darnault 2000, 118, 128; Kaefer 1981, 7; [Woodbury] 1895, 218; Barhydt 1892, 20. The Steinbach mill began production of raw stock by 1848; BFK Rives announced its first photographic papers in 1851. The Platinotype Company began a working partnership with the Steinbach mill in 1885 and with the BFK Rives mill in 1887.

9. For the use of raw paper for a wide variety of commercially available products, see Sarah S. Wagner, "Manufactured Platinum and *Faux Platinum* Papers, 1880s–1920s," in this volume.

10. "Photographic Paper" 1880, 373. In the late nineteenth and early twentieth centuries, the market for platinum photography was growing alongside a robust demand for silver processes, and discussions of raw stock in the trade literature do not always indicate a specific photographic purpose. The same conditions considered essential for platinum paper have also been outlined in trade literature discussing silver processes. Processes that incorporate a baryta layer, however, were considered less sensitive to chemical impurities, and as a result, manufacturers may have utilized more wood or grass pulp, and more fillers, than recommended for direct, single-layer processes such as platinum and albumen. Paper for photo-reproductive processes such as cyanotype may also have incorporated larger amounts of wood or grass pulps because permanence was less a concern.

11. "Invention and Development" 1894, 124.

12. Jacobson 1876, 196; Clapperton and Henderson 1929, 167, 193. The slower speed enhances settling and felting of the fibers as the pulp is shaken on the wire, increasing paper strength and density, but only if the pulp is well beaten (not cut), as it was at Steinbach.

13. "Joining Prints" 1880.

14. "Photographic Paper" 1880, 373; "Platinotype Processes" 1899, 325. BFK Rives no. 74 was recommended for platinum work, although the author has only seen the watermark in albumen prints.

15. "Expansion of Paper" 1890; "Joining Prints" 1880. Machine-made paper expands and stretches much more against the grain direction than with the grain direction. Tests conducted on photographic raw stock determined that significant stretching occurred after wetting and mounting the paper to board.

16. Timár-Balázsy and Eastop 2012, 33–34. Cotton and linen rags were already processed to remove the woody (noncellulosic) parts of the plant and had greater strength and flexibility than unprocessed fibers. Cotton textiles may be composed of up to 99% cellulose, with 70–80% crystalline cellulose. The crystallinity of cellulose in linen is even higher, around 90%.

17. Cross and Bevan 1892, 213; Evans and Wirtz 1892; Hartley 1892. The preponderance of cotton in Whatman papers refutes Hartley's report that they were primarily composed of linen.

18. Scavia 1903, 147. "Flax," the term used by Scavia in his report, refers to the plant source from which linen is made. "New" cotton, also mentioned in the report, refers to unworn cotton textiles.

19. Analysis in 2014 by Jennifer McGlinchey Sexton and Paul Messier identified fiber composition and characteristics of fifteen photographs from the Prints and Photographs Division, Library of Congress, submitted as copyright deposits or tipped into dated trade journals. The declining availability and increasing cost of linen rag, determined by changing tastes in fashion and increasing trade restrictions, may have placed pressure on manufacturers to use greater amounts of cotton in their papers. Sexton and Messier's unpublished "Materials Assessment Report," September 2014, is available from Paul Messier LLC, or the author of this essay, with permission. For a discussion of *faux platinum* prints, see Wagner, "Manufactured Platinum and *Faux Platinum* Papers," in this volume.

20. Fibrillation is the process of breaking down the outer cell wall of cellulose fibers and causing them to delaminate and split longitudinally into microfibrils, increasing surface area for hydrogen bonding between fibers and promoting their hydration in water—necessary for imparting strength to the dried sheet. The percentage of fibrillated fibers is promoted by dulled blades, agitating the pulp in water with a slight gap between the blades and bedplate, and recovering microfibrils from the drained water.

21. Jacobson 1876, 196; Laboulaye 1874, 22.

22. Scavia 1903, 152–53.

23. Sexton and Messier, "Materials Assessment Report," September 2014.

24. Dalen 1907, 238–39. The article provides a full description of all spots and flaws in photographic paper and their probable causes during manufacture, including those imparted by the most common metallic contaminants, iron and bronze.

