Preservation Directorate, Preservation Research and Testing Division
The Library of Congress, 101 Independence Avenue SE, Washington, DC 20540-4560

Advanced Image Processing of Multispectral Images of The Sussex Declaration

PRTD Scientist(s):	Fenella France, Meghan Wilson, Chris Bolser, Eric Monroe, Sarah Fiddyment – University of York
Requesting Scholar:	Danielle Allen, Emily Sneff (Declaration Resources Project, Harvard University - HU)
Additional Contributor(s):	Christina Duffy, Cordelia Rogerson (British Library - BL) Simon Hopkins, Wendy Walker (West Sussex Record Office - WSRO)
Start Date:	August 2017
Completion Date:	November 2017 *(additional analyses completed March 2018)*

Executive Summary

- The Sussex Declaration was brought to the British Library for analysis in August 2017. Multispectral imaging, microscopy, and x-ray fluorescence conducted. Spectral data was provided to the Library of Congress for advanced image processing of multispectral data.
  - Principle component and other imaging analyses were conducted of areas of interest, including the erasure at the top of the document in an attempt to discern the removed date. Processing rendered this partially readable, but some areas were still obscured due to heavy historic treatment and erasure.
  - Spectral curve analysis was conducted to assess congruency of ink across the document, specifically comparing the title to the body text with a focus in areas of potential correction. All ink responded very similarly in composition with slight variations found only in reflectance values due to the intensity of ink application.

  - Matching side-by-side comparison of the four areas of loss along the left and right side of the document indicates the four corners were aligned at time of loss.
  - Identification of the white deposit identified the presence of both calcium carbonate and poly(propylene ethylene) at differing ratios.

  - Parchment analyses indicated sheep for the document in question, different to the high quality calf from US BNA1543 which was high quality calf.

Project Objectives

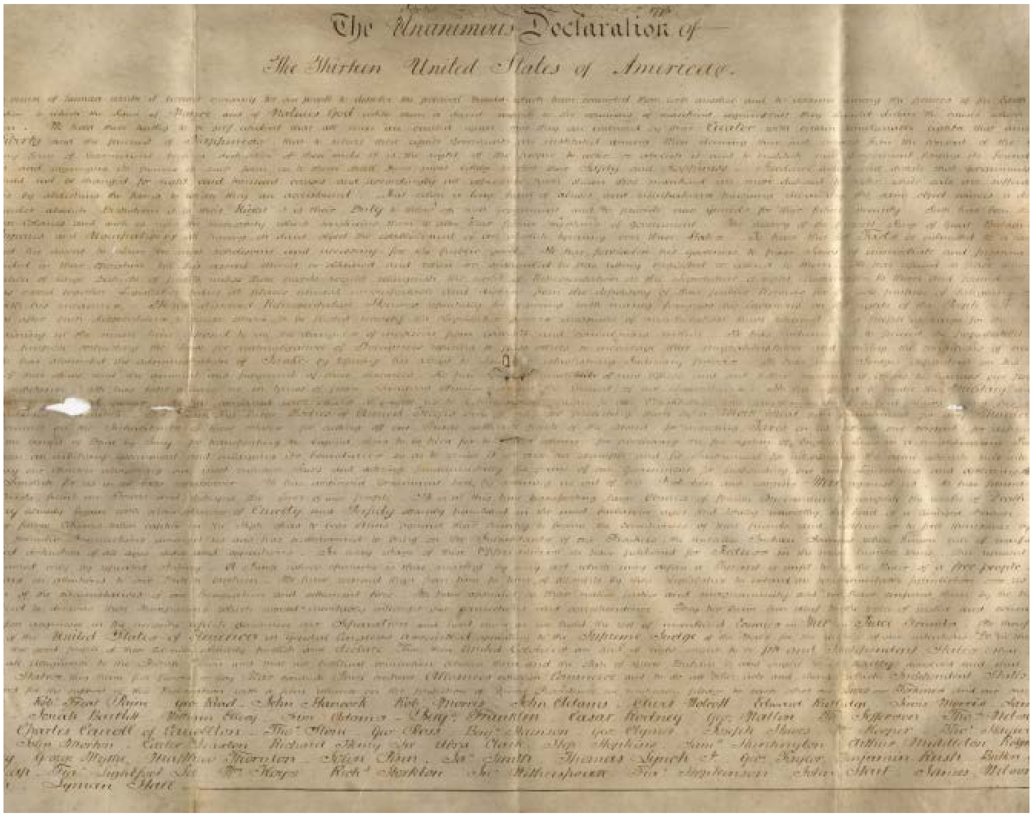
Analysis of the Sussex Declaration was the subject of the MOU, with the Library of Congress being responsible for the advanced image processing of the multispectral data captured at the British Library, as well as additional analyses. Specific areas of interest included the rendering the erasure at the top of the document, analysis of the congruency of the ink used to write the document especially in areas of potential correction, analysis of a fluorescent stain found on the verso of the document, and a comparison of areas of loss along the edges of the document.

Background

The Sussex Declaration, housed at the West Sussex Record Office in Chichester, UK, is one of three known parchment manuscript copies of the Declaration of Independence. The Declaration Resources Project of Harvard University, USA, is interested in analysis of the Sussex Declaration to determine its provenance, specifically dating the manuscript, determining who commissioned it and why, and identifying how and when the document moved to the United Kingdom.[1]

The parchment document is 24” x 30” in dimensions, considered late 18th century, with the exact date unknown. Marginal ruling with justified round hand script and decorative penwork. Evidence of nail holes and losses along left and right edges and in areas along the center crease.[1]

[1] “The Sussex Declaration.” *The Declaration Resources Project, Harvard University*. <https://declaration.fas.harvard.edu/resources/sussex-dec>. 11/15/2017.



Color image of the Sussex Declaration, recto

Methodology

To undertake spectral image processing for non-invasive analysis of inks and redactions, multispectral imaging files were provided by BL in raw captured format as digital negative graphics (DNGs) a standard recommended image file format, as well as flattened 16 bit tagged image file format (TIFF) files use for image processing.

Advanced image processing was conducted via principal component analysis (PCA) and spectral curve analysis. PCA is a mathematical algorithm to detect and visually highlight differences in spectral response between the various inks and other components on an object. This processing was undertaken using two software package, ImageJ and ENVI ITT (Harris) software. A spectral curve is a visual representation of a materials spectral data that illustrates the reflectance of light from its surface (y-axis) wavelength-by-wavelength (x-axis) forming a curve that is unique to that material (ink, colorant, substrate, as well as the combination of the base substrate it is attached to or written on. The reflectance properties of a material depend on its physical and chemical properties. The spectral curve analysis was completed in ENVI software.

