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Soft Clouds: Analytical Pigment Identification for Historical Paste Papers From Harvard University's Rosamond B. Loring Collection

INTRODUCTION

In *A Yorkshire Source for Decorated Paper in the Eighteenth Century*, Tanya Schmoller relates the story of a colleague introducing her to the Moravian Church archives and the fascinating history she unraveled through the records there. Two points are of particular note: her colleague's casual mention of marbled papers, which were later found to be "not really marbled," and a historical anecdote from a 1763 church ledger (2003, 5). According to the ledger, a visitor to the English Moravian community in Yorkshire observed the making of paste papers by boiling red rags, mixing the resulting liquid into paste, and "appl[ying] neat clouds to the paper with one's fingers" (2003, 7). This anecdote is included in some of the best-researched reference works for paste paper and other decorated papers as a production insight. None of these resources, however, ask the obvious follow-up question: How were the rags colored in the first place?

Paste paper is a distinct category of heritage artifact that is largely unacknowledged in academic literature and under-recognized compared with other types of decorated paper. Paste papers have been misdescribed by booksellers, librarians, and conservators, and have historically been considered of lower intrinsic and artistic value than marbled, block-printed, or brocade (a.k.a. Dutch gilt) papers. The few specialist books discussing historical paste papers focus on their social history and pattern description rather than physical characterization. Given the competitive nature of color production in the pre-industrial era, contemporary recipes and "books of secrets" often contain dubious or unscrupulously copied information, leaving modern historians and conservators with little more than the artifacts themselves as testimony to their composition, production, and provenance. This project aimed to improve our understanding of historical paste papers by using analytical pigment identification to uncover their cultural, material, and bibliographic contexts.

The literature review portion of this project was limited to English language resources and rough translation of German, Spanish, and Dutch language texts. Many relevant resources on historical bookbinding and the production of decorated papers were originally published in German. While the present research cannot be called comprehensive, it is still confidently among the first to carry out analytical pigment identification for historical paste papers. The authors hope that readers will share any relevant sources that may have been neglected.

BACKGROUND

Paste paper (German: *Kleisterpapier*) is a style of surface-decorated paper characterized by colored starch paste modified with various tools and techniques to render an array of designs (fig. 1). The technique originated in southern Germany around 1600 and remained popular across Europe for book papers, wallpapers, and furniture linings through the early 1830s (Haemmerle 1977, 137; Wolfe 1991, 24–25; Schmoller 2008, 47–49; Krause and Rinck 2016, 110).

Although distinct from more popularly recognized marbled papers, ambiguous terminology and a lack of academic literature have led to confusion and nescience of paste papers among both public and specialized audiences (Haemmerle 1977, 137–44; Schmoller 2003, 5; Krause and Rinck 2016, 110; Beattie 2018). Paper marbling developed across East Asia and the Ottoman Empire for centuries before it was introduced into Europe in the 17th century (Wolfe 1991, 2–13). Germany was already established as a producer of woodblock-printed fabrics and papers by 1600, and the earliest extant paste-colored papers date from around 1650 (Gurbat 1971, 12; Haemmerle 1977, 137; Wolfe 1991, 18–25). The simplicity and affordability of the paste paper technique spurred its adoption by bookbinders across Europe who could produce "fancy" papers without the expense or expertise required for marbled, gilt, or block-printed papers (Zaehnsdorf 1890, 35; Wolfe 2008, 43, 45).

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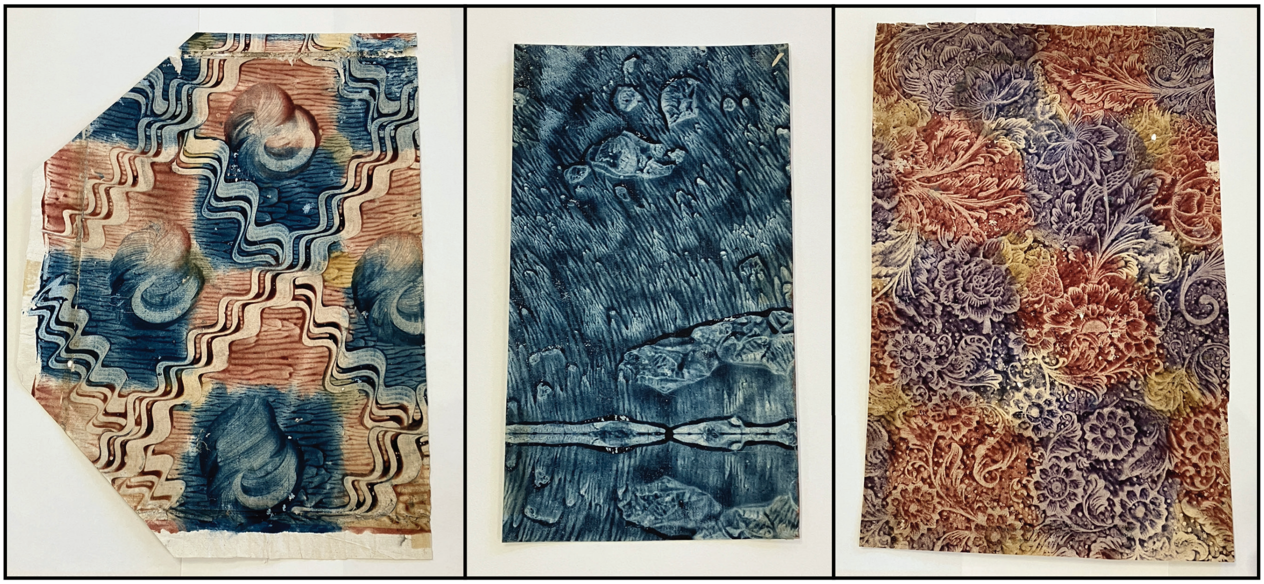