25. Darnault 2000, 131; "Notes Concerning Conditions Essential to the Manufacture of Photographic Paper," c. 1907–8, Paper Sample Collection files, National Gallery of Art. Darnault notes the use of steel to replace bronze or copper. The unpublished description of the Rives mill specifies the exact composition of the beater bars, showing a large amount of copper (87%), with small amounts of tin, iron, zinc, phosphorus, and lead.

26. Wilson 1882.

27. "Manufacture of Photo Paper" 1916; "Photographic Paper Technology" 1919, 13.

28. Hitchins 1923, 227. Wood and straw fiber assisted in creating a closed surface, due to their much finer dimensions over rag fiber.

29. Darnault 2000, 128, 131–32.

30. Results of ongoing analysis of the Paul Messier Historic Photographic Papers Collection were briefly summarized in Sexton and Messier, "Materials Assessment Report," September 2014. The report presented findings related to fiber content in fifteen platinum and *faux platinum* photographs with well-established dates in the collection of the Library of Congress, noting only two samples with a significant amount of wood pulp (38–39%) along with rag fiber.

31. Daffner 2014, 56.

32. Chemical treatment included bleaching with chlorine, hypochlorite, and/or chlorine dioxide, with caustic extraction (sodium thiosulfate) and washing cycles between each exposure.

33. "Manufacture of Photo Paper" 1916.

34. Schnauss 1874, 159.

35. Hunt 1852, 18; Brückle 1993b.

36. Mike Ware, "The Technical History and Chemistry of Platinum and Palladium Printing," in this volume.

37. Evans and Wirtz 1892; Cross and Bevan 1892, 213; Hartley 1892. Hartley's claim that the aforementioned papers were acidic was later refuted by the other cited authors, in part due to the finding of trace minerals possibly introduced by spring water or caustic alkali used for processing the paper pulp, which neutralized any free acid.

38. Schnauss 1874, 162; Griffin and Little 1894, 438–39.

39. "New Photographic Paper" 1874. The "new" BFK Rives paper was watermarked with three stars, known as "Stern" paper.

40. Scavia 1903, 147. See also Darnault 2000, 130.

41. Chalmers 1920, 24; "Notes Concerning Conditions," Paper Sample Collection files; Wilson 1882.

42. Brückle 1993a; "Notes Concerning Conditions," Paper Sample Collection files. The latter document also notes the use of cochineal, the insect source for red dye. Its use is surprising given its known sensitivity to light and acidic conditions.

43. Darnault 2000, 123; Marion & Company advertisement for Rives papers in various colors, *The British Journal Photographic Almanac and Photographer's Daily Companion, 1882* (London: Henry Greenwood, 1882), 9; Blanchet Frères & Kléber 1895, 3. Darnault lists photographic papers available in white or cream, gray, blue, green, *chamois*, and orange. A classified listing for Marion & Company, a supplier of photographic paper with an exclusive contract with BFK Rives, lists unsensitized Rives papers in shades of rose, blue, violet, and mauve. The Rives paper sample book (Blanchet Frères & Kléber 1895) contains parchmentized papers in *azurée* and *chamois*.

44. Hübl 1895, 27.

45. Pizzighelli and Hübl 1883, 129; Schnauss 1874, 163; "Advice to Beginners" 1859; Pabst 1889, 368. Prior to the platinum era, ultramarine may have been added to papers used for early photographic processes. "Advice to Beginners" notes the early use of ultramarine in "French papers," perhaps referring to BFK Rives papers, and Schnauss reports on the use of ultramarine in Steinbach paper.

46. Matthew L. Clarke, analysis report, November 28, 2011, Scientific Research Department, National Gallery of Art, and examination of prints at the National Gallery of Art in 2015. Several early platinum prints prepared by William Willis, and donated to the Photograph Conservation Department Study Collection, National Gallery of Art, by Hans Kraus Jr., contain smalt, determined by x-ray fluorescence and microscopic examination.

47. Sizing may have been skipped if the paper was to be parchmentized.

48. Clapperton and Henderson 1929, 265–72, 308; Chalmers 1920, 109; Hitchins 1923, 228. Surface sizing by machine occurred by passing the continuous web of paper through a trough of warm gelatin or after cutting it into sheets and hand-dipping, similar to sizing handmade paper.