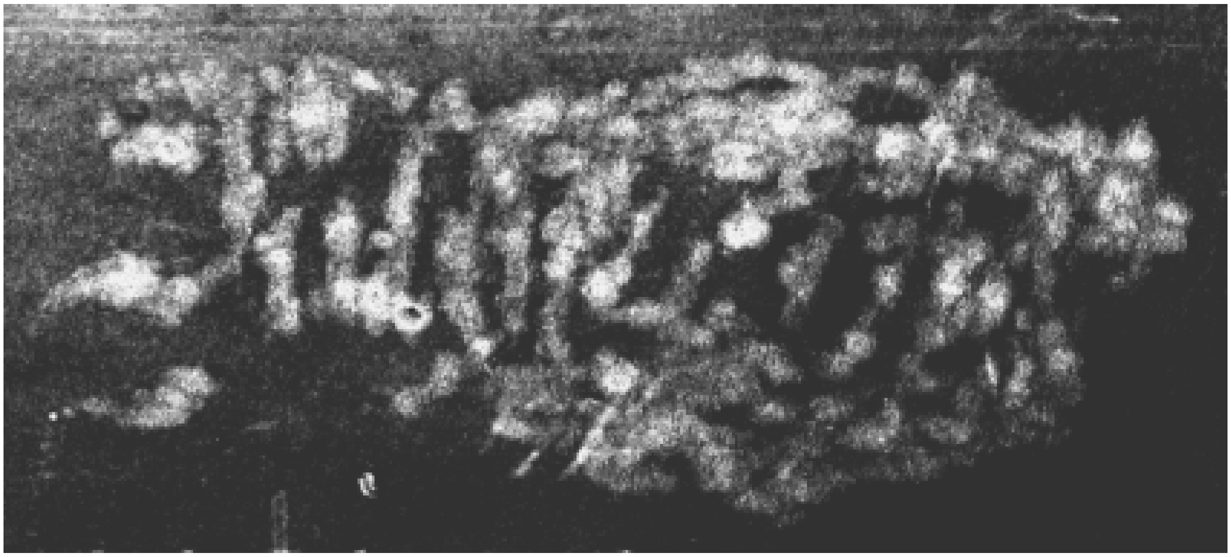
Results

Erasure

Multispectral imaging revealed an erasure at the top of the document. It was not in line with the written title of the document and appeared to have been made before any of the visible text of the document was written, as the ink in the vicinity of the erasure appeared undisturbed. The erasure appeared to be obscuring of a date though it cannot be determined at what time this attempted removal occurred in the history of the document's construction.

The original ink in the erasure had been completely removed and was undetectable via PCA or other spectral imaging algorithms (i.e. spectral angle mapper classification and adapted coherence estimator functions in ENVI software). The component that was enhanced in the processed images illustrated the ink remaining from the removal process, a process potentially of extreme rubbing or a chemical abrasion which complicated visibility and processing of the images. The erasure component responded different spectrally to the spectral response of the parchment substrate, and the visible ink of the rest of the document but was congruent within itself.

Some words and numbers were discernable. "July" seems to be the first word, followed by a "4". It is difficult to confirm whether it is a "4" alone or if there was a character before the "4", however this could just be a product of the erasure process. The next two numbers are likely "17" but it is almost impossible to discern the rest of the date due to significant interference, perhaps removal of embellishment in that area. What can be stated is that the third digit appears to be a curved figure such as "8" or *9". Below are four examples of resulting PCAs. Additional images can be found in Appendix A.

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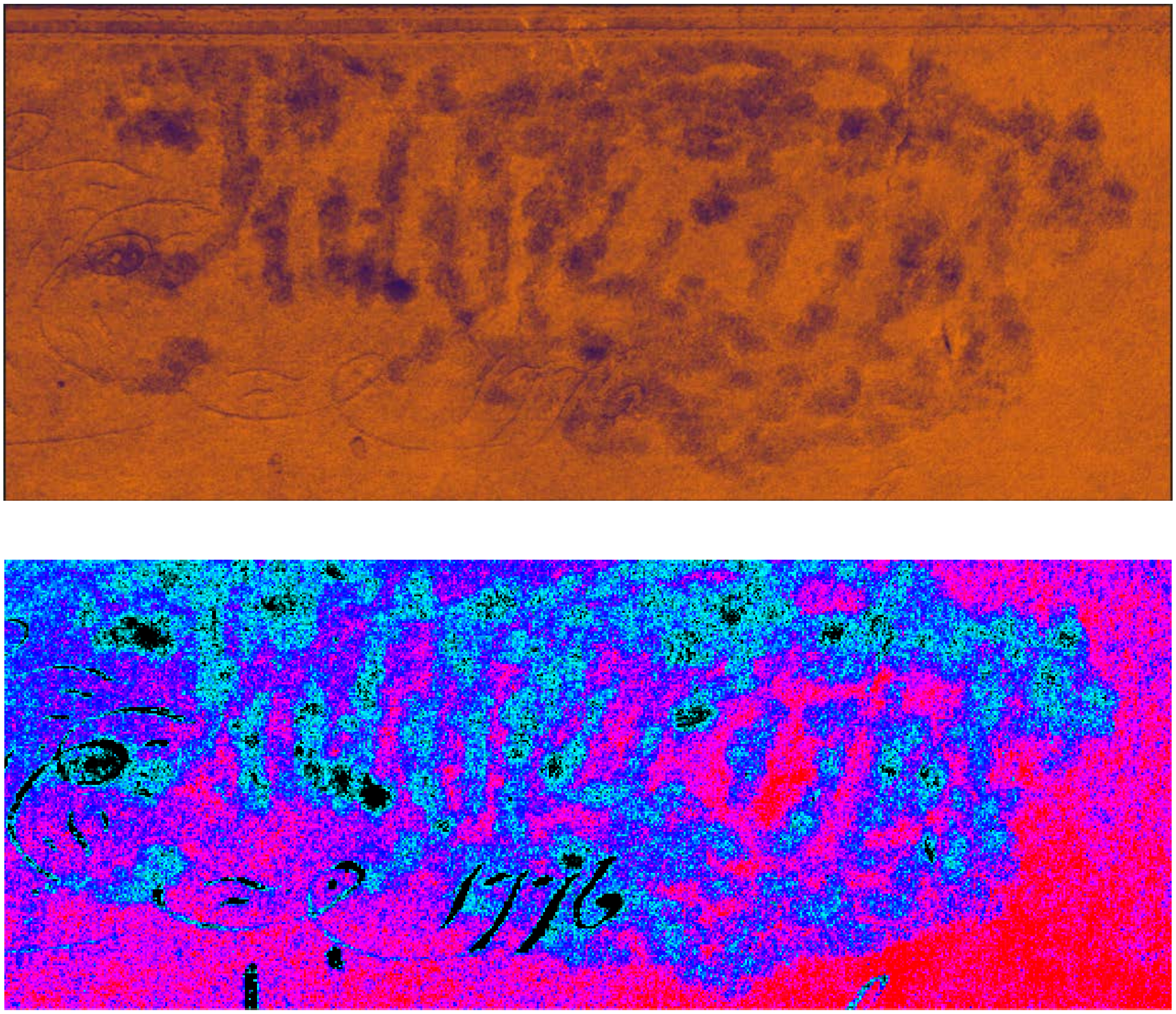


Figure 1. Four PCA renditiions illustrating different false-color images to highlight differences
and components within the erasure

Ink Congruency

Initial PCA false-color images suggested different responses between parts of the title and the main body text of the document. Further inspection indicated that these perceived differences were due to changes in the intensity (thickness or thinness of application of the ink), not due to a chemical or spectal difference. This was confirmed with spectral curve analysis where the chape of the spectral curve remained the same, but the intensity (height) of the curve changed due to the ink intensity. PCA and spectral curve analysis re complementary and often used in conjuction to support hypotheses.