Fig. 1. Examples of 18th-century paste papers. (a) Multicolor (quadrille) veined paper with impressed designs, previously a book covering, Rosamond B. Loring Collection [LOR.IV.33.c]. (b) Blue veined paper, Rosamond B. Loring Collection [LOR.IV.2.d]. (c) Multicolor (quadrille) veined paper with block-printed designs, Rosamond B. Loring Collection [LOR.IV.34.d]. Images M. Gundrum.

Paste papers are often associated with the Unity of Brethren (Latin: *Unitas Fratrum*), a Protestant sect founded in 1457 and suppressed to near extinction by the early 18th century. In 1722, exiles from Moravia and Bohemia found asylum and established the settlement of Herrnhut on the estate of one Count Nikolaus Ludwig, Graf von Zinzendorf, in the German state of Saxony. Missions were established in England by the 1730s and in the American colonies by the 1740s, and in 1764, the Sisters in those communities officially began producing decorated papers as a means of income. The distinctive quality and style of the so-called "Herrnhuter" papers earned them such popularity that the term prevails today as an imprecise catchall for paste-decorated papers (Haemmerle 1977, 139; Wolfe 1991, 24–25; Schmoller 2008, 49; Verheyen 2015; Beattie 2021; Britannica 2023; Dubansky 2023).

Beyond this social history, published literature limits material awareness of paste papers to pattern categorization, whereas associated colorants, origins, and usage trends for those patterns remain obscure. While colorant identification research is well developed for paintings, textiles, objects, illuminated manuscripts, and wallpapers, English language literature concerning analytical pigment identification for decorated book papers is lacking. Recent research on bookbindings (Delbey et al. 2019; Ortegon 2023; Tedone 2023), 18th- and 19th-century marbled papers (Torner, Sil, and Tirado 2006: Spanish language), and starch mediums used in historical paste papers (Maier 2019b: German language) approach this gap while leaving plenty of room for exploration.

In their discussions of historical decorated paper production, the major reference works defer to the plethora of 17th- to 19th-century manuals and "books of secrets" for compositional data (Haemmerle 1977, 137–44; Wolfe 1991, 166–78; Krause and Rinck 2016, 110–39; Rinck and Krause 2021). The commoditized nature of color and decorated papers in the pre-industrial era made methods of production valuable secrets—contemporary recipes and manuals are often unscrupulous reprints of popular treatises that proliferate apocryphal or even purposefully misleading information (Harley 1982, 2; Kirby, van Bommel, and Verhecken 2014, 45–47). Alchemical recipes, wide experimentation, and nonstandardized language for materials and techniques further contribute to a tangled history of traditional knowledge that is often counter to a modern understanding of effectiveness (Vest and Wouters 1999; Porter 2001, 2005; Kirby, van Bommel, and Verhecken 2014; Baty 2018; Maier 2019a). This combination of factors calls for skepticism: While the claims of historical recipes are not unilaterally inaccurate, they are, at best, unproven. Recent research refuting long-standing claims about the use of the Tyrian purple pigment (derived from *Murex* molluscs) on valuable manuscripts demonstrates the necessity of verifiable data to trace the production of cultural artifacts (Aceto et al. 2017, 2019). To let extant paste papers demonstrate their own composition was the goal of this research.

ANALYSIS

The Rosamond B. Loring Collection of Decorated Papers was assembled by Loring during her career as a maker and historian of decorated papers and was donated to Houghton Library in 1952. It contains around 10,000 pieces of decorated paper from around the world dating from the 16th to the mid-20th centuries, along with papers made by Loring, photographs, reference texts, and tools (Rosamond B. Loring collection of Decorated Papers (*52L-1000). Houghton Library, Harvard University; Loring 1942, vii–viii, 65–70).

