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Putting the World in Its "Proper Colour": Exploring Hand-Coloring in Early Modern Maps

STEPHANIE ELIZABETH STILLO
Department of History, Washington and Lee University, Lexington, Virginia, USA

This article explores the utility of X-Ray Florescence (XRF) in identifying pigments used in early modern hand-colored prints. Published accounts of the use of XRF on hand-colored documents are rare. As a consequence, historians and conservators know little about the pigments used in hand-colored prints, information that is not only vital for the preservation of extant colored documents, but also essential for helping historians periodize hand-coloring and assess its usage. In collaboration with the Preservation, Research, and Testing Division (PRTD) at the Library of Congress, this study compared early modern coloring manuals with XRF analysis of printed and hand-colored cartographic compilations from Amsterdam (Fredrik de Wit, Atlas*, c. 1688 printing) and London (Richard Blome,* Geographical Descriptions of the Four Parts of the World*, c. 1670 printing).The combination of textual and technological analysis resulted in a more nuanced understanding of the materials used in hand-coloring prints in early modern Europe. The study also exposed surprising actors in the history of the analyzed documents, highlighting the exciting potential of XRF to verify the historical authenticity of hand-coloring.*

KEYWORDS early modern cartography, early modern Europe, Fredrik de Wit, hand-coloring, pigments, Richard Blome, STEM research, X-ray florescence

Address correspondence to Stephanie Elizabeth Stillo, Department of History, Washington and Lee University, 204 West Washington St., Lexington, VA, 24450, USA. E-mail: stillos@wlu.edu

INTRODUCTION

The Rare Books and Special Collections Division of the Library of Congress holds a fully hand-colored copy of Dutch mapmaker Fredrik de Wit's late seventeenth-century compiled world atlas. The Library's copy of the de Wit compilation has a certain clumsy elegance. The hand-coloring throughout the bound atlas is often cumbersome, thick, and uneven. Colors careen into one another at political borders and coastlines, and the brilliance of the cartouches and decorative festoons are often lost on the interior continental features. Nonetheless, the color is faithful, never failing to illuminate relevant features—the hand of a committed, but perhaps not exceptionally skilled, colorist. The frontispiece features the Greek titan Atlas (Figure 1). Excepting a flowing red cloak, the colossus stands nude atop a green and yellow tinged globe, roped snug in the red lines showing the Tropics of Cancer and Capricorn. Flanked by a bright yellow sun and distant moon, Atlas performs his time-honored duty of upholding the heavens, represented in the de Wit frontispiece as a fierce tempest of pink and blue clouds within a celestial sea of bright yellow stars. The maps that follow take the viewer on an equally colorful journey through America, Africa, and Asia, with significant sojourns in Europe, the Mediterranean, and beyond (Figure 2).

Despite the atlas's inherent worth as extant evidence of popular cartography in the late seventeenth-century Golden Age of Printing in the Dutch Republic, important historical questions remain. Though printed in Amsterdam sometime during the late seventeenth century, the bound atlas (or variant pieces) fell into the hands of one Soranzo di Giaco who signed an initial flyleaf in 1722. The atlas emerged again in the mid twentieth century, when it was purchased by the Library of Congress. Sometime between the printing of the atlas in late seventeenth-century Amsterdam and its absorption into the Library of Congress' rare book collection, the printed pages of the compilation were colored. But where? And, by whom?

The question of authorship in hand-colored maps during the late seventeenth and eighteenth centuries is the principal preoccupation of this article. Excluding some successful attempts to print in color prior to the nineteenth century, most colored prints from the early modern period were printed in black-and-white and later hand-colored. However, verifying when, where, and by whom is a notoriously difficult task. Historians interested in the intersection of color and print remain rightly cautious of speaking in resolute terms. Even in early modern retail settings, where we know a remarkable amount about printing processes and patterns of demand, who exactly applied hand-color is difficult to determine. As the de Wit atlas suggests, printed materials often moved fluidly across political borders and oceans and bear the deteriorative scars of this transition through time and space. Determining the exact genealogy of printed documents is a herculean, if not sometimes utterly impossible, task.