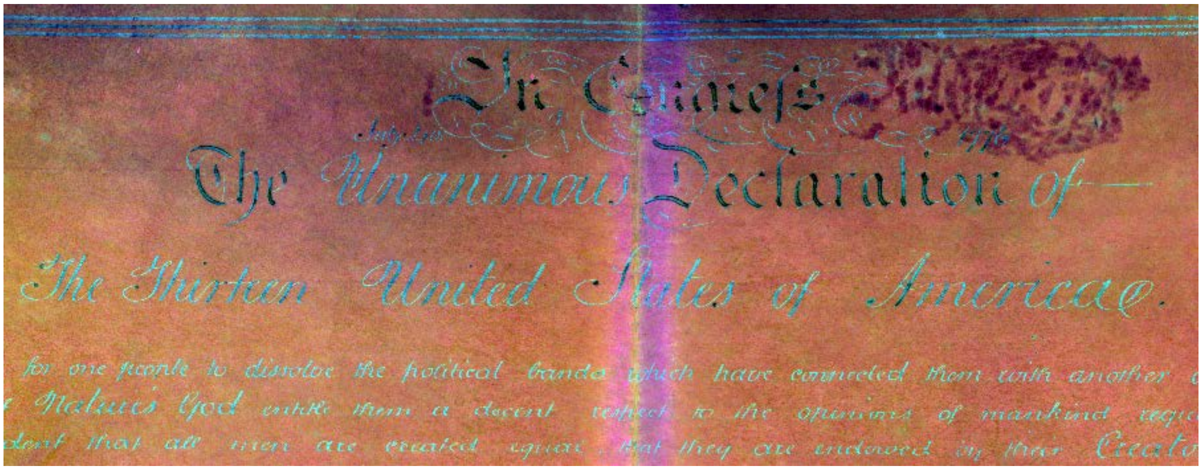


Figure 2. PCA showing congruency of ink between title and body text with variations seen in areas of fluctuating thickness of ink.

As noted above, spectral curve analysis confirmed that the ink was the same. The difference in heights of the curves reflects the differences in thick and thin application of the ink as it appears visibly darker (lower curve height) and lighter (higher curve height). The similar shapes and points of inflection indicate the similarity in chemical composition of the ink.

There was an observed correlation between the spectral curves of words of the same *writing style* within the title. The spectral curves for the words “The” and “Declaration” which have a bold construction are closest to one another in reflectance value as are the thinner and more curvelinear words “unanimous” and “United” to one another. Again, for the aforementioned reasons, this is likely due to the difference in thickness of the ink application of these words. It remains a scholarly question for those more familiar with writing styles of the time to determine whether these stylistic differences indicate two different authors, a supposition that can not be definitively confirmed from this data. However, if that was supposed, the spectral curves illustrate that all ink of the document, regardless of number of authors, was applied in a close proximity of time.

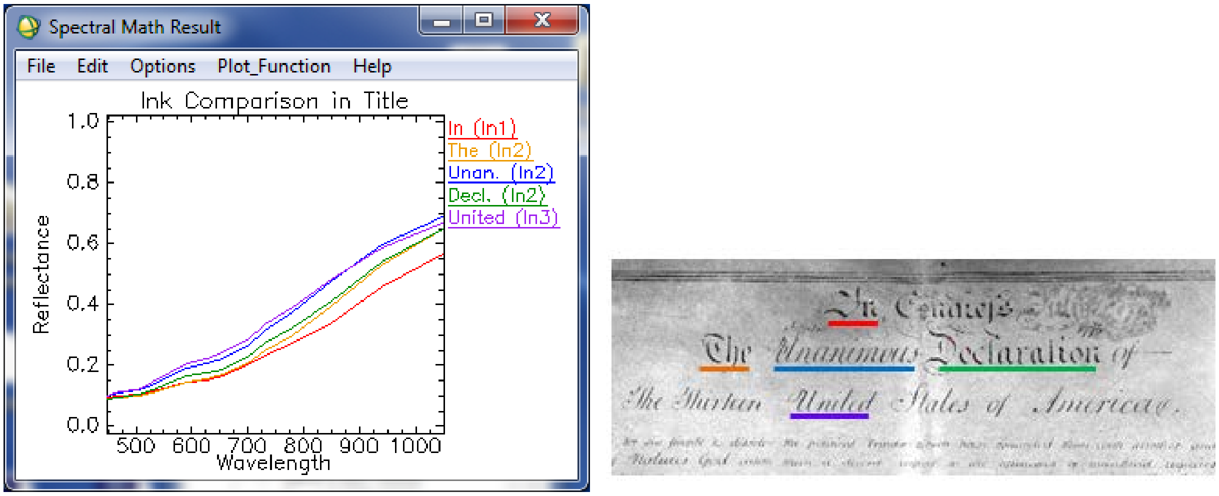


Figure 3.Spectral curve comparison of ink in title of document, with noted regions of interest

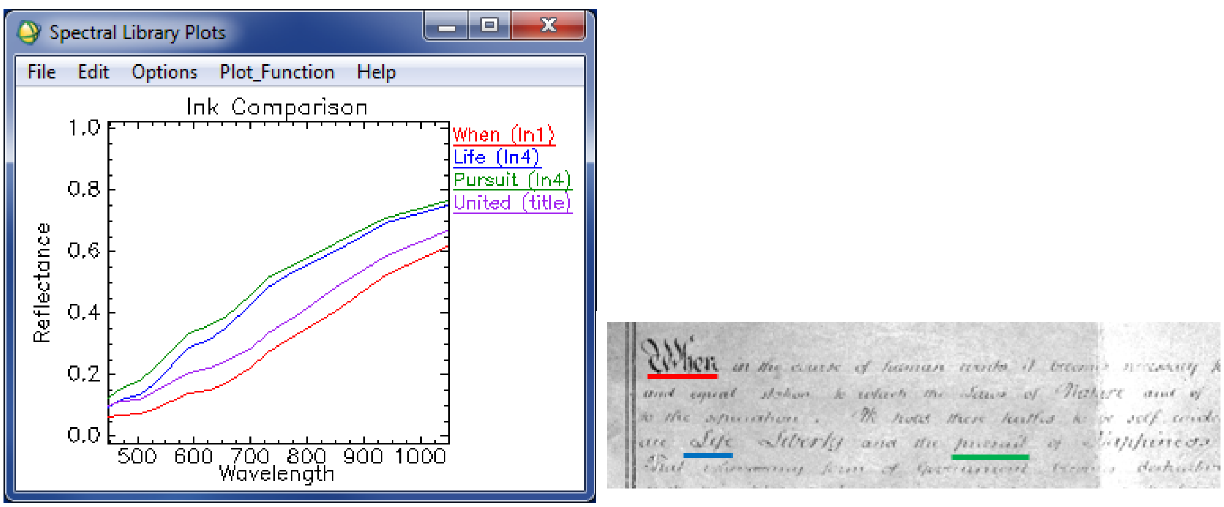


Figure 4. Spectral curve comparison of body text and title, with noted regions of interest