The survey included an assessment of every cataloged paste paper item in the Loring collection. The analytical sample was selected by focusing on (1) items ostensibly produced from 1680 to 1830 and (2) papers with distinct areas of blue coloring. In its earliest stages, this project focused on the measurement of mineral pigments via X-ray fluorescence spectroscopy (XRF). Blue was thus chosen as the target color family considering the number of blue mineral pigments—including azurite, Prussian blue, smalt, and cobalt blue—which have well-researched histories spanning the target time period and would be readily identifiable via XRF. Organic indigoids, it was reasoned, could be distinguished from these by their lack of XRF signal (Berrie 1997, 192–95, 211; Eastaugh et al. 2004; Douma 2008; Delamare 2013, 37–98, 119–94; Berrie 2015, 312–22; Baty 2018, 44–67).

Thus, this project included an item-level survey of 229 samples of paste papers and paper-covered objects from the Loring collection, plus 26 paste paper-containing 18th-century book objects from private collections, for a total of 255 items. Of the Loring collection papers, approximately 169 were of the appropriate time period based on available evidence, 122 contained suitably distinct areas of blue coloration, and 16 were ultimately selected for analysis at the Weissman Preservation Center, Harvard Library.

Visual Assessment

Visual examination of paste papers from the collection was conducted in the Houghton Reading Room. A spreadsheet was used to catalog format, colors, and patterns for each object, along with inscriptions and bibliographic information recorded by Loring.

Microscopy

Microscopic assessment and imaging was carried out using reflected light at approximately 60x magnifications with a Leica MZ16 stereomicroscope (.63 objective, 10x binocular eyepieces, and adjustable Ergo tube 10°–50°), Leica IC90 E camera, Leica KL 1500 LCD fiber optics system, and Leica LAS X imaging software.

Spectral Examination and Imaging

A Foster and Freeman Video Spectral Comparator (VSC 8000) facilitated various types of spectral examination. Near-infrared imaging was captured between 780 and 925 nm. Reflectance spectra were measured between 400 and 1000 nm at 15x with a nearly 122 nm spot size. Spectra from the paste paper samples were compared to reference spectra for presumed colorants. Composite false-color imaging was completed with RGB channels set to 555 nm, 996 nm, and 405 nm, respectively.

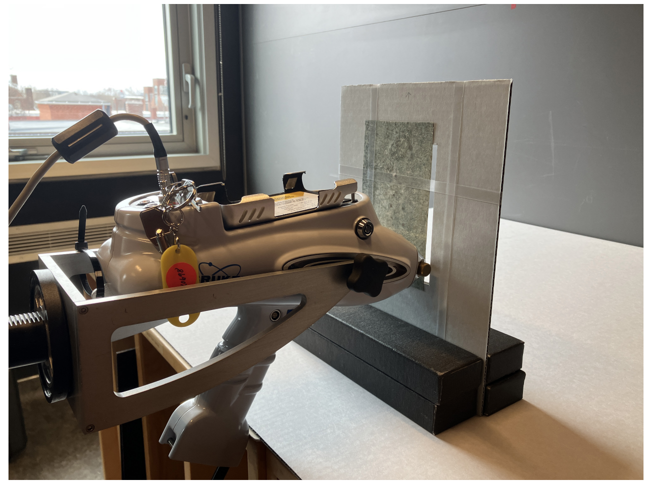

Fig. 2. Orientation of paste papers for XRF analysis. Image M. Gundrum.

X-ray Fluorescence Spectroscopy

XRF measurements were taken using a Bruker TRACER III-V XRF portable analyzer equipped with a rhodium X-ray tube, silicon pin detector, and 3 × 4 mm oval spot size. All measurements were taken without filters or vacuum with the energy and current set at 40 kV and 10 µA, respectively. The collection time for each analysis was 120 seconds. Spectra were collected with S1PXRF software (3.8.30) and processed with ARTAX software (8.0.0.446). To avoid sampling irrelevant background materials behind the thin paper, the samples were mounted upright on boards with cutouts behind the sample site (fig. 2).

RESULTS

Visual Assessment

Visual examination of the collection in the Houghton Reading Room suggested that many historical paste papers from the Loring collection were removed from bookbindings (fig. 3). Forty-two items were determined to be endpapers through the presence of sewing holes or edge decoration. An additional 30 items were paper-decorated boards or other book coverings no longer connected to a bookblock. These items contribute useful color, pattern, and object orientation data, but unfortunately, no bibliographic information was preserved for the book objects from which these papers were taken.

