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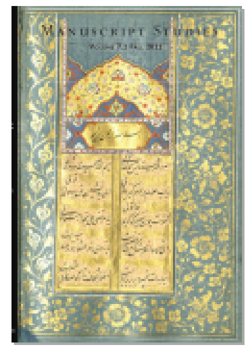

Abigail Slawik, Margaret Holben Ellis, William A. Sethares, C. Richard Johnson Jr.

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User-Friendly Software for Identifying Moldmates and Twins in Antique Laid Paper: Case Study of a Disbound Blank Book

Abigail Slawik, *New York University*
Margaret Holben Ellis, *New York University*
William A. Sethares, *University of Wisconsin, Madison*
C. Richard Johnson, Jr., *Cornell University*

Watermarks, chain lines, and laid lines are characteristic structural features of European pre-machine-made laid paper.[1] All three features have been studied by codicologists to pinpoint the date or geographic origin of a paper's manufacture and to determine collation. By far, the feature receiving the longest and most focused attention is the watermark. The study of watermarks is a multi-century endeavor, best represented by Charles-Moïse Briquet in 1907 with *Les Filigranes: Dictionnaire*

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1 The term "pre-machine-made" is used here to exclude modern handmade laid papers, which may not adhere to the structural norms of handmade papers from the hand press period.

historique des marques du papier dès leur apparition vers 1282 jusqu'en 1600.[2] His catalogue contained tracings of watermarks found in papers from across Europe dated before 1600, as well as the surrounding chain lines and frequency of laid lines for each document examined. The title, *Les Filigranes*, also lent its name to the field of study of watermarks: *filigranology*.

Briquet records the date of the document and the location of the archive in which the document is found. The papers are not identified by their actual date and place of production; however, the records do provide clues as to when and where the paper was in use. Furthermore, like all compilations of watermarks, identification of watermark types is dependent upon accurate images—since the majority of images are tracings made using transmitted light, many are incomplete due to marks (printing, drawing, and other media) on the surface of the paper. Despite these shortcomings, paper scholars, bibliographers, codicologists, and art historians have continued the tradition of watermark identification via Briquet and others, with the goal of matching up papers with similar watermark types.[3] In reality, these efforts may yield misleading and incorrect identification of one mill, region, or production date, due mostly to indecipherable or inaccurate images and clumsy comparison methods.

Moldmates: What Are They, and Why Do They Occur?

Even more problematic than simply matching up watermark types is the quest to identify sheets as moldmates. Moldmates, as the name implies, are sheets of paper made from the same papermaking mold. Just as one would expect, two sheets made from the same mold will have spatially identical structural features impressed by the mold (watermark shapes, chain line intervals, and laid line frequencies).[4]

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2 Charles-Moïse Briquet, *Les Filigranes: Dictionnaire historique des marques du papier dès leur apparition vers 1282 jusqu'en 1600*, 4 vols. (Geneva: A. Julien, 1907).

3 The Bernstein Consortium has centralized images from many watermark databases on the Memory of Paper website and enables a multilingual keyword search. The Memory of Paper (website), Bernstein Consortium, updated 7 June 2021, http://www.memoryofpaper.eu.

4 While some shrinkage may occur during drying, this is generally negligible in the analysis presented in this paper.

The identification of moldmates can reveal more significant information than just matching watermark types—that is, an eagle, star, or shield. Moldmates are either from the same paper run (determined by their arrangement within a group) or from that particular mold's lifetime of use, estimated at two years for popular formats.[5] Therefore, both the dates and places of origin of papers that are moldmates are more precise and meaningful than a simple association of watermark type.

The reason for the existence of pairs of moldmates in paper stocks is tied to the production methods of handmade paper mills. To increase efficiency, the vatman would have two molds to dip in the vat to avoid standing idle while the coucher pressed the mold with the freshly pulled sheet onto a felt (fig. 1). Each mold would be similarly crafted to produce the same product: the same watermark, the same size, the same or similar number of chain and laid lines. However, because each mold was assembled by hand, with wires bent in the shape of the watermark and sewn onto the screen, differences would be inevitable. The purpose of the watermark itself was to provide information about the paper; there was no reason that the two molds, making the same type of paper, needed to be precisely matched in their spacing of chain lines and shape of watermarks. The watermark acted as a symbol, not an image. Therefore, the wire forms of watermarks on twin molds, used as a pair at the vat to produce the same product, were not absolutely identical.

Paper scholars have referred to sheets of paper made from one and the other of a pair of molds as twins.[6] A set of moldmates comes from a single mold, and those moldmates have a corresponding set—their twins, which come from the other mold. The paper scholar Neil Harris likens these pairs of molds to pairs of shoes.[7] It is easy to visualize, as illustrated by Diderot's

5 The usable lifetime of a papermaking mold would vary according to the intensity of its use. Neil Harris estimates that a mold for a commonly used paper size—for example, "chancery" or *rezzute*—might last as little as six months, while much larger, more infrequently used molds could remain usable for a decade or more. Neil Harris, *Paper and Watermarks as Bibliographical Evidence*, 2nd ed. (Lyon: Institut d'histoire du livre, 2017), 77.