Spectral curve analysis does show close correlation in intensity of the ink between words of the same writing style within the title. The words “In”, “Congress”, “the”, and “Declaration” have a bold construction as compared to the thinner and more curvelinear words “unanimous” and “of”.

PCA shows that the body text of the document remains congruent, even in areas of staining or suspected correction.

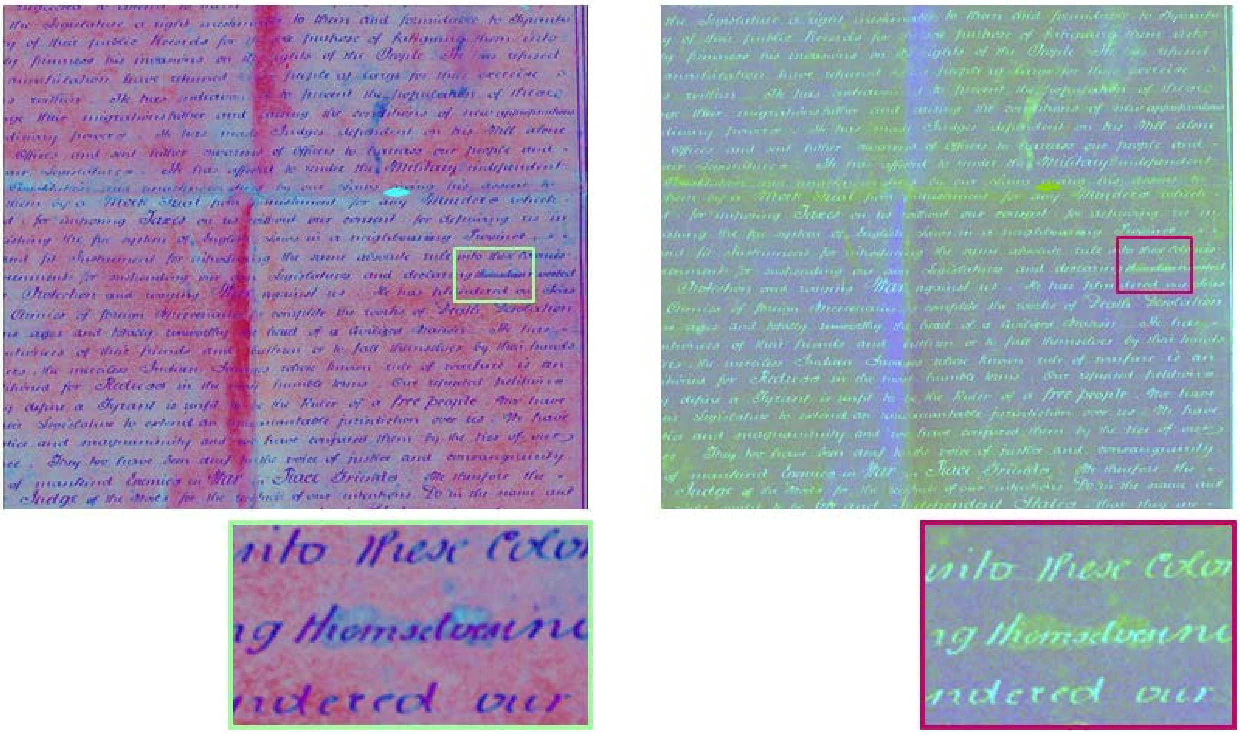


Figure 5. Overall body text with detail of stained or potentially corrected area

There was a noticeable difference in the response of “-ger” in Roger Sherman’s name at the bottom of the document. In visible light this area seems to have potentially been a correction in the text. In the PCA below, notice that the majority of the body text from the PCA false-color processing renders in yellow and this particular area renders in orange. However, considering the response of the larger area of the document, this is likely due to a difference in ink application (thickness) not in chemical composition.

Comparatively, there are indications of a similar response in other words among the main body text (yellow to yellow-orange rendering) where the word is written with a heavier application of ink but with no indication of suspected correction (e.g. “people”, “judge”, etc.). This is confirmed with spectral curve analysis where the curves have different heights due to differences in thick and thin application of the ink but the similar shapes and points of inflection indicate the similarity in chemical composition of the ink.