From the full 255-item sample, 183 were single-color, 23 two-color, 13 three-color, and 23 four-color papers. Color information was not recorded for the remaining 13 items which were modern productions falling outside the scope of the project. Single-colored papers are ubiquitous across the sample; two-color papers, interestingly, skewed toward the 19th and

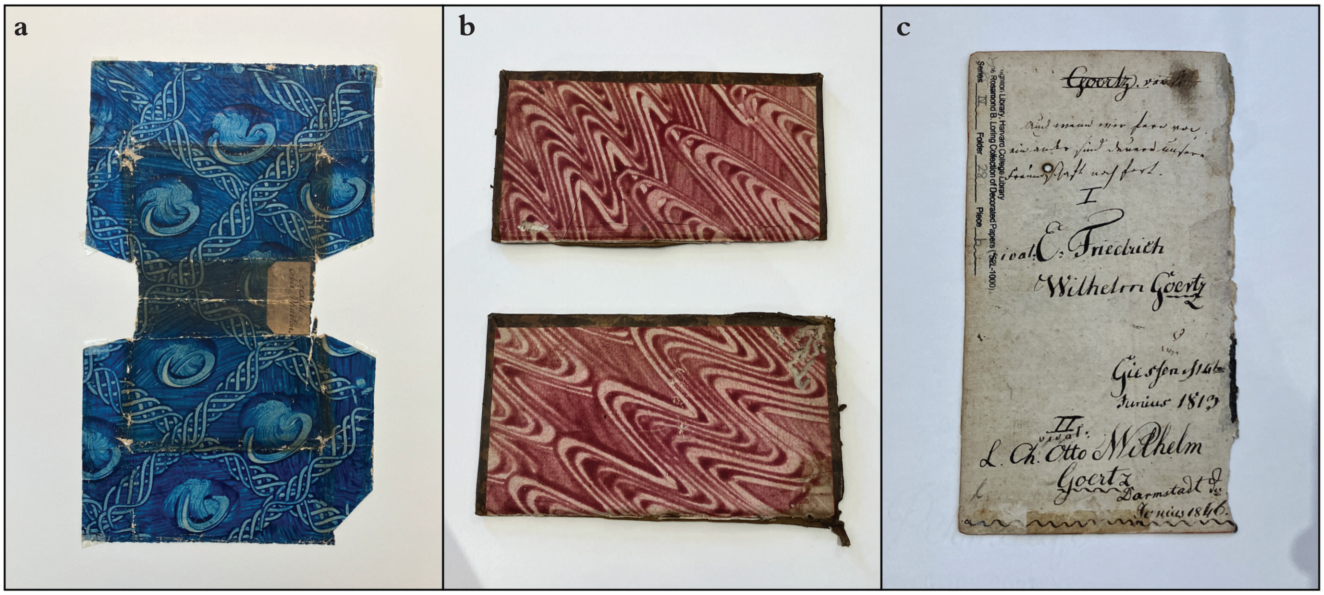

Fig. 3. Paste papers previously used in bookbindings. (a) Blue veined paper with impressed designs previously used as a book covering or overcover, Rosamond B. Loring Collection [LOR.IV.111]. (b) Crimson brushed papers with impressed designs, used as pastedowns for now loose boards, Rosamond B. Loring Collection [LOR.XII.20]. (c) Reverse of paste paper fragment previously used as a decorative flyleaf, showing ink ownership inscriptions, trimmed edges, and edge sprinkling, Rosamond B. Loring Collection [LOR.IV.28.b]. Images M. Gundrum.

20th centuries in this sample, whereas three- and four-color papers are most prevalent from the first half of the 18th century. Among dated samples, multicolor checkerboard- or quadrille-patterned papers (fig. 4) seem to peak from the 1730s to around 1780; the 18 undated examples of this feature are cataloged by Loring as 18th-century productions. The most prevalent colors across the sample were red (109 examples), blue (81), purple (41), yellow (34), brown (33), green (27), and black (17).

Of 60 items with discernible geographic association (usually the imprint of a book including paste papers), 26 reference cities in Germany. Most of the French (12), American (8), and Italian (4) examples are presumed to be 20th-century productions based on pattern style, substrate, and bibliographic information provided by Loring. While associations of this type can be problematic—both decorated papers and printed texts were traded beyond their countries of origin—the correlation between paste papers and German imprints is expected and strengthened by this dataset.

Pattern analysis began with categorization of the sampled papers by the method of application used for their primary or