6 Allan Stevenson, "Watermarks Are Twins," *Studies in Bibliography* 4 (1951–52): 57–92.

7 "Twin moulds, and thus twin watermarks, evolved naturally from the practice of having two men, the vatman and the coucher, working together as a team. At some point the practice was

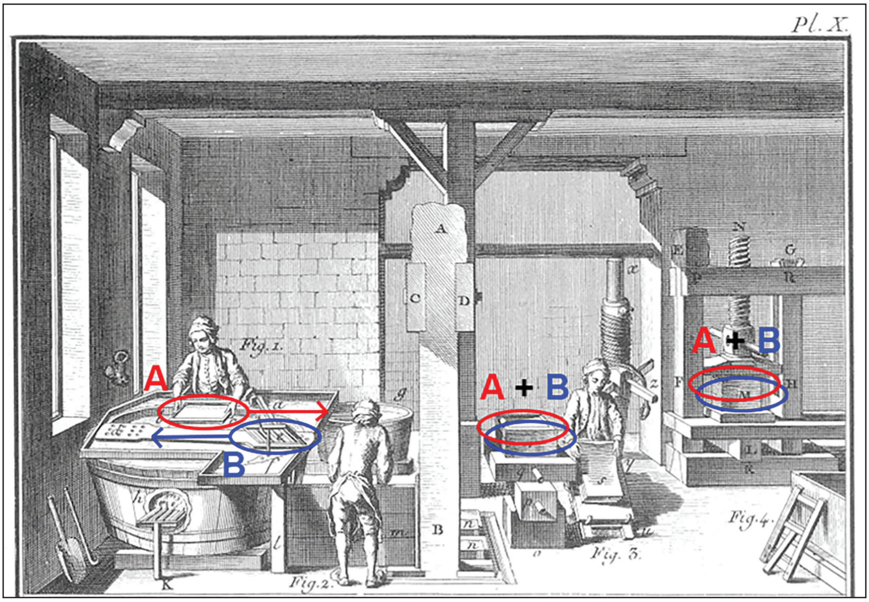

FIGURE 1. Volume 5 of Diderot's *Encyclopédie ou Dictionnaire raisonné des sciences, des arts et des métiers* of 1765 illustrated papermakers at work in plate X, titled *Papetterie: Cuve à Ouvrer*. The leftmost figure is the vatman, and before him are two molds, circled in red and blue: Mold A and Mold B, respectively. The arrows indicate the path of the molds: once it is filled with a sheet of wet paper fibers, Mold A is passed to the center figure, the coucher, who turns it pulp-side down and presses it onto a stack of felts. Meanwhile, the vatman collects Mold B and pulls another sheet by drawing it up through the vat of suspended fibers before him. When this mold is handed to the coucher, it is then pressed next onto the stack of papers and felts, making a single stack of papers from Mold A and Mold B (A + B, center), alternating every other one. Eventually, the sheets would be laid directly on top of one another and put into a press to expel more water (A + B, right). Image in plate X from *Recueil de planches, sur les sciences, les arts libéraux et les arts méchaniques, avec leur explication*. Philadelphia, University of Pennsylvania, Kislak Center for Special Collections, Rare Books and Manuscripts, AE25.E562 v.5.

Encyclopédie: a post of wet sheets fresh from the vat, laid on top of one another with felts in between, each moldmate alternating after the last, like footsteps.

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established of organising twin moulds as if they were a pair of shoes, with one watermark in the left-hand mould and its twin in the right-hand mould." Harris, *Paper and Watermarks,* 48.

Therefore, when a ream of paper went to market, it is not unreasonable to assume it could still contain undispersed sets of moldmates and twins. They would not have retained their evenly alternating pattern in the ream, as they would be first distributed in a loft to dry, then possibly later sized and dried again, without any regard to retaining the alternating pattern. After all, from the papermaker's perspective, these moldmates and their twins were all the same product; there would be no need to separate or differentiate them in any way. Functionally, the twins bore only the slightest visual difference between them, which could be observed when held up to the light.

When the ream of paper reached the end user, the groups of moldmates and twins would possibly remain loosely in the order in which they had been produced. This is evidenced by the incidence of repeated moldmates in printed books and manuscripts. Stocks with different watermarks were certainly mixed together. Would it not also be possible that papers were taken straight from the paper stock and bound in precisely these same groups of moldmates from only two molds, each set twins with the other? Neil Harris writes that two sets of moldmates interspersed can reliably identify a paper stock.[8] However, to gather conclusive evidence, a more precise, not to mention more efficient, method than tracing and matching watermarks by eye is required.

Identifying Moldmates: The Current Approach

A team currently studying Leonardo da Vinci's codices has developed custom software that allows researchers to determine, using images of the paper structures listed above, whether the papers in question are moldmates through the generation of both numerical data as well as didactics for confirmation.[9]

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8 "Twinship establishes identity and a paper-stock is only identified when both its watermarks are clearly recognized." Harris, *Paper and Watermarks,* 48.

9 Computational coding of Leonardo's papers began with expertise honed by C. Richard Johnson, Jr., in the WIRE project at Cornell University, which examined watermarks in Rembrandt's etchings; C. Richard Johnson, Jr., "Decision Trees for Watermark Identification in Rembrandt's Etchings," *Journal of Historians of Netherlandish Art* 12, no. 2 (Summer 2020), https://doi.org/10.5092/jhna.12.2.5; C. Richard Johnson Jr., William A. Sethares, and Margaret Holben Ellis, "Overlay Videos for Quick and Accurate Watermark Identification,

The suite of software includes a program to measure chain line intervals (ChainLineMarker), a program to measure watermark features (Watermark-Marker), and a program to automatically generate overlay animations of watermarks (VisualizeOverlays).[10] The purpose of this annotation is to demonstrate the usefulness of these programs for the study of manuscripts.