49. Clapperton and Henderson 1929, 111–12; Hitchins 1923, 227–28. In machine-sizing, rosin was added to the pulp before sheet formation. For this reason, it is referred to as "engine size" or "internal size" in the trade literature. Rosin added to the vat was reacted with an alkaline compound to make a soluble rosin soap, which allowed it to chemically bond with the cellulose.

50. True alum is a double salt of aluminum, such as potassium aluminum sulfate, i.e., "potash alum." However, the term is used in the trade literature to refer to any compound containing hydrated aluminum sulfate, such as sodium aluminum sulfate, ammonium aluminum sulfate, and aluminum sulfate, i.e., "papermaker's alum."

51. Scavia 1903, 149; Jacobson 1876, 196; Wilson 1882.

52. Clapperton and Henderson 1929, 272.

53. Lietze 1888, 81; Anderson 1923, 198; Pizzighelli and Hübl 1883, 129; Hübl 1895, 31–32. For this reason, period trade literature often referred to mill-sized papers as "half-sized." Secondary sizing agents included gelatin, arrowroot starch, carrageenan, tragacanth, rosin, and agar-agar. Historical accounts indicate that papers sized with gelatin produced cool tones, and starch yielded warmer tones. Crane's machine-made paper (c. 1980) sized at the mill with alum-rosin and added starch appears neutral in tone. Constance McCabe, personal communication, June 17, 2014.

54. [Woodbury] 1895, 216; Barhydt 1892, 20; Darnault 2000, 128.

55. [Woodbury] 1895, 218; Barhydt 1892, 20.

56. Sheppard 1923, 32, 91; Platinotype Company 1883, 2. The temperature recommended for hot development by the Platinotype Company ranged from 170 to 190°F (77–88°C). According to Sheppard, the exact temperature at which gelatin swells and dissolves depends on the composition and concentration of the dried film, but on average it will swell up to 5–10 times its weight in water and begin to dissolve at temperatures above 20°C (68°F).

57. "Photographic Papers and Paper Makers" 1887, 507. Mike Ware, "Technical History and Chemistry of Platinum and Palladium Printing" in this volume, notes the inhibitory effect of gelatin on platinum chemistry.

58. Balston 1998, 211.

59. Balston 1998, 210–12; "How Paper Is Sized" 1892, 698; Hitchins 1921, 36; Kolbe 2004, 26. Balston 1998 and "How Paper Is Sized" discuss historically used gelatin sources for fine papers. Hitchins 1921 notes that the purest gelatins used for photographic emulsions are obtained from the first extractions at lower temperature. According to Kolbe 2004, the paper industry benefited from the increased availability of purified photographic gelatin, produced on an industrial scale by the mid-nineteenth century.

60. Balston 1998, 210–12; Hitchins 1921, 36. The methodology used for extracting gelatin from hides is crucial to its strength and purity.

61. Kimberly and Hicks 1931, 820, 827. The study notes the influence of iron in causing rosin to darken in paper but did not include the best grades of rosin likely used for better-quality papers.

62. Kimberly and Hicks 1931, 820, 827; Barrow 1974. Barrow's comprehensive analysis of alum-rosin-sized book papers, for example, did not consider the deleterious influence of iron or mechanical wood fiber content on the aging of paper.

63. Ashe 1894, 82–83; "Rosin, Size and Sizing" 1899, 213; "Photographic Papers and Paper Makers" 1887, 507. The two best grades, so clear they were classified as "water-white" and "window glass," were exported from the southern United States to European paper mills.

64. Towler 1866, 293; Harrison 1887a, 102; Harrison 1887b, 507; "Photographic Paper" 1903; "Photographic Paper Technology" 1919. Alum creates a chemical charge with the hydrophobic rosin that allows it to chemically bond with the hydrophilic paper.

65. "Alum for Sizing" 1912; Clapperton and Henderson 1929, 116; Brückle 1993b, 53. Iron and free sulfuric acid causes metal-induced oxidation and acid hydrolysis of cellulose, which in turn cause embrittlement and darkening in paper, particularly in sunlight.

66. "Rosin, Size and Sizing" 1899, 214; Remington et al. 1911, 788; "Engine Sizing" 1895.

67. Brückle 1993b.

68. Clapperton and Henderson 1929, 111–12; "Engine Sizing" 1895; Remington et al. 1911, 788. The authors of these publications describe several theoretical mechanisms for alum-rosin sizing proposed during the platinum era.