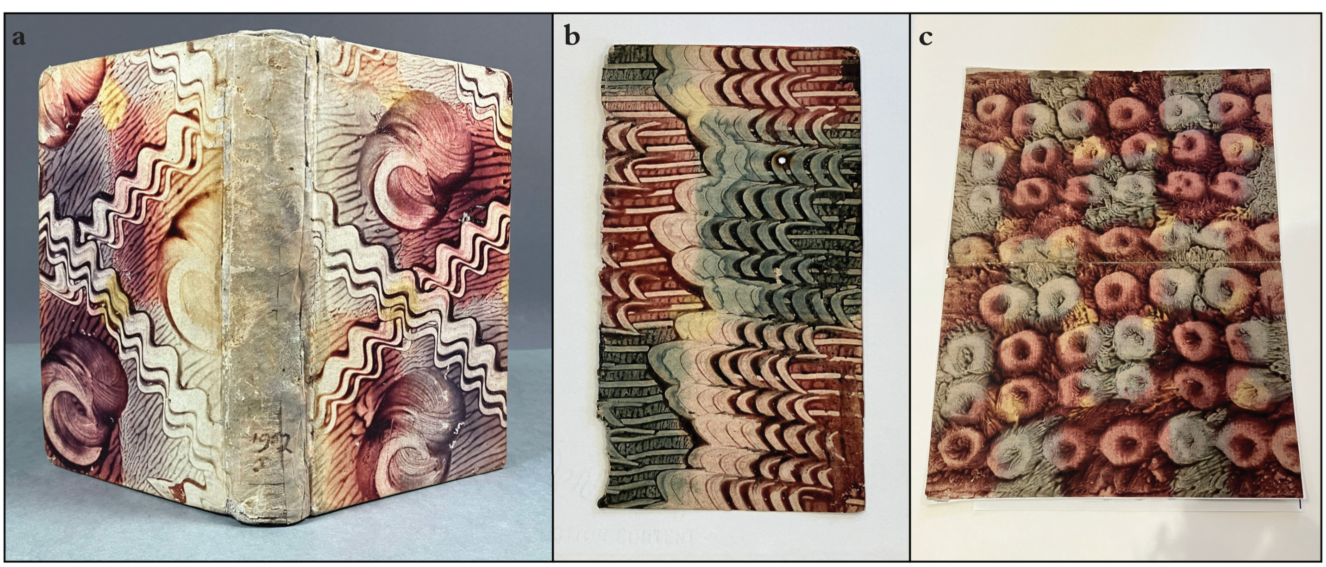

Fig. 4. Examples of checkerboard- or quadrille-patterned paste papers. (a) Personal collection [MG.21.085]. (b) Rosamond B. Loring Collection [LOR.IV.28.b]. (c) Rosamond B. Loring Collection [LOR.IV.17]. Images M. Gundrum.

Fig. 5. Examples of directly (left) and indirectly (right) impressed decorations. Images M. Gundrum.

base paste layer. The categories included veined, brushed, and brush-patterned papers, each of these with or without additional impressed designs, keeping in mind that many of the surveyed papers involve a combination of decoration techniques. A further distinction was made between directly and indirectly impressed designs—that is, marks made directly into the wet paste layer versus those made through the back of a paper sheet either while folded or while two sheets are sandwiched with paste in between. Indirect impressions are discerned by their softer edges and by transverse veins formed after the impressions were made, as the paper sheets were pulled apart (fig. 5).

While many papers from the Loring collection were recovered from bindings and are thus undated, it was possible to derive a few preliminary trends from the dated objects. Veined-patterned (German: *geädert*) papers—with or without additional impressed designs—are by far the most popular in the sample (148 examples) and persist across the full timeframe. As derived from dated samples, veined papers with impressed designs are distinctly prevalent from around 1730 to 1790. A prevalence of extra-finely veined papers appears to begin around 1790 and persist through the 1830s. Several of these examples are on French imprints, suggesting perhaps a local production and aesthetic preference.

Microscopy

Under magnification, the fiber content of the paper substrates was observed where the reverse face of the samples was not obscured by lining or mounting materials. The presence of blue, red, and yellow fibers in some samples evidences the production of paper from recycled textiles, along with the "bluing" technique of optically brightening yellowish organic fibers by adding blue fibers or pigments to the pulp mixture (Delamare 2013, viii; Baty 2018, 55).

Visual distinctions were made between two major colorants (Prussian blue and indigo), which were identified by later analyses. Prussian blue, a synthetic iron colloid with a less than 1 µm particle size, rendered a uniform color layer that was sky blue and slightly shimmery in the paste binder. Indigoids (chemically identical compounds derived from various organic sources) have larger, irregular particles that appear clumpy, opaque, and unevenly distributed in the paste layer (fig. 6).