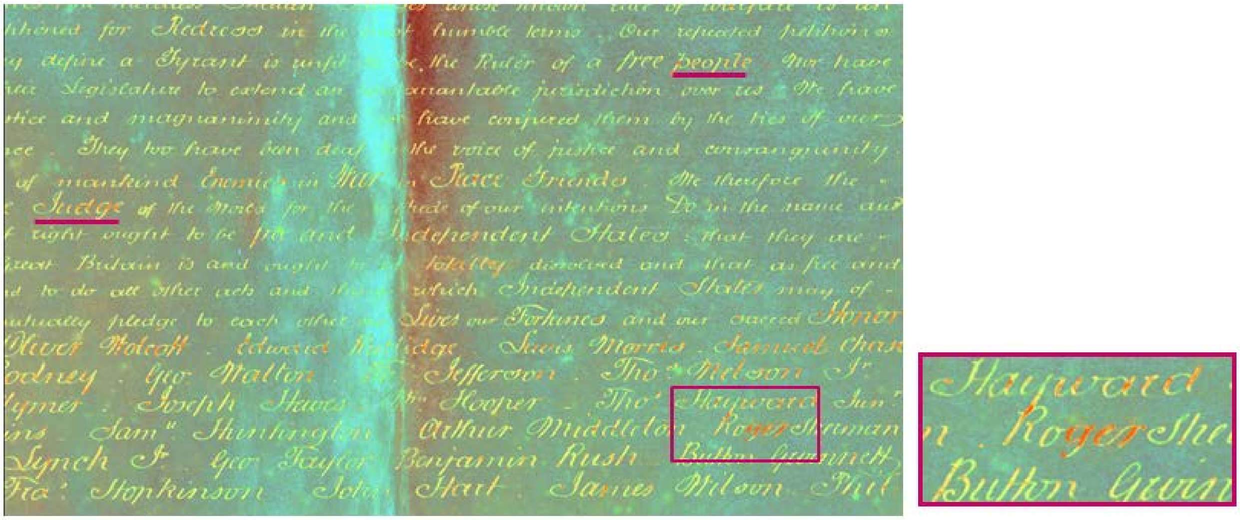


Figure 6. PCA of body text with detail of Roger Sherman's name

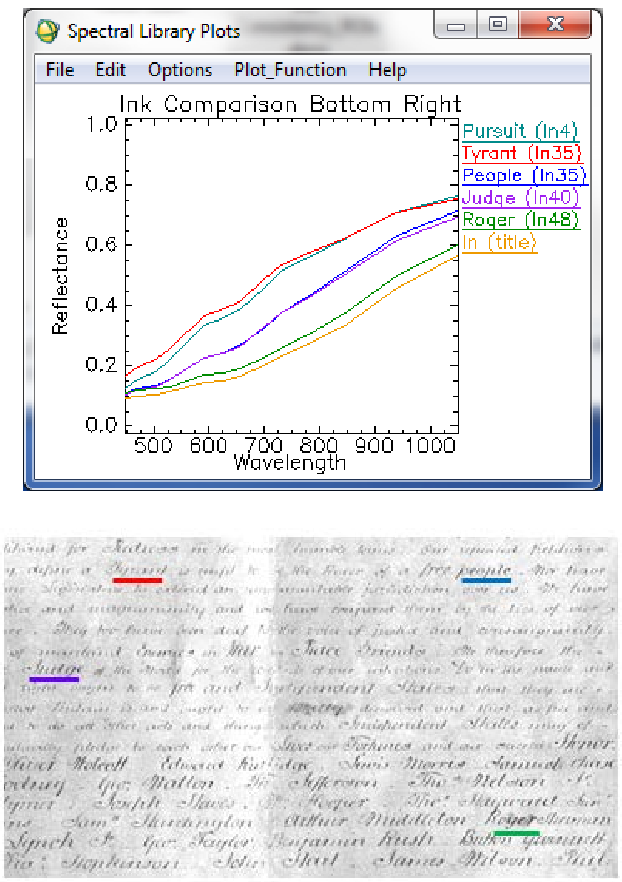


Figure 7. Spectral curve comparison of ink in Roger Sherman's name and surround body text,

with noted regions of interest

Ruling

The body text of the document was lined. The title was not lined but was written horizontally straight. The erasure next to the title, likely to have be written and erased before any of the currently visible text was laid down, was positioned in a downward slanting manner, not congruent with the structured and "lined" composition of the rest of the writing in the document. Though supposition, this could lend credence to the hypotheis about the construction and authors of the document, as discussed in conference with scholar Danielle Allen, with the potential for a junior or apprentice being overseen by a more experienced scribe.

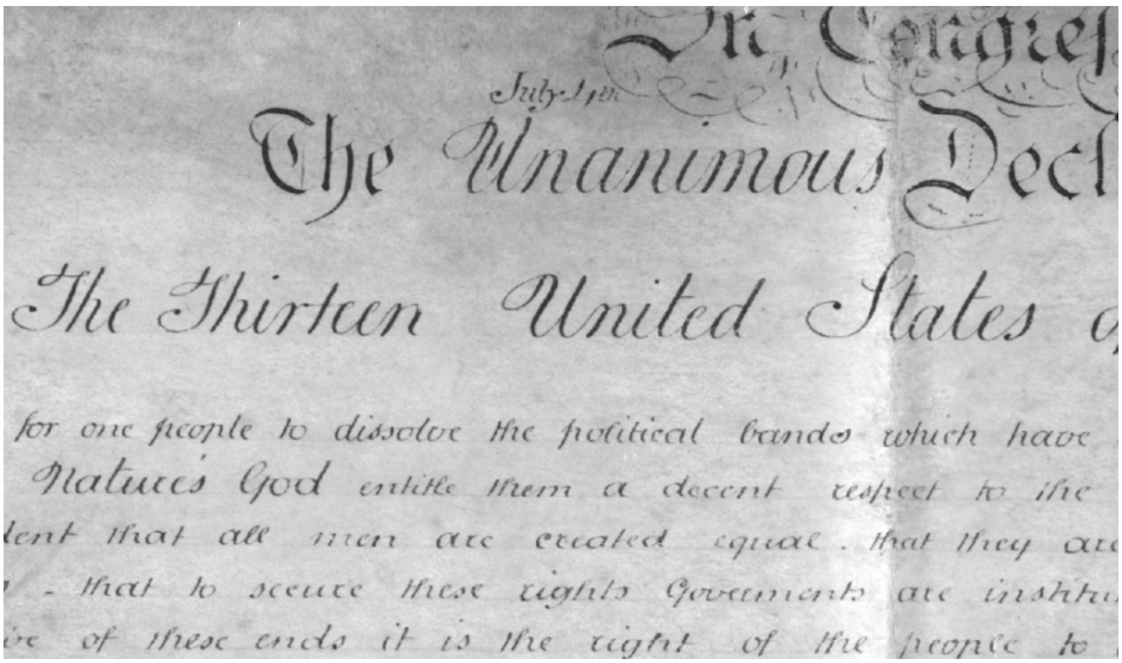


Figure 8. Faint ruling seen in body text

Fluorescent Stain on Document Verso

PCA was used for analysis of a stain on the verso of the document which was noticably fluorescent during image capture. No additional markings can be found in this area nor specific indications of the composition or cause of the stain.

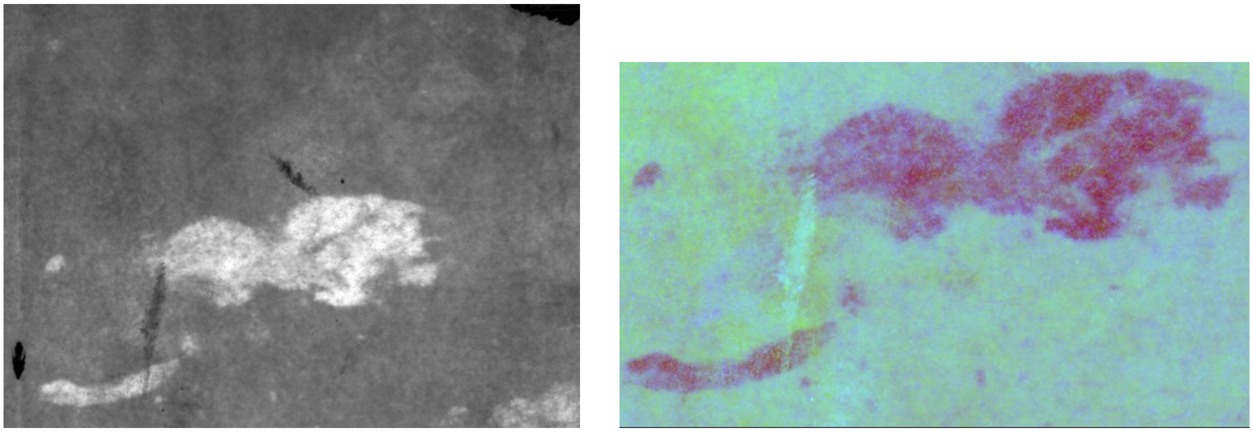


Figure 9. LHS: Stain as seen under UV illumination, RHS: PCA of stain

Areas of Loss Along Left and Right Edges

The areas of loss in each corner of the document were compared to investigate how the document may have been folded together at the time the loss occured. To make the comparison, the corners were overlaid in Photoshop and each area of loss compared to the bottom left corner. To simulate folding, the top two corners were flipped vertically and the right two corners flipped horizontally (thus the top right corner was flipped both vertically and horizontally).
As seen in the image below, the markings align to one another, likely indicating the corners were folded onto one another (the document perhaps folded in quarto) when the loss occurred.