69. Clapperton and Henderson 1929, 111.

70. Hofmann 1873, 87; "Photographic Paper Technology" 1919, 13. In "Photographic Paper Technology," the author recommends casein and wax, in addition to starch and gelatin, to reinforce alum-rosin size in gelatin silver papers.

71. Andés 1923, 4; "Parchmentizing Prints" 1908, 407. The author advises a more dilute 2:1 sulfuric acid and water bath for 30 seconds for Whatman drawing paper, less for thinner papers. Whatman drawing papers intended for watercolor work are the types of papers recommended in platinum manuals.

72. Pizzighelli and Hübl 1883, 129; see note 3 above. Parchmentized papers are often referred to as "vellum." However, the use of this term in photographic trade literature may imply only that the paper is wove, not parchmentized. For example, Pizzighelli and Hübl recommend an "ivory vellum" made by Gustav Röder and Company near Vienna, available hot-pressed or "unglazed" (i.e., natural grain).

73. "Manufacture of Photo Paper" 1916; Hofmann 1873, 333–34. Any free sulfuric acid from parchmentization is reacted with caustic baryta, forming barium sulfate, which closes the pores of the paper. Alum has also been used with sulfuric acid to parchmentize paper.

74. Clarke et al. 2015, 213–23.

75. Blanchet Frères & Kléber 1895, 3.

76. Krill 1987, 34–38.

77. Krill 1987, 36–37.

78. Hübl 1895, 28.

79. Hitchins 1923, 229.

80. Blanchet Frères & Kléber 1895, 6.

81. Wilson 1882.

82. Hitchins 1923, 229.

83. Hübl 1895, 28–30; Jones 1911, 292; Chesterman 1893; "Papers Used in Photographic Work" 1916. The paper was known as *pyramidenkornpapier*. A variation was produced by C. Schauffelen.

84. "Brevet d'invention de cinq ans" 1845, patent 7485; Wilson 1882; Bruylant 1880, 698–99. Figure 17 illustrates the mill's use of cursive script and "No." designation in its watermark, similar to several watermark designs submitted for patent renewal in 1880. See also "De l'utilite des filigranes du papier" 1888, 159–60. According to testimony by Mssr. Blanchet in a forgery case, the BFK watermark in Roman letters did not begin until the end of 1885.

85. "Notes Concerning Conditions," Paper Sample Collection files.

86. Osterman 2005.

References

"Advice to Beginners" 1859 "Advice to Beginners." *Photographic Notes* 75 (1859): 131–34.

"Alum for Sizing" 1912 "Alum for Sizing." *Paper Trade Journal* 54, no. 18 (1912): 56.

Anderson 1923 Anderson, Paul L. *The Technique of Pictorial Photography*. New York: J. P. Lippincott, 1923.

Andés 1923 Andés, Louis Edgar. *The Treatment of Paper for Special Purposes*. London: Scott, Greenwood, 1923.

Ashe 1894 Ashe, William Willard. *The Forests, Forest Lands, and Forest Products of Eastern North Carolina*. Raleigh, N.C.: Josephus Daniels, 1894.

Balston 1998 Balston, John. *The Whatmans and Wove (Velin) Paper: Its Invention and Development in the West*. West Farleigh, Kent: John Balston, 1998.

Barhydt 1892 Barhydt, Jerome A. *Crayon Portraiture: Complete Instructions for Making Crayon Portraits on Crayon Paper and on Platinum, Silver and Bromide Enlargements*. Rev. ed. New York: Baker & Taylor, 1892.

Barrow 1974 Barrow, William J. *Physical and Chemical Properties of Book Papers, 1507–1949*. Permanence/Durability of the Book 7. Richmond, Va.: W. J. Barrow Research Laboratory, 1974.

Blanchet Frères & Kléber 1895 Blanchet Frères & Kléber. *Papiers de Rives.* Sample book. Paris: Blanchet Frères & Kléber, 1895.

"Brevet d'invention de cinq ans" 1845 "Brevet d'invention de cinq ans." *Description des machines et procédés consignés dans les brevets d'invention, de perfectionnement et d'importation* 58 (1845): 233.

Brückle 1993a Brückle, Irene. "Historical Manufacture and Use of Blue Paper." In *Book and Paper Group Annual* 12 (1993): 5–12. Online at cool.conservation-us.org.