Case Study: A Disbound Ledger Book

The study collection of the Conservation Center, Institute of Fine Arts, New York University, includes several ledger books with few or no entries that provide an ideal case study to demonstrate the use of the software tools mentioned earlier. One particular set of disbound folio format leaves was chosen for two reasons. First, this stack of papers had been foliated in pen and brown ink in the upper right, but the pages are no longer bound or attached along the centerfold.[11] Thus, a stack of half-sheets in a known order could be photographed easily in transmitted light. Second, the sheets had complex watermarks and countermarks, making each half-sheet an ideal candidate for WatermarkMarker.

Comparison, and Matching," *Journal of Historians of Netherlandish Art* 13, no. 2 (Summer 2021). Margaret Holben Ellis and William A. Sethares joined Johnson in investigating watermarks and chain line intervals in Leonardo da Vinci's Codex Leicester and Codex Arundel; William A. Sethares, Margaret Holben Ellis, and C. Richard Johnson, Jr., "Computational Watermark Enhancement in Leonardo's Codex Leicester," *Journal of the American Institute for Conservation* 59, no. 2 (2020): 87–96; Margaret Holben Ellis, William A. Sethares, and C. Richard Johnson, Jr., "A Powerful Tool for Paper Studies: The Computational Coding of Watermarked Papers in Leonardo's Codex Leicester and Codex Arundel," *The Quarterly: The Review of the British Association of Paper Historians*, no. 119 (July 2021): 1–18. The latest study presents moldmates discovered between the two codices. A GitHub repository with the latest version of all software used in these investigations is linked at the end of this article. An online compendium of the moldmates found in the Codex Leicester and Codex Arundel are presented via an online database: leocode.org.

10 In Appendix II of their recent article in *The Quarterly*, Ellis, Sethares, and Johnson detailed the process by which one may determine moldmate status for papers imaged and processed in this way. Ellis, Sethares, and Johnson, "A Powerful Tool for Paper Studies," 14–16.

11 The sheets are foliated fols. 186–199 and 204–306, followed by one final unfoliated half-sheet. Fols. 200–203 are missing.

FIGURE 2. The stack of ledger sheets, with ruling, and foliation in the upper right corner, in pen and brown ink. The foliation begins at 186 and ends at 306. Leaves 200 through 203 are missing. The sheets show evidence of binding, are gilded on the edges, and have been torn completely along every centerfold. Uncatalogued disbound ledger book photographed by the primary author in standard illumination, Conservation Center Study Collection, Institute of Fine Arts, New York University.

Each folio, seen stacked in the original order in figure 2, measures 320 × 210 mm and has trimmed and gilded edges. The watermark represents the coat-of-arms of Le Tellier of three stars over three lizards, surrounded by scrollwork and topped with a knight's helmet, while the countermark reads "H. J. Cusson," with a fleur-de-lys in the space between the J and the C.[12] Sheets appear to have a *tranchefile* on either side, which is a wire placed under the mold, along both short sides, with a chain line sewn to it.[13] The sheets

12 According to Raymond Gaudirault's monograph on French papers from the seventeenth and eighteenth centuries, there were several papermakers from a family with the surname Cusson active in the Auvergne region of France between ca. 1650 and 1750. Raymond Gaudriault, *Filigranes et autres caractéristiques des papiers fabriqués en France aux XVII^e et XVIII^e siècles* (Paris: CNRS Éditions and J. Telford, 1995), 89.

13 Tranchefiles first appear in handmade laid paper in the late fifteenth century, developed to help strengthen the mold along the short sides. They are closer to the next adjacent chain line than the normal chain line interval and can indicate the edge of the sheet. Harris, *Paper and Watermarks,* 21.

also have a small undetermined monogram toward the center of the sheet on the long edge, which is only partially visible on each half-sheet.

Based on these simple characteristics, and lacking any provenance, the techniques of filigranology lead to a few conclusions about the time and place of origin of the paper. The relative complexity of the watermark suggests an origin later in the hand press period, as watermarks generally started simple and became more complicated over the centuries. Countermarks in handmade laid paper first appear in the late fifteenth century.[14] The watermark type thus roughly indicates the paper is seventeenth- or eighteenth-century paper, most likely French in origin from the Auvergne region.

To begin further investigation using the digital tools mentioned above, images of the sheets were obtained according to the standards for transmitted light photography of works on paper for conservation documentation presented in *The AIC Guide to Digital Photography and Conservation Documentation*.[15] The sheets were placed on a commercially available light sheet on a copy stand and photographed using a Nikon D700 DSLR camera with a 60 mm lens (fig. 3). The exposure was set to ⅕ second, 200 ISO, and an aperture of f/11. Before capturing, the surface of the tracing pad was leveled to the lens of the camera using a laser level.[16] The images were converted to monochrome using Adobe Photoshop® software. Then, the levels were adjusted to increase the contrast within the area of the sheet for maximum visibility of watermark features (fig. 4). Limits selected were generally 71 for black, 0.3 for middle gray, and 238 for white. However, the images of some sheets were adjusted slightly differently on a case-by-case basis, as is necessary due to the thickness and degradation variations present in handmade paper.

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14 Harris, *Paper and Watermarks,* 51.

15 Jeffrey Warda, ed., *The AIC Guide to Digital Photography and Conservation Documentation*, 3rd ed. (Washington, DC: American Institute for Conservation, 2017), 121–23, available from https://www.culturalheritage.org/publications/books-periodicals/shop/the-aic-guide.

16 This is an important step in obtaining images for paper structure analysis, as the spatial features in a given sheet are measured and compared with one another. Any skewing of the plane of the paper to the lens will distort these internal relationships.