Spectral Examination and Imaging

Items imaged under near-infrared radiation (780–925 nm) demonstrated the reflectance (brightness) of indigo versus the absorption (darkness) of Prussian blue (fig. 7). As these

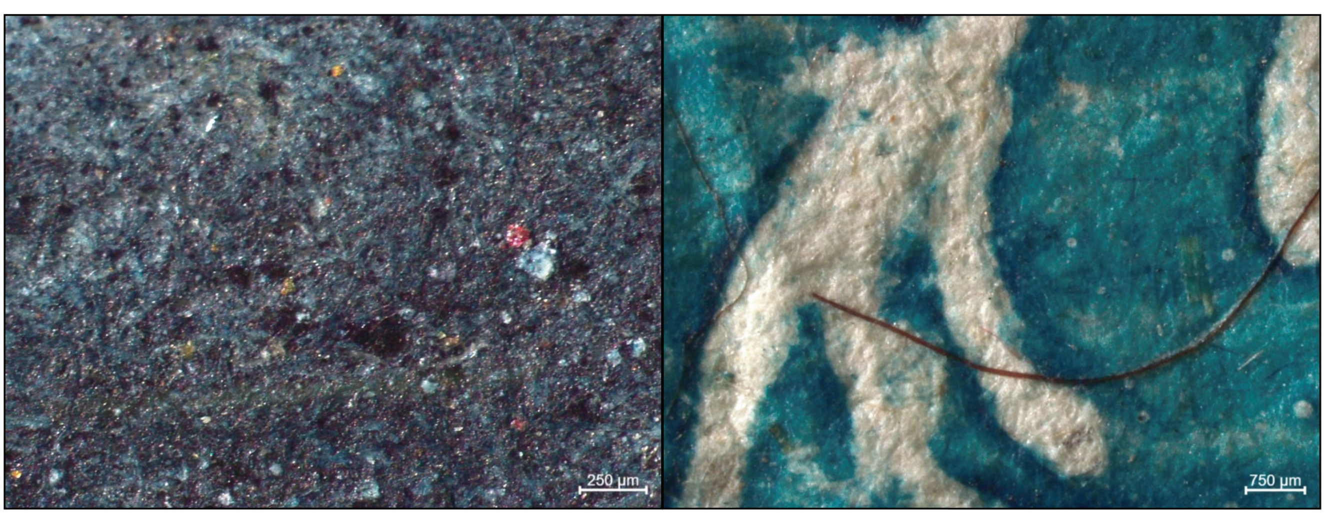

Fig. 6. Characteristics of indigo (left) and Prussian blue (right) at 50x magnification. Images M. Gundrum.

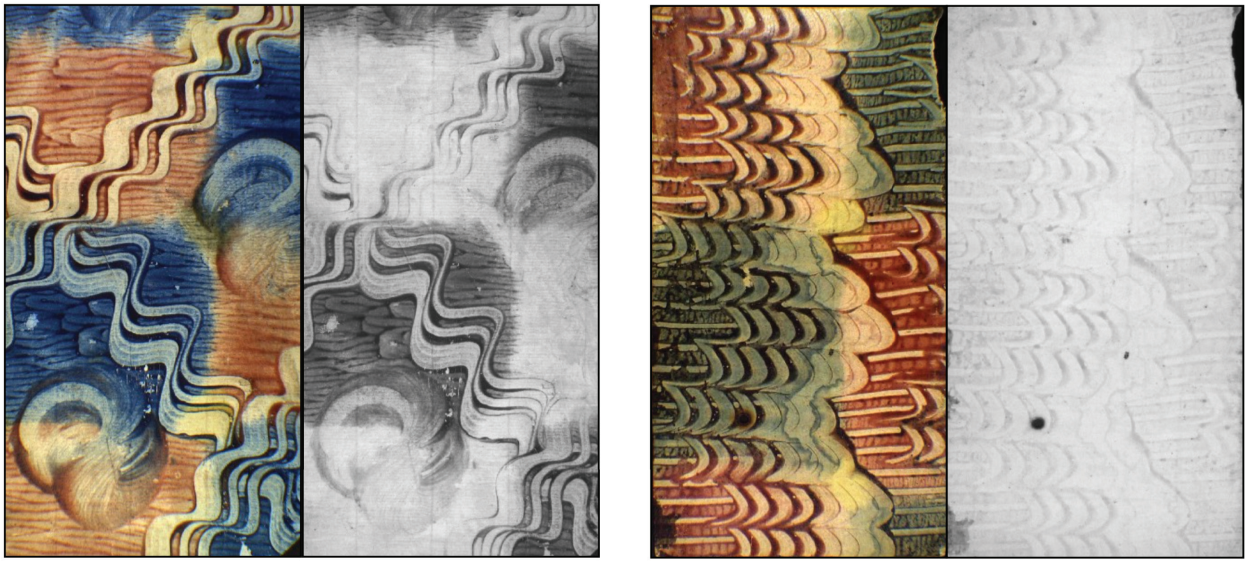

Fig. 7. Near-infrared imaging of inorganic Prussian blue (LOR.IV.33.c, left) and organize indigo/woad (LOR.IV.28.b, right). Images D. Mayer.

behaviors are not unique to these two colorants, near-infrared imaging served as a quick screening technique rather than conclusive identification. This technique provided a tentative identification for all but two of the sample items, which underwent additional testing.