Brückle 1993b Brückle, Irene. "The Role of Alum in Historical Papermaking." *Abbey Newsletter* 17, no. 4 (1993): 53–57. Online at cool.conservation-us.org.

Bruylant 1880 Bruylant, E. *Recueil des marques de fabrique et de commerce les marques deposes en Belgique en conformite de la loi du 1 avril 1879.* Brussels: Ministère de l'industrie et du travail, 1880.

Chalmers 1920 Chalmers, Thomas Wightman. *Paper Making and Its Machinery, Including Chapters on the Tub Sizing of Paper, the Coating and Finishing of Art Paper and the Coating of Photographic Paper*. London: Constable & Company, 1920.

Chesterman 1893 Chesterman, C. T. "Photography in Russia." *Photographic News* 37 (1893): 139.

Clapperton and Henderson 1929 Clapperton, Robert Henderson, and William Henderson. *Modern Paper-Making*. London: Ernest Benn, 1929.

Clark 1890 Clark, Lyonel. *Platinum Toning: Including Directions for the Production of the Sensitive Paper*. London: Hazell, Watson & Viney, 1890.

Clarke et al. 2015 Clarke, Matthew L., Constance McCabe, Christopher A. Maines, Silvia A. Centeno, Lisa Barro, and Anna Vila. "An Investigation into Japine Platinum Photographs: William Willis's Proprietary Paper." *Journal of the American Institute for Conservation* 54, no. 4 (2015): 213–23.

Cross and Bevan 1892 Cross, Charles Frederick, and Edward John Bevan. "The Acid Action of Drawing Paper of Different Makes." *Journal of the Society of Chemical Industry: A Monthly Record for All Interested in Chemical Manufacturers* 11, no. 3 (1892): 213–14.

Daffner 2014 Daffner, Lee Ann. "Dive: A Materialist History of the Photographic Industry in Germany and the Soviet Union between the Wars." In *Object:Photo, Modern Photographs: The Thomas Walther Collection, 1909–1949,* edited by Mitra Abbaspour, Lee Ann Daffner, and Maria Morris Hambourg, 50–69. New York: Museum of Modern Art, 2014. Online at www.moma.org.

Dalen 1907 Dalen, Gustav. "Spots in Raw Paper." *Professional and Amateur Photographer* 12, no. 6 (1907): 233–41.

Darnault 1997 Darnault, Carole. *Papier sensible: L'image révélée.* Exh. cat., L'Orgère. Rives: Association rivoise des amis de l'histoire, 1997.

Darnault 2000 Darnault, Carole. *Rives, la mémoire du papier: Histoire d'une papeterie dauphinoise*. Grenoble, Saint-Martin d'Hères: Presses universitaires de Grenoble, 2000.

"De l'utilite des filigranes du papier" 1888 "De l'utilite des filigranes du papier et de leur signification a propos d'un récent procès." *Bulletin du Bibliophile et du Bibliothécaire* (1888): 159–68.

Engelmann 1904 Engelmann, Karl. "Preparation of Platinotype Paper." *Practical Photographer* 1, no. 6 (1904): 24–28.

"Engine Sizing" 1895 "Engine Sizing." *World's Paper Trade Review: A Weekly Journal for Paper Makers and Engineers* 24, no. 15 (1895): 1–2.

Evans and Wirtz 1892 Evans, P. Norman, and Quirin Wirtz. "The Acid Action of Drawing Paper of Different Makes." *Journal of the Society of Chemical Industry: A Monthly Record for All Interested in Chemical Manufacturers* 11, no. 3 (1892): 212.

"Expansion of Paper" 1890 "Expansion of Paper and Distortion." *American Journal of Photography* 11, no. 11 (1890): 316–17.

Fairbanks Harris et al. 2006 Fairbanks Harris, Teresa, Michael Fuller, and Maureen Green. "Papermaking and the Whatmans." In *Papermaking and the Art of Watercolor in Eighteenth-Century Britain: Paul Sandby and the Whatman Paper Mill*, edited by Teresa Fairbanks Harris and Scott Wilcox, 61–119. Exh. cat., Yale Center for British Art and the Virginia Museum of Fine Arts. New Haven: Yale University Press, 2006.