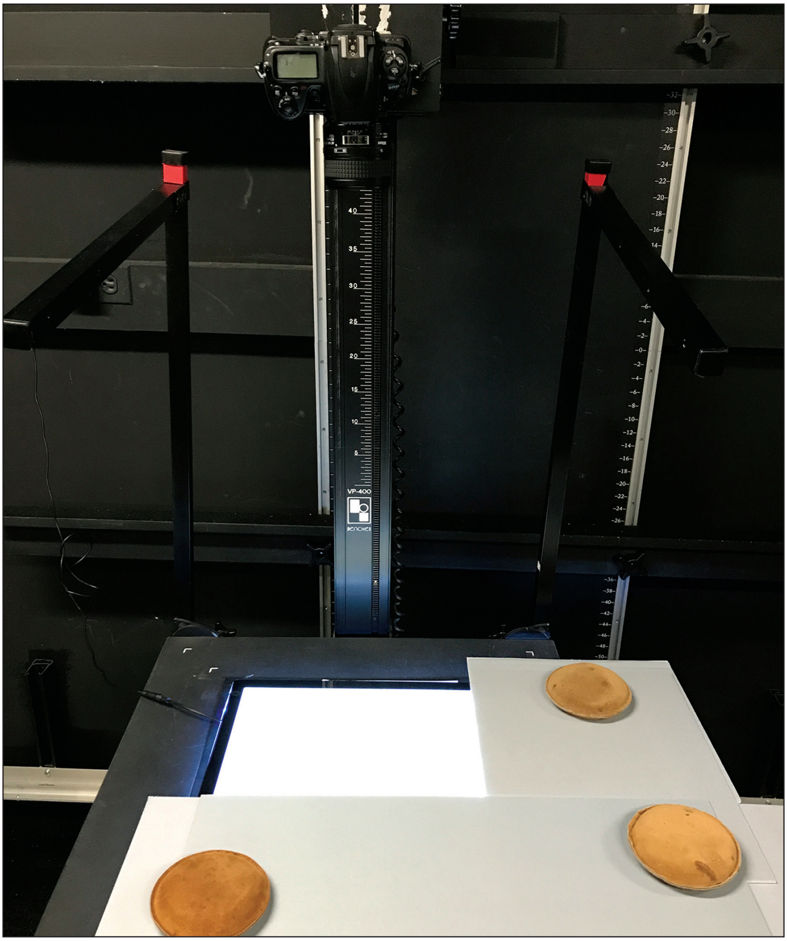

FIGURE 3. One imaging setup for transmitted light photographs of paper structure is a standard copy stand setup, with a light sheet placed under the object, and opaque masking placed around the edges of the paper. Overhead lights were left on in this photograph for the purposes of illustration only; during photography, the only source of light was the light sheet. Photograph by the primary author.

In post-processing, the images of each sheet were flipped and rotated to the same position, when necessary. For the watermarks, the images were flipped so that the scrollwork to the right of the knight's helmet was higher than the scrollwork on the left. For the countermarks, this was in the readable

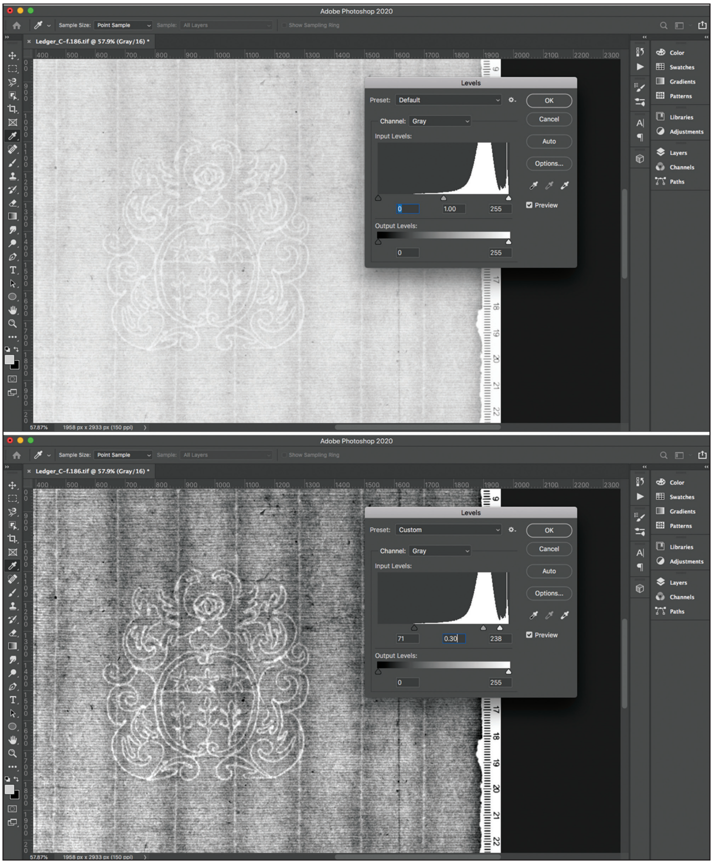

FIGURE 4. Screenshots demonstrating the adjustment of levels in Adobe Photoshop® software to enhance the visual clarity of the watermarks. The upper screenshot shows the image when first converted to grayscale mode; the lower screenshot shows the watermark detail, after adjusting the levels. Adobe product screenshots reprinted with permission from Adobe. Uncatalogued disbound ledger book photographed by the author in transmitted light, Conservation Center Study Collection, Institute of Fine Arts, New York University.

orientation. Images thus prepared allowed for careful visual observation of discernable differences. This close looking led to the identification of two types of watermarks and two types of countermarks (fig. 5).[17]

17 Weislogel and Johnson systematized this visual categorization process when looking at foolscap watermarks in the papers of Rembrandt's prints. Andrew C. Weislogel and C. Richard