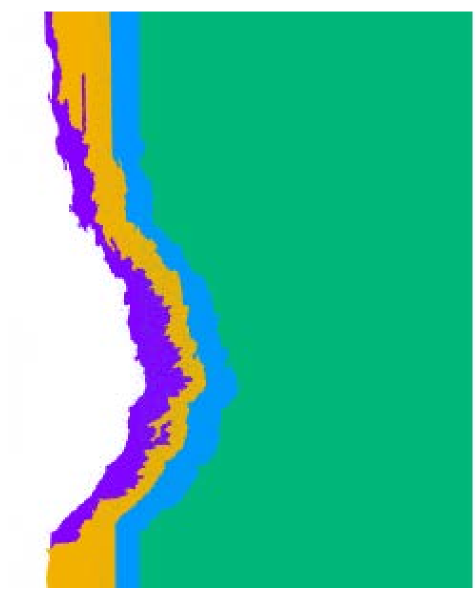


Figure 10. Purple – bottom left, Orange – top left, Blue – bottom right, green – top right

Parchment Protein Analysis

A recent non-invasive technique that consists of taking an eraser rubbing from the parchment document allows an analysis of the species of animal that the parchment was made from.
Analyses were undertaken by Sarah Fiddyment, University of York.
The Sussex MS8981 manuscript parchment was identified as sheep.
Two eraser rubbing samples taken from a potentially comparative document provided by Tara O'Brien, Director of Conservation and Preservation Services, Historic Society of Pennsylvania, indicated that the Charter of Incorporation BNA#1543 document (ca. 1781) was calf parchment with a high parchment quality index.

Identification of the White Deposit Collected from the Parchment

Due to the minute sample provided, analysis was delayed until a new technique could be accessed.
This analysis was performed by Eric Monroe (PRTD) and Ron Rubinovitz (Senior Applications Scientist, Thermo Fisher Scientific) on 3/8/18 at the Thermo Fisher Scientific Applications Laboratory.

In order to identify the powder collected from the parchment, samples were taken to the Thermo Fisher Applications Lab for analysis with a Thermo iN10 Infrared Microscope. This instrument allows for the visual and chemical inspection of samples using optical imaging and Fourier Transform Infrared (FTIR) spectroscopy, respectively. A small amount of the collected powder was removed from the sleeve and placed into a diamond compression cell in order to flatten the samples and enable transmission FTIR spectra to be collected.

A total of 15 particles (Figure 11) were selected for analysis using an automated particle finding algorithm. Each of the collected spectra was compared to existent spectral libraries to identify the composition of the particles using both single and multi-component searches.

The spectra from each of the 15 particles were similar to one another and were identified as containing calcium carbonate with poly(propylene ethylene). One particle contains almost pure calcium carbonate while the other particles contain a mixture of the compounds (Figure 12). Using a multicomponent fitting tool, the particles range from 15-70% poly(propylene ethylene) with the rest being calcium carbonate. Most particles contained 40-60% calcium carbonate. (Figure 13).

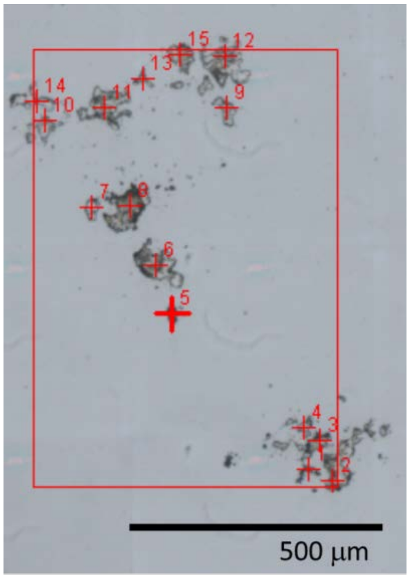


Figure 11. Optical image of particles following preparation in compression cell

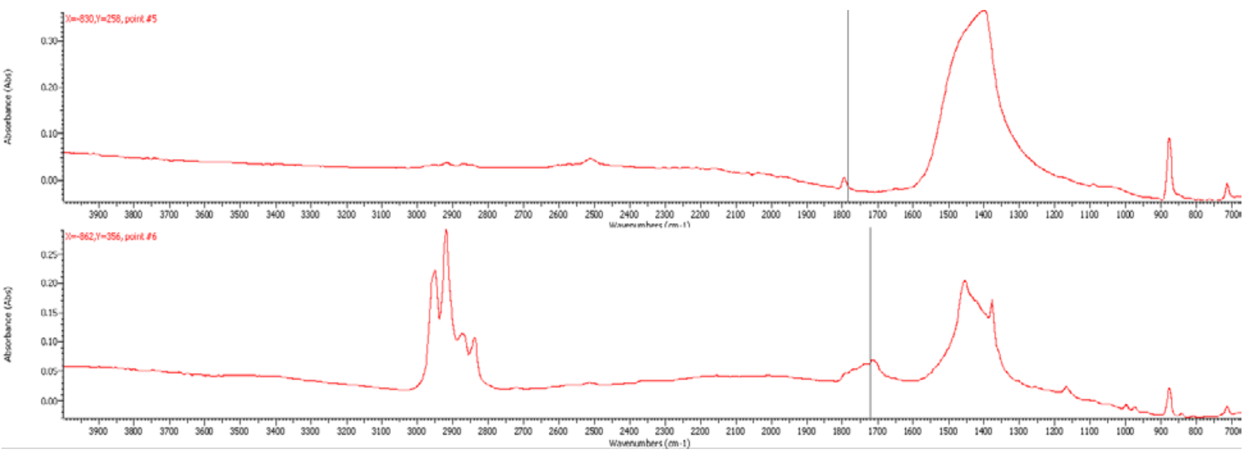


Figure 12. Selected FTIR spectra from two selected particles

The top spectrum in this spectra indicated that the white deposit samples was almost exclusively calcium carbonate while the bottom spectra contained a significant amount of poly(propylene ethylene).