Griffin and Little 1894 Griffin, Russell B., and Arthur D. Little. *The Chemistry of Paper-Making, Together with the Principles of General Chemistry: A Handbook for the Student and Manufacturer*. New York: Howard Lockwood, 1894.

Hartley 1892 Hartley, Walter Noel. "The Acid Action of Drawing Paper of Different Makes." *Proceedings of the Chemical Society* 8, no. 104 (1892): 19.

Harrison 1887a Harrison, W. H. "A Criticism of the Platinotype Discussion." *British Journal of Photography* 34, no. 1398 (1887): 101–2.

Harrison 1887b Harrison, W. H. "Photographic Papers and Paper Makers, III." *British Journal of Photography* 34, no. 1423 (1887): 507–8.

Hitchins 1921 Hitchins, Alfred B. "Gelatin." *Photographic Journal of America* 58 (1921): 35–36.

Hitchins 1923 Hitchins, Alfred B. "The Peculiarities of Photographic Paper." *Photographic Journal of America* 60 (1923): 227–29.

Hofmann 1873 Hofmann, Carl. *A Practical Treatise on the Manufacture of Paper in All Its Branches.* Philadelphia: H. C. Baird, 1873.

"How Paper Is Sized" 1892 "How Paper Is Sized." *Anthony's Photographic Bulletin* 23 (1892): 698–99.

Hübl 1895 Hübl, Arthur von. *Der Platindruck*. Halle a. d. Saale: W. Knapp, 1895.

Hunt 1852 Hunt, Robert. *Photography: A Treatise on the Chemical Changes Produced by Solar Radiation, and the Production of Pictures from Nature, by the Daguerreotype, Calotype, and Other Photographic Processes.* New York: S. D. Humphrey, 1852.

"Invention and Development" 1894 "The Invention and Development of Photographic Papers." *American Journal of Photography* 15, no. 171 (1894): 120–24.

Jacobson 1876 Jacobson, Emile, ed. "Papier." In *Chemisch-technisches Repertorium, übersichtlicht geordnete Mittheilungen der neuesten Erfindungen, Fortschritte und Verbesserungen auf dem Gebiete der technischen und industriellen Chemie mit Hinweis auf Maschinen, Apparate und Literatur* 13–14 (1876): 194–99.

"Joining Prints" 1880 "Joining Prints in Mounting and the Expansion of Paper." *British Journal of Photography* 27, no. 1036 (1880): 122.

Jones 1911 Bernard Jones, ed. *Encyclopaedia of Photography*. London: Cassell, 1911.

Kaefer 1981 Kaefer, Walter. "Propos d'archéologie industrielle: Les Malmediéns Jules Steinbach et Romain Talbot, leur contribution au developpement de l'industrie photographique." *Folklore Stavelot-Malmédy-Saint-Vith* 45 (1981): 5–19.

Kimberly and Hicks 1931 Kimberly, Arthur Evarts, and John Frederick Gross Hicks. "Light Sensitivity of Rosin Paper-Sizing Materials." *Bureau of Standards Journal of Research* 6, no. 5 (1931): 819–27.

Kolbe 2004 Kolbe, Gesa. "Gelatine in Historical Paper Production and As Inhibiting Agent for Iron-Gall Ink Corrosion on Paper." *Restaurator* 25, no. 1 (2004): 26–39.

Krill 1987 Krill, John. *English Artist's Paper: Renaissance to Regency*. London: Trefoil, 1987.

Laboulaye 1874 Laboulaye, Charles. “Papier.” *Encyclopédie technologique: Dictionnaire des arts et manufactures,* 3:1–28. 4th ed. Paris: Librairie du dictionaries des arts et manufactures, 1874.

Lietze 1888 Lietze, Ernst. *Modern Heliographic Processes*. New York: Van Nostrand, 1888.

“Manufacture of Photo Paper” 1916 “The Manufacture of Photo Paper.” *Paper: A Weekly Technical Journal Devoted to the Manufacture, Sale and Use of Pulp and Paper* 17, no. 24 (1916): 194.

“New Photographic Paper” 1874 “A New Photographic Paper.” *Photographic News: A Weekly Record of the Progress of Photography* 18 (1874): 213.

Osterman 2005 Osterman, Mark. “Rolling and Burnishing of Nineteenth-Century Photographic Prints.” In *Coatings on Photographs: Materials, Techniques, and Conservation,* edited by Constance McCabe, 96–107. Washington, D.C.: American Institute for Conservation, 2005.