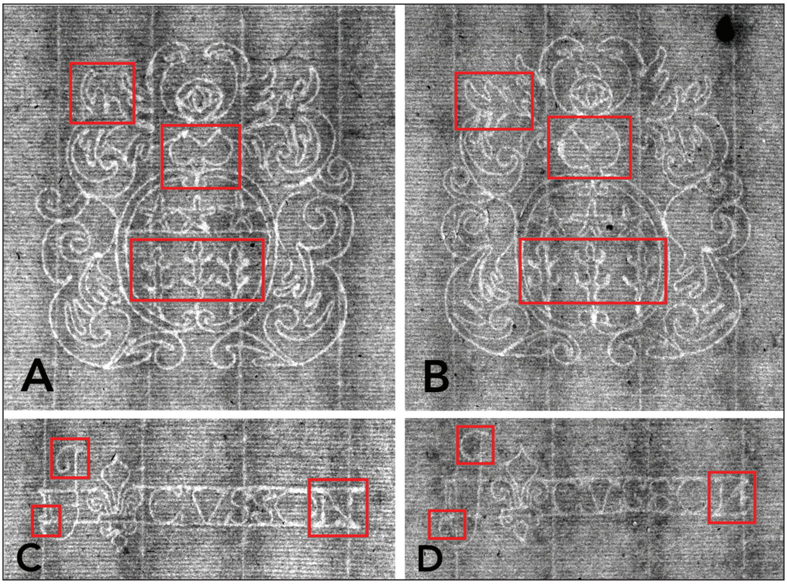

FIGURE 5. During initial visual observation of the watermarks and countermarks present in fols. 186–209, two types of each were observed. Their easily discernible differences likely preclude them from being moldmates with one another. In the figure, three main points of difference in each watermark type are indicated in red. In watermark A, the upper left scrollwork has a thin outer curve, while the same curve in watermark B is noticeably fatter. The breastplate under the knight's head is spade-shaped in watermark A, while in watermark B, it has more of a teardrop shape. Lastly, the lizards in watermark A are smaller and more closely grouped together, with chain lines outside the trunks of the outer lizards, while the chain lines in watermark B touch the trunks of the outer lizards. In countermark C, the top of the "J" curls in on itself, while the same element in countermark D loops around and stops at the trunk of the letter. The end of the hook of the "J" in countermark C meets but does not cross a chain line, while the hook in the "J" in countermark D crosses a chain line. Lastly, the "N" in countermark D is backwards. A through D in this illustration are taken from transmitted light images of fols. 186, 193, 187, and 192, respectively. Uncatalogued disbound ledger book photographed by the primary author in transmitted light, Conservation Center Study Collection, Institute of Fine Arts, New York University.

Johnson, Jr., "Decision Trees and Fruitful Collaborations: The Watermark Identification in Rembrandt's Etchings (WIRE) Project at Cornell," in *Lines of Inquiry: Learning from Rembrandt's Etchings*, ed. Andrew Weislogel and Andaleeb Badiee Banta (Ithaca, NY: Herbert F. Johnson Museum of Art, Cornell University, 2017), 32–57.

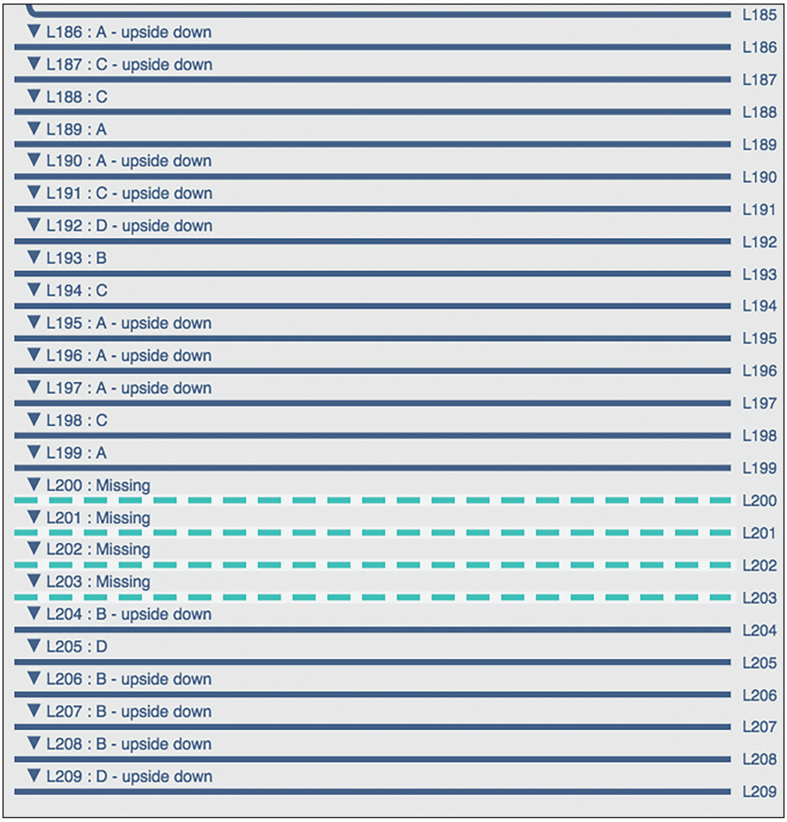

FIGURE 6. Collation chart generated in VisCodex of fols. 186–209 showing the incidence of marks A through D, as well as indicating whether they are upside down. Bifolio attachments and gatherings have not yet been determined. Image generated from the VisCodex online collation visualization tool developed by the University of Toronto Libraries and the Old Books New Science lab at the University of Toronto.