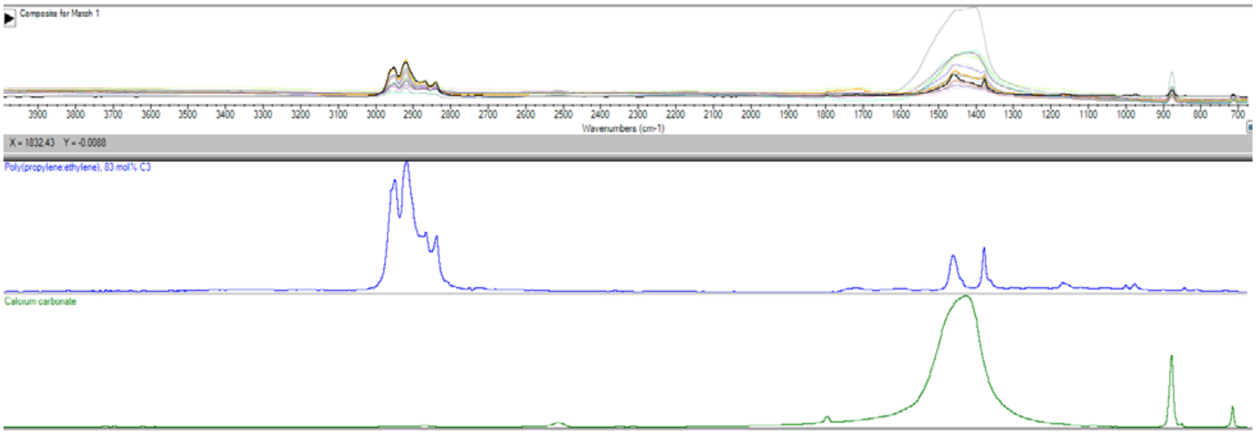


Figure 3. Automated multicomponent searches identified the presence of both calcium carbonate and poly(propylene ethylene) at differing ratios.

The top panel in this image is an overlay of all 15 spectra. The bottom two spectra are from the library search for the spectrum in black (particle 6 in Figure 11) where the composition was identified as 70% poly(propylene ethylene) and 30% calcium carbonate.

The presence of a modern polymer suggested this was a 21st century contribution to the document.

Conclusion

Advanced image processing of the multispectral images of the Sussex Declaration was conducted at the Library of Congress which primarily consisted of principal component analysis and spectral curve analysis. These techniques addressed questions about regions of interest from the researchers in relation to the construction and provenance of the document, and possible authorship.

An erasure found at the top of the document was enhanced for readability though some parts remained obscured due to the extreme removal process. A possible date from the erasure was identified, with the critical 3rd numeral being inconclusive but clearly circular in nature, potentially an “8” or “9”. Some differences in the intensity of the writing and writing styles in the title led to a discussion of whether there was a junior and master scribe involved in the creation of the document.

The ink across all areas of the document, including the title, body text, and areas of suspected correction, were assessed for congruency and determined to be of similar chemical composition. Examination of a fluorescent stain on the verso of the document rendered no additional invisible markings in that area. Comparison of areas of loss along the left and right edges of the document revealed similarity in shape indicating the document was folded so that all corners aligned at the time of this loss.

Identification of the parchment showed the parchment to be made from sheep.
Identification of a white deposit indicated a combination of calcium carbonate and poly(propylene ethylene). Different particles showed varying amounts of the two materials. The presence of a modern polymer suggested this was a 21st century contribution to the document.

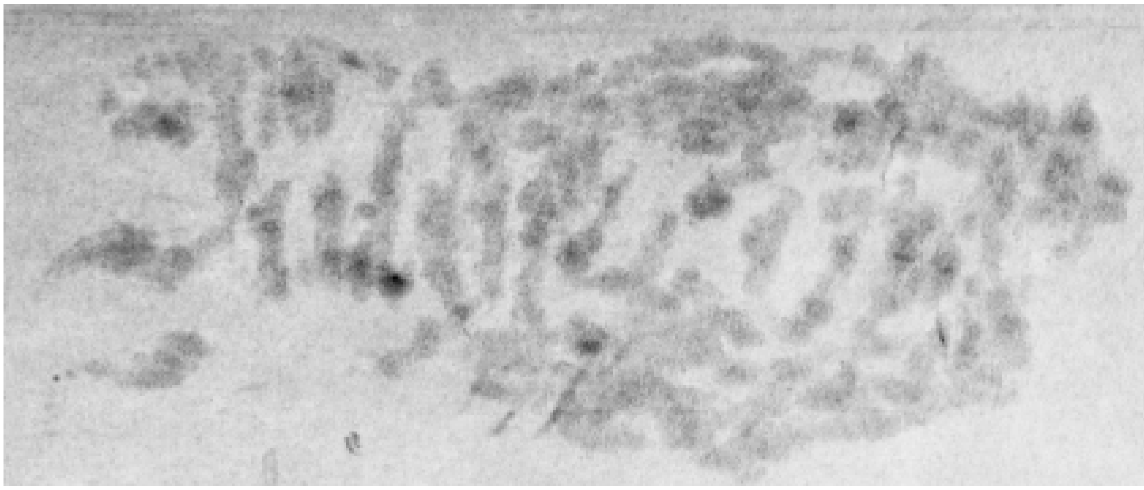
Recommendations

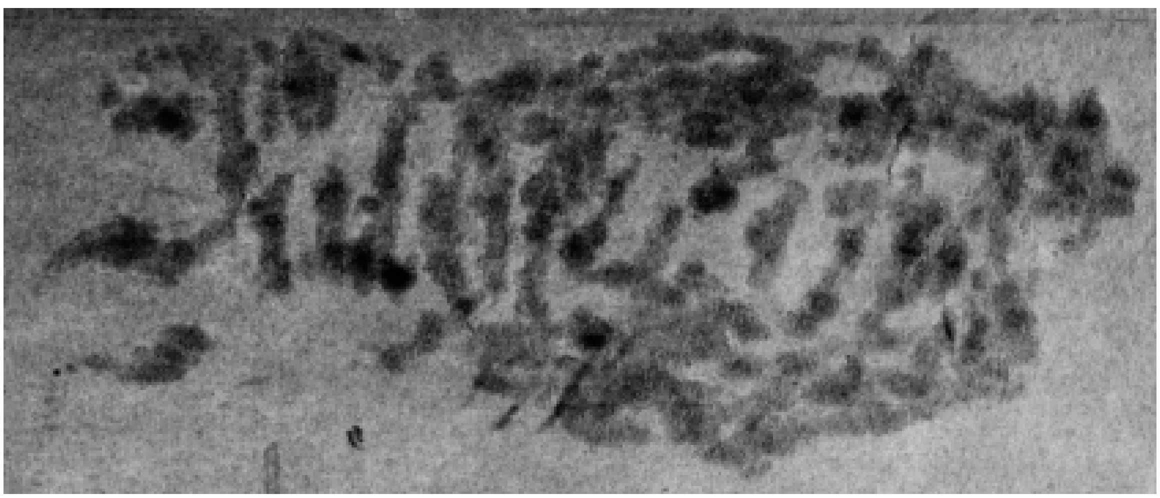
Preliminary X-Ray fluorescence (XRF) at BL did not indicate any specific ink composition data. However, instrumentation at LC allows the identification of smaller elements, as well as a semi-quantitative ink comparison, that could add further information to the imaging data. XRF mapping allows a line scan to track elemental information across a specific area, rather than just a point source and this could be extremely helpful.