Reflectance was measured across a range of wavelengths from 400 to 1000 nm to produce a spectral reflectance fingerprint for several papers (fig. 8). Comparing these fingerprints against reference spectra for known pigments rendered reliable identification for six of the seven items analyzed with this

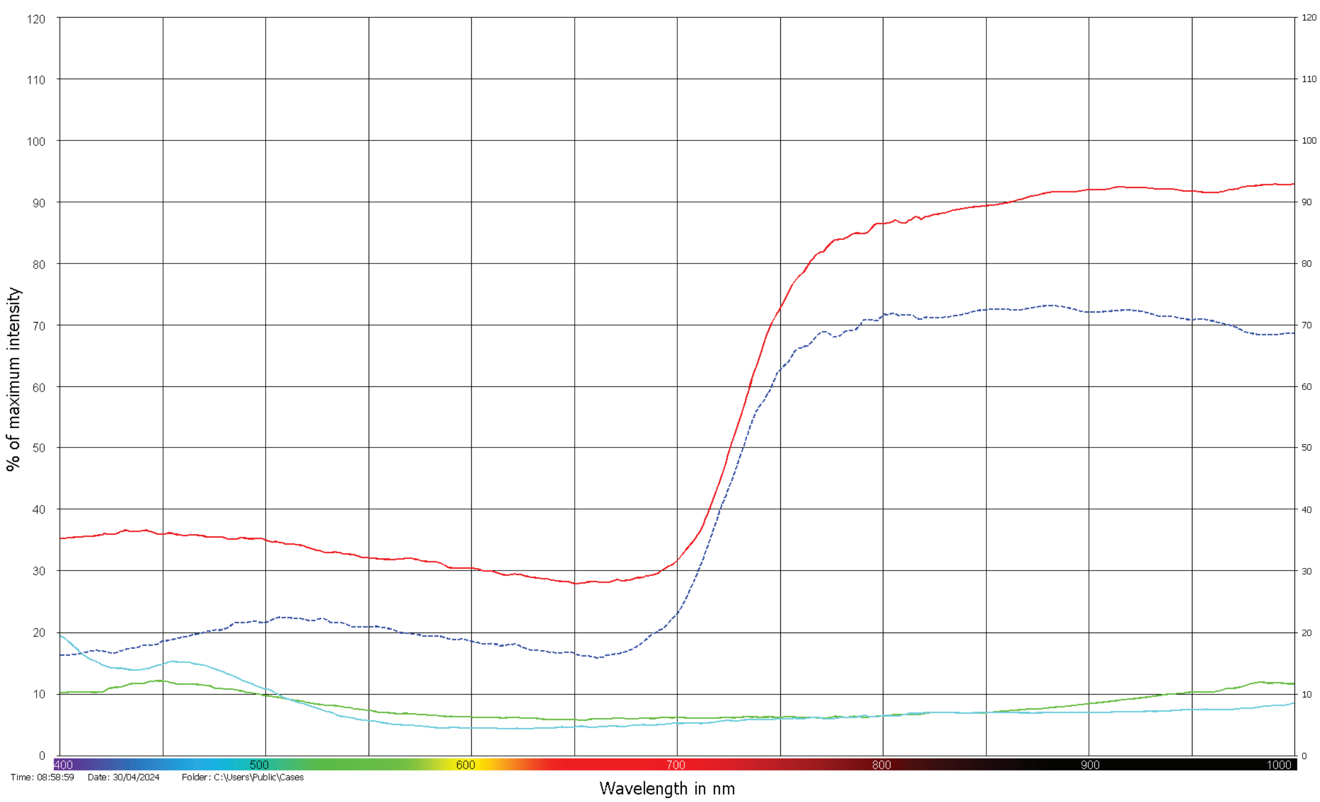

Fig. 8. Example of reflectance spectra showing characteristic lines for indigo (red: Cheryl Porter reference pigment, blue: paste paper sample LOR.IV.2e) and Prussian blue (turquoise: Kremer reference pigment, green: paste paper sample LOR.IV.33c). Spectra D. Mayer.

Sample	Elements Detected	Materials Inferred
Item 2.c	Ca	Organic blue colorant; calcium carbonate from paper manufacture
Item 2.e	As, Ca, S, Fe	Orpiment, organic blue colorant; calcium carbonate and iron from paper manufacture
Item 33.c	Fe, Ca	Prussian blue; calcium carbonate from paper manufacture
Item 35.a	Fe, Pb, Cr	Prussian blue and lead chromate
Item 36.e	Fe, Ca, K	Prussian blue; calcium carbonate and alum from paper manufacture
Item 48	Fe, Ca, K	Prussian blue; calcium carbonate and alum from paper manufacture

Table 1. XRF analysis results and inferred mineral constituents. Analysis and interpretation K. Piotrowski

technique. Results that could not be matched to reference spectra could be attributed to colorant mixtures or to colorants for which reference spectra were not available for this experiment.