Pabst, M. 1889 Pabst, M. “Platinotypie.” In *La Photographie*, 366–74. Vol. 5 of *Encyclopedie chimique,* edited by Edmond Fremy, and Paul Louis Chastaing. Paris: Marpon et E. Flammarion, 1889.

“Papers Used in Photographic Work” 1916 “Papers Used in Photographic Work.” *Paper: A Weekly Technical Journal for Paper and Papermaking* 17 (1916): 17–18.

“Parchmentizing Prints” 1908 “Parchmentizing Prints.” *Bulletin of Photography* 3, no. 72 (1908): 406–7.

“Photographic Paper” 1880 “Photographic Paper.” *British Journal of Photography* 27 (1880): 373–74.

“Photographic Paper” 1903 “Photographic Paper.” *The Paper Mill and Wood Pulp News* 26 (1903): 22.

“Photographic Paper Technology” 1919 “Photographic Paper Technology.” *Paper: Everything Regarding the Manufacture, Sale and Use of Pulp and Paper* 23, no. 17 (1919): 11–13.

“Photographic Papers and Paper Makers” 1887 “Photographic Papers and Paper Makers.” *British Journal of Photography* 34*,* no. 1423 (1887): 507–8.

“Photographic Supplies” 1901 “Photographic Supplies.” In *Report of the Trial Commission on Arts and Industrial Combinations*, 13:173–205. Washington, D.C.: Government Printing Office, 1901.

Picard 1891 Picard, Alfred. *Rapports du jury international exposition universelle de 1889.* Paris: Imprimerie nationale, Ministère du Commerce, de L’Industrie et des Colonies, 1891.

Pizzighelli and Hübl 1883 Pizzighelli, M. Joseph, and Arthur von Hübl. “Platinotype.” *Photographic Journal* 7 (1883): 128–34.

Platinotype Company 1883 *Instructions for Working the Platinotype Process*. 6th ed. London: Platinotype Company, January 1883.

“Platinotype Processes” 1899 “Platinotype Processes.” *New Photo-Miniature* 1, no. 7 (1899): 319–55.

Remington et al. 1911 Remington, J. Stewart, Douglas A. Bowack, and Percy Davidson. “The Sizing of Paper with Rosin Compounds.” *Der Papier-Fabrikant* 26 (1911): 787–90.

“Rosin, Size and Sizing” 1899 “Rosin, Size and Sizing.” *Paper: A Weekly Technical Journal Devoted to the Manufacture, Sale and Use of Pulp and Paper* 1, no. 8 (1899): 213–14.

Scavia 1903 Scavia, Michelangelo. “Rassegne tecniche e notizie industrial: Le carte fotografiche.” *La rivista tecnica delle scienze, delle arti applicate all’industria e dell’insegnamento industriale* 3 (1903): 147–53.

Schnauss 1874 Schnauss, Julius. “Albumin und Albuminpapier in Der Photographie.” *Photographische Korrespondenz* 123 (1874): 157–66.

Scolik 1893 Scolik, Charles. “Photographic Printing Papers with Light-Sensitive Iron Salts.” *Photographic Times and American Photographer* 23, no. 635 (1893): 657–60.

Sheppard 1923 Sheppard, Samuel Edward. *Gelatin in Photography.* Monographs on the Theory of Photography 1, no. 3, edited by C. E. Mees, Mildred Spargo Schramm, and Elsie L. Garvin. New York: D. van Nostrand Company, 1923.

Timár-Balázsy and Eastop 2012 Timár-Balázsy, Ágnes, and Dinah Eastop. *Chemical Principles of Textile Conservation*. Hoboken, N.J.: Taylor and Francis, 2012.

Towler 1866 Towler, John. “Photographic Printing Paper.” *Humphrey’s Journal of Photography and the Allied Arts and Sciences* 17, no. 19 (1866): 292–95.

Wilson 1882 Wilson, Edward L. “The Rives Paper Manufactory.” *Photographic News: A Weekly Record of the Progress of Photography* 26, no. 1242 (June 1882): 364.

[Woodbury] 1895 [Woodbury, Walter E.]. “Alfred Clements and His Work.” *Photographic Times* 27, no. 4 (1895): 216–20.