The occurrence of marks A through D were entered into a collation visualization program called VisCodex (fig. 6).[18] Currently, folios 186–99 and 204–10 have been investigated (fols. 200–203 are missing). Folios 211–306 have been imaged, but are yet to be visually examined in detail and coded.

18 VisCodex (https://viscodex.library.utoronto.ca/) was developed by the University of Toronto Libraries and the Old Books New Science lab at the University of Toronto (https://oldbooksnewscience.com/).

In the collation visualization, watermarks and countermarks that are rotated 180 degrees are noted as "upside down."

Using WatermarkMarker, WatermarkPointMarker, and VisualizeOverlays

With the watermarks and countermarks categorized loosely into four groups, the measuring of ratios between precisely located equivalent points using WatermarkMarker was undertaken to determine if moldmate status might be quantitatively determined. The procedure to locate points in each watermark was undertaken to use points that occur in any version of the watermark as well as those that are the easiest to pinpoint systematically.[19] According to the procedure laid out by Ellis, Sethares, and Johnson, moldmate status can be claimed if the range of each coded ratio across a group of moldmates varies by no more than 0.1. Fourteen points were chosen for the coat-of-arms mark (fig. 7), and nine for the countermark (fig. 8). The points chosen were as follows:

Coat-of-arms watermark:

1. Where the top right scrollwork crosses over a chain line
2. Where the top left scrollwork crosses over a chain line
3. The inner point of a scrollwork beside the knight's helmet, on the right
4. The inner point of the same scrollwork beside the knight's helmet, on the left
5. Where an outer curl on the left crosses over a chain line
6. Where the upper left side of the outer line of the center emblem scroll meets a chain line
7. Where the upper right side of the outer line of the center emblem scroll meets a chain line

19 See Appendix II of Ellis, Sethares, and Johnson, "A Powerful Tool for Paper Studies," for a description of locating points using WatermarkMarker.

8. Where an outer curl on the right crosses over a chain line
9. Where the right end of the horizontal line in the coat of arms meets the inner outline of the center emblem scroll
10. Where the left end of the horizontal line in the coat of arms meets the inner outline of the center emblem scroll
11. Where the lower left outer curve of scrollwork crosses over a chain line
12. Where the lower right outer curve of scrollwork crosses over a chain line
13. Where the underside of the bottom scroll on the right crosses over a chain line
14. Where the underside of the bottom scroll on the left crosses over a chain line

"H. J. Cusson" countermark:

1. Where the end of the hook of the "J" meets the underline
2. Where the top loop of the "J" leaves the stem
3. Where the stem of the "J" meets the underline
4. The top tip of the fleur-de-lys
5. Where the top line of the countermark meets the chain line to the right of the fleur-de-lys
6. The base of the "V" where it meets the underline
7. Where the bottom curve of the first "S" crosses the chain line; or, if this does not occur, the plateau of the curve
8. Where the left vertical line of the "N" meets the underline
9. Where the right vertical line of the "N" meets the top horizontal line

Not surprisingly, after this procedure, the visual appearance of the lines in the watermarks and countermarks still coincided with the four groups (figs. 9 and 10). Examining the visual appearance of the lines, however, is not the purpose of the software. Instead, the images produced by the program are accompanied by the numerical ratios of their relationships (the codes), that may then be compared against one another to determine the variance

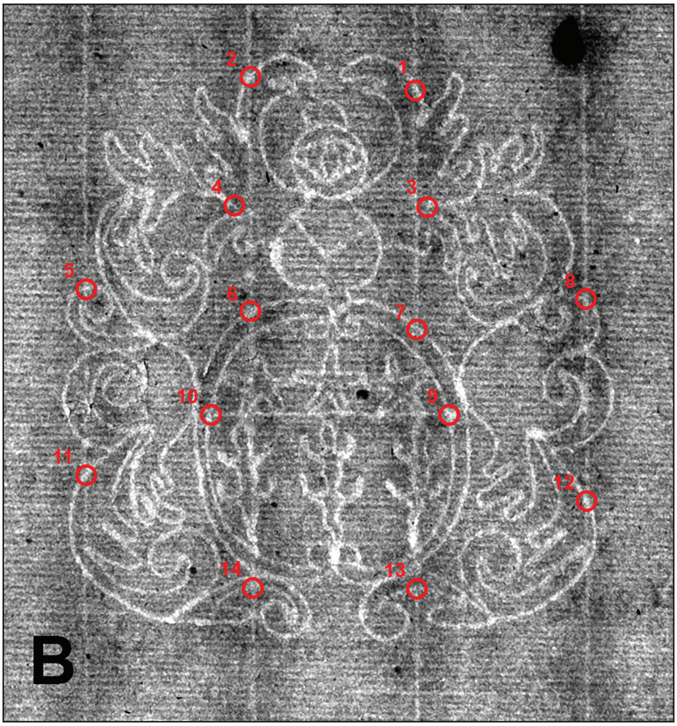

FIGURE 7. Locations of the fourteen points chosen on the coat-of-arms watermark, pictured on the transmitted light image of the watermark from fol. 193. Uncatalogued disbound ledger book photographed by the primary author in transmitted light, Conservation Center Study Collection, Institute of Fine Arts, New York University.

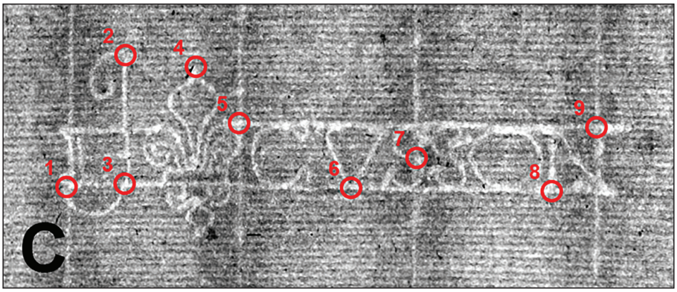

FIGURE 8. Locations of the nine points chosen on the "H. J. Cusson" countermark, pictured on the transmitted light image of the watermark from fol. 187. Uncatalogued disbound ledger book photographed by the primary author in transmitted light, Conservation Center Study Collection, Institute of Fine Arts, New York University.