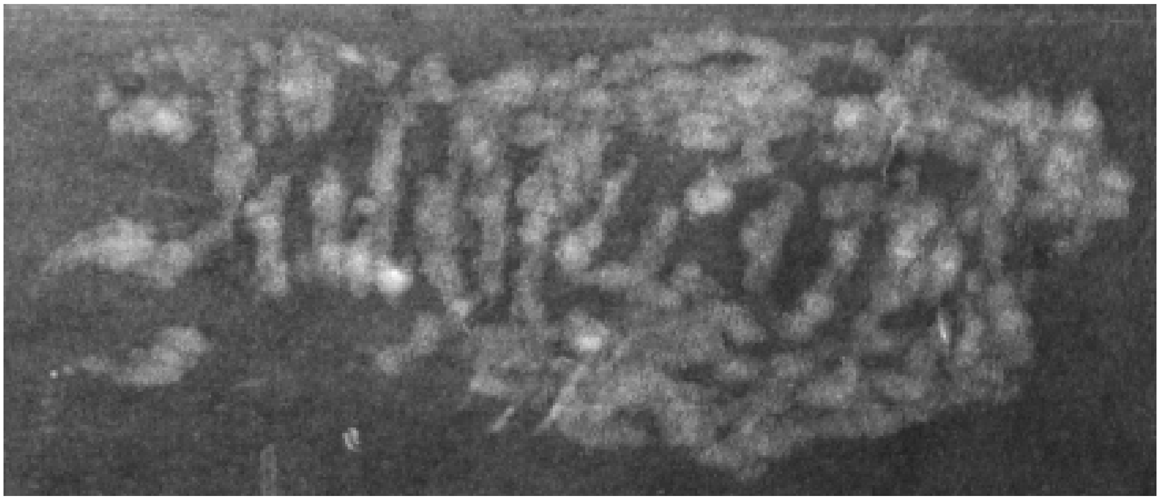
Additional analyses like Fourier transform infrared spectroscopy (FTIR) or fiber optic reflectance spectroscopy FORS) have been found to be extremely useful in assessment of organic components, and along with XRF mapping of trace metals in the upper and erased inks, could be helpful in further enhancement of the erasure at the top of the document. This instrumentation has a higher sensitivity at a microscopic level and could potentially identify traces of the original ink (if it is present) and distinguish it from the blurred remnants of the erasure we see presently. Should the document be able to travel, LC would be willing to undertake additional analyses to assist scholarly interpretations and questions.

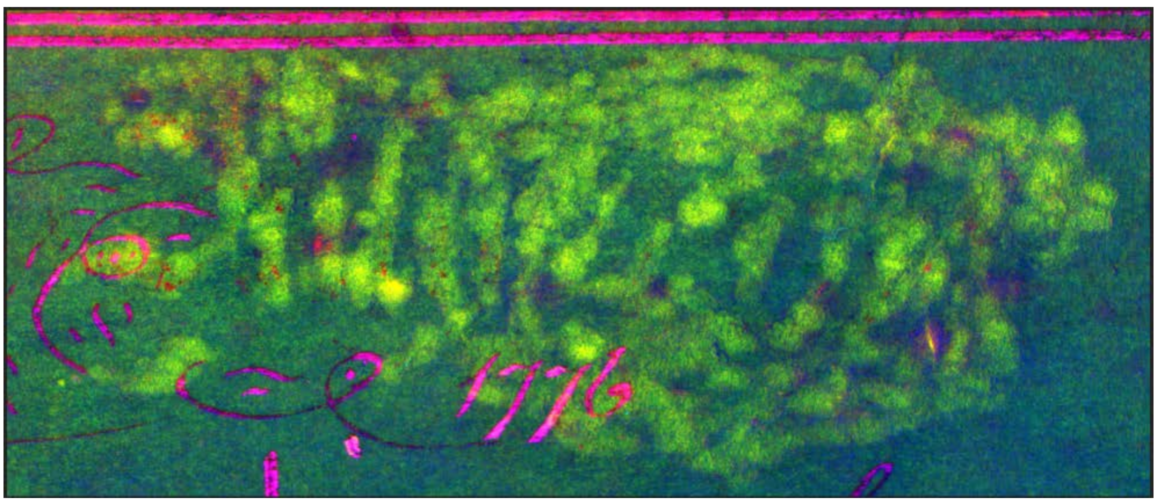
Appendix A

Additional PCAs of erasure at top of document





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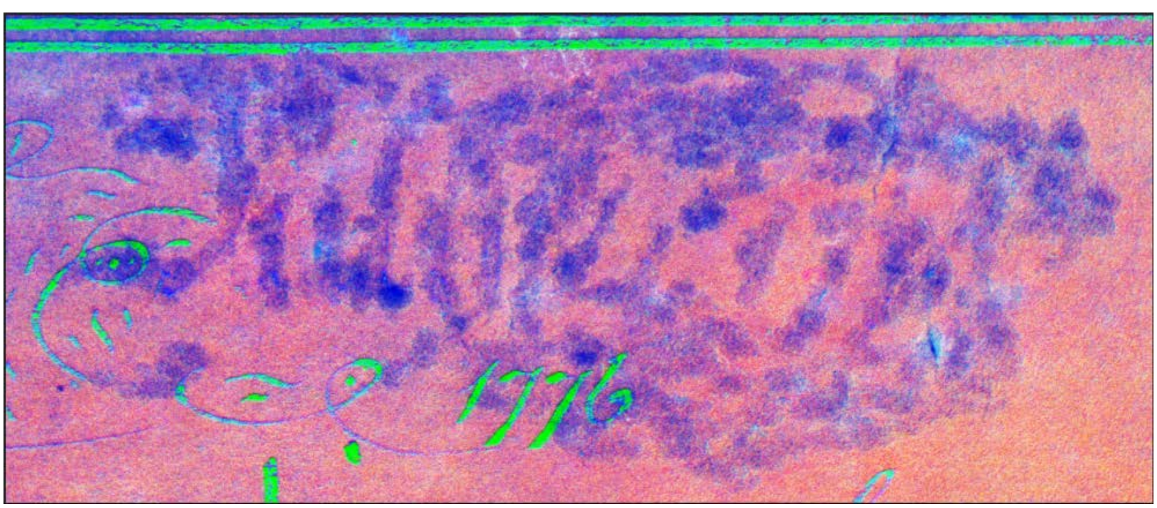
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