X-ray Fluorescence Spectroscopy
Of the six items analyzed, three displayed primary iron (Fe) peaks (table 1). While molecular analyses such as RAMAN or FTIR would be required for definitive identification of this compound, the lack of other historical iron-based blue pigments prompted a confident identification as Prussian blue (ferric ferrocyanide, $Fe_7(CN)_{18}$). Item 35.a displayed peaks for iron, lead, and chromium, suggesting a mixture of Prussian blue and chrome yellow (lead chromate). Item 2.e displayed arsenic (As) and sulfur (S) peaks, suggesting the presence of yellow orpiment (arsenic sulfide, As_2S_3) plus a nonregistering organic blue colorant (indigo or woad), which was corroborated by additional infrared imaging analyses. Item 2.c returned only a peak for calcium, which, considering the pale blue hue and flocked appearance of the pigment layer under magnification, is suggested to be attributable to calcium carbonate (chalk), plus a nonregistering organic blue colorant.

All six samples displayed peaks for calcium and/or potassium, elements associated with calcium carbonate and potassium aluminum sulfate (potassium alum or alum), which are common fillers and surface treatments from the papermaking process (Brückle 1993). Alum, notably, is also used as a mordant in the production of marbled papers.

Colorant Identification
Of the 16 analyzed samples, 8 samples were confidently identified as indigo (*Indigofera tinctoria*) or a related organic colorant such as woad (*Isatis tinctoria*), 7 samples as Prussian blue, and 1 sample remained inconclusive from the tests performed. Because VSC methods require comparison with known reference samples, the inconclusive paper may be colored either with a mixture of pigments or with a colorant that was outside of the suspected palette and for which a reference sample was therefore not available at the time of analysis. Inherent variation in the composition, origin, processing, and application of natural colorants precludes the organization of anything like a comprehensive reference palette without analyzing and compiling data for a larger sample of historical paste papers.

DISCUSSION AND CONCLUSIONS

This research is believed to be the first to analytically identify Prussian blue and indigo as primary colorants for historical paste papers, characterizing the physical composition of these artifacts in a manner previously only accomplished by anecdotal evidence. While these findings are certainly open to adjustment through larger, broader, and more analytically intensive surveys in the future, they do present several useful benchmarks upon which new work can be built:

- Complementary analyses proved more effective than any individual technique in identifying paste colorants. Through the use of a suite of analytical tools, it was determined that spectral analysis and XRF in tandem were particularly effective at nondestructive characterization of a range of historical colorants.
- Surveying a collection of objects offered the opportunity for more holistic characterization of a family of artifacts in context than any comprehensive investigation of a single item would have done. For historical paste papers, building this generic material characterization will help inform baseline ideas of commonality/rarity, and contribute to defining trends in their development and use over time.
- While analytical samples were chosen based on their hues to maximize potential colorants, the binary results demonstrated similarities between and variation within indigoid and Prussian blue subsets, which may be attributed to production methods, color mixtures, or degradation. This suggests that hue alone is not a reliable method of colorant identification for historical paste papers. Pattern data, by contrast, revealed compelling temporal trends even across this small sample. Changes in the use of particular patterns during the 18th century provide a degree of precision—trends of 30 to 50 years—which is sure to improve as more data is gathered. Proposed trends in the use of quadrille, fine vein, and veined with impressed design patterns were supported by both the research data and the experience of consulting subject matter experts. Statistical analysis of combined colorant and pattern data points might provide more precision than either individual technique.
- Decisive provenance trends are only possible through an expanded dataset, especially with objects tied to explicit geographic and temporal data points. This research would benefit greatly from additional surveys measuring more hue families, organic colorants, and broader time periods,

and utilizing other analysis techniques. Furthermore, while the work of individual researchers can make significant contributions to art history knowledge, the combined efforts of a global community can be of immeasurable benefit. The publication of a web-based decorated paper database will make instantly available the relevant compositional data from relevant research projects and serve itself as a dataset from which new insights can be derived. Collaborative art–historical databases such as the University of Delaware's Poison Book Project and Penn Libraries' BASIRA have demonstrated the productivity and wider engagement facilitated by this crowdsourced approach (Ellertson and Herman, n.d.; Tedone and Grayburn, n.d.).

During the more than 200 years that have passed since the 1763 Moravian church ledger entry describing red rags and neat clouds, the colorant composition for historical paste papers has not been verified. To finally move beyond anecdotal evidence lends credibility to paste papers as a category of decorated paper with a distinct and critical role in the history of book arts, craft tradition, and art history in general. These findings contribute to a refined characterization of paste papers as unique cultural heritage artifacts with distinct contextual values and conservation needs, prompting more informed consideration by heritage professionals and researchers at large and highlighting the potential for additional research in this field.

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Additional data and analytical results from this research are available by request.

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