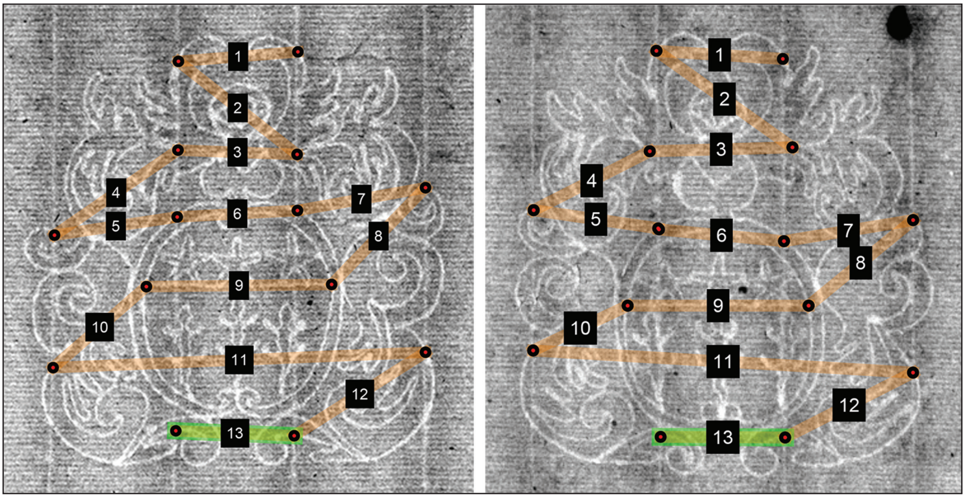

FIGURE 9. Watermarks A and B, after coding using WatermarkMarker software to fix points on each that correspond with one another. Note how the orange lines in each type create a slightly different shape. Uncatalogued disbound ledger book photographed by the primary author in transmitted light, Conservation Center Study Collection, Institute of Fine Arts, New York University.

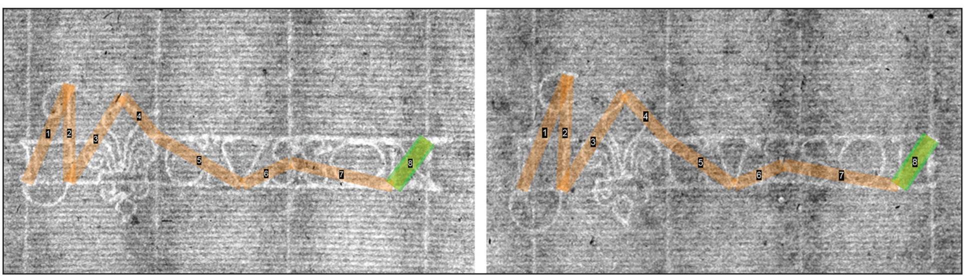

FIGURE 10. Countermarks C and D, after coding using WatermarkMarker software to fix points on each that correspond with one another. Note how the orange lines create a slightly different shape, especially in the "J" on the left. Uncatalogued disbound ledger book photographed by the primary author in transmitted light, Conservation Center Study Collection, Institute of Fine Arts, New York University.

between suspected moldmates. This data is presented in line graphs in figures 11 and 12. The ratios of the line lengths between the points marked in WatermarkMarker mostly fell within the range of 0.1 for the suspected moldmate groups.

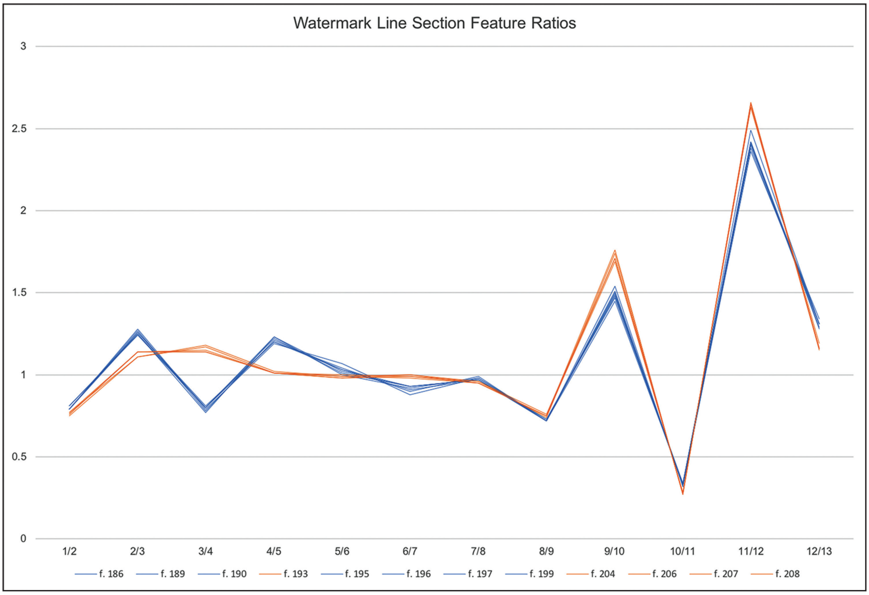

FIGURE 11. The relationship between the length of the lines bridging the points chosen in each watermark, expressed numerically on the y-axis, with the ratio represented on the x-axis. The two groups of suspected moldmates were colored blue (type A) and orange (type B).

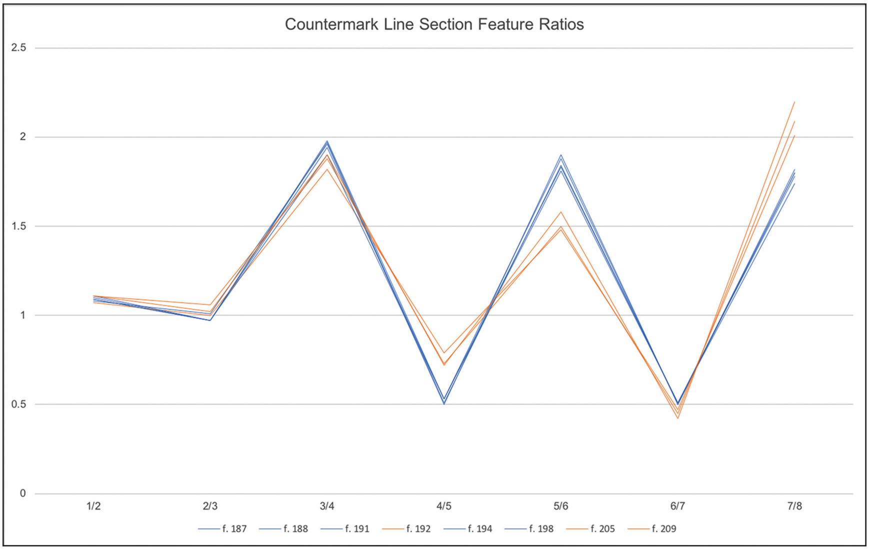

FIGURE 12. The relationship between the length of the lines bridging the points chosen in each countermark, expressed numerically on the y-axis, with the ratio represented on the x-axis. The two groups of suspected moldmates were colored blue (type C) and orange (type D).

Lastly, six animated overlays were made to align and visually compare examples of watermarks A and B, and countermarks C and D. The first step is to use another program in the suite, WatermarkPointMarker, to number precisely locatable points in each watermark and countermark. Then, the marked images may be aligned using VisualizeOverlays, and an animated GIF file generated that fades one image into another in a loop. The GIFs are available via the following links:

https://ifa.nyu.edu/people/faculty/ellis/animationLedger_C-f.186_processed-Ledger_C-f.189_processed(hl).gif
https://ifa.nyu.edu/people/faculty/ellis/animationLedger_C-f.186_processed-Ledger_C-f.193_processed(hl).gif
https://ifa.nyu.edu/people/faculty/ellis/animationLedger_C-f.193_processed-Ledger_C-f.204(hl).gif
https://ifa.nyu.edu/people/faculty/ellis/animationLedger_C-f.187_processed-Ledger_C-f.188_processed(hl).gif
https://ifa.nyu.edu/people/faculty/ellis/animationLedger_C-f.187_processed-Ledger_C-f.192_processed(hl).gif
https://ifa.nyu.edu/people/faculty/ellis/animationLedger_C-f.192_processed-Ledger_C-f.205(hl).gif

The first GIF shows folios 186 and 189, which appear to be moldmates of type A. The next GIF is of types A and B, from folios 186 and 193, and the third GIF shows two watermarks suspected to be type B on folios 193 and 204. For the countermarks, folios 187 and 188 (suspected moldmates) were overlaid, and an animation of folios 187 and 192 in the fourth link shows the noticeable differences. Lastly, two countermarks suspected to be type D were overlaid, folios 192 and 205.

Next Steps: A Work in Progress

In the roughly 115 leaves of the disbound ledger in the study collection at the Conservation Center, the results from examining and coding about 20 percent of the sheets already show two distinct groups of watermarks and countermarks. Thus far, it has not been determined which pairs of the two countermarks and watermarks came from the same mold. However, we expect the results to be more conclusive following the examination and coding of the remainder of the sheets. The current hypothesis is that watermark A was on the same mold as countermark C, and watermark B was with countermark D, due simply to their occurrence in the ledger, where they are generally grouped with one another.

Conclusion

The motivation in conducting the study described here is to introduce these easy-to-use moldmate matching tools to book historians. As ledgers with dates of their use are the subject of many paper studies due to the incidence of blank paper with easily viewed watermarks, so might these data be collected for comparison with watermarks in other sources, from books to manuscripts, drawings, or prints. The method presented here offers one possible and effective approach for collecting these data by tailoring and streamlining the functionality of three relatively simple software applications—ChainLineMaker, WatermarkMarker, and VisualizeOverlays—to perform this specific task.

Throughout the long history of handmade papermaking in Europe, papermakers used watermarks and countermarks in producing and selling their product; likewise, publishers and binders made intentional choices when using that product to make books. These choices could be influenced by individual or regional factors. Physical data present in the internal structures of paper supports more robust exploration of paper manufacture and use in the hand press period and allows scholars to dig more deeply into the nuances of the multiple ways in which historic paper could be used in the production of manuscripts and printed books. The applications used in this particular study demonstrate how modern technologies can be employed in an archeological approach to paper study, in this case demonstrating how paper structures of individual sheets can be more concretely associated with one another as moldmates than by simply identifying a watermark type or measuring the spacing of chain lines. Much still remains to be learned, but it is hoped this demonstration encourages further study.

The software mentioned in this article, along with user guides and sample images, can be found at the GitHub repository:

https://github.com/setharesB/PaperStudies

The modules are released under an open-source license and use the (free) Wolfram Player. Complete instructions can be found in the Readme file.