FIGURE 1 Fredrik de Wit, *Frontispiece* (late seventeenth-century printing).

In addition to the challenges of provenance and authorship, the colored prints that have survived the long journey from early modern collections to modern cultural heritage institutions are visually deceiving. Pigments in colored prints fade or erode over time, challenging our interpretation of the function of color in any particular document. These chemical processes, often occurring over centuries, also damage the prints themselves. Somewhat ironically, the most historically popular pigments are the most vicious

FIGURE 2 Ferdrik de Wit, *America* (late seventeenth-century printing).

offenders. Copper-based pigments such as verdigris and azurite not only discolor over time but deteriorate the cellulose in paper, resulting in brittle, discolored versions of original compositions. The danger posed to the archive by early modern colored prints makes understanding the pigments used in extant colored documents essential.

The challenges posed by hand-coloring often lead historians and conservators back to the same fundamental questions: who applied color to printed materials? And, does the composition of applied color—both chemical and artistic—reveal anything about the way Europeans interacted with prints in the early modern period?

This article will focus on framing the hand-coloring phenomena in a way that suggests new actors in the landscape of early modern hand-coloring in print. It will also discuss a promising digital tool for assessing authorship and periodization in hand-color. This research emerged out of collaboration between myself (a historian) and scientists in the Preservation, Research, and Testing Division (PRTD) at the Library of Congress in 2012–2013. Sponsored by a grant from the Council on Library and Information Resources (CLIR), this fellowship was part of a new initiative supported by the Andrew W. Mellon Foundation to encourage collaboration between Humanities scholars and Science, Technology, Engineering, and Mathematics (STEM) experts (in our case, preservation scientists) in a project that utilized the Library's PRTD labs. The PRTD labs support preservation efforts throughout the Library, including environmental monitoring of sensitive documents and objects, 3D imaging, and corrosive media studies. My collaboration with PRTD focused on interpreting data from X-Ray Florescence (XRF) on pigments used in early modern European printed cartographic compilations from Amsterdam (Fredrik de Wit, *Atlas*, c. 1688 printing) and London (Richard Blome, *Geographical Descriptions of the Four Parts of the World*, c. 1670 printing).

XRF's noninvasive, nondestructive approach to analyzing the elemental composition of pigments has made the technology a standard practice for appraising artwork, ranging from colored pottery to paintings, in many cultural heritage institutions around the globe.[1] Unfortunately, results from XRF analysis rarely make it into archival catalogs or historical research, a fact evidenced by the conspicuous lack of technological studies in scholarly bibliographies outside of art history. Subsequently, historians remain alarmingly silent on the technology that could potentially revolutionize the archives of colored documents.

With a few notable exceptions, published accounts of the use of XRF on early modern colored prints are rare. Consequently, historians and conservators know little about the pigments used in early modern prints, information that is not only essential to the material security of extant colored documents, but also essential for helping historians periodize hand-coloring and its variant usages. The organization and layout of this article reflects what was often a surprising process of discovery into early modern hand-coloring. The intended goal of this study was to employ XRF analysis to identify pigments used in printed hand-colored maps and compare those results with early modern textual instructions for hand-coloring prints. Through this comparison we hoped to determine authorial faithfulness to coloring instructions and determine whether the use of different types of pigments (i.e., organic vs. inorganic) could broaden our understanding of coloring techniques and authorship in early modern colored prints. However, our project was often commandeered by unexpected, though unquestionably relevant, results. For example, though we were able to positively identify pigments in both Frederick de Wit's atlas and Richard Blome's *Geographical Descriptions*, the former clearly indicated the presence of twentieth-century color intervention. Additionally, while XRF results gave us invaluable data about inorganic pigments used in printed maps, we were unable to satisfactorily explore the various organic pigments used in both works. In spite of these varied results, the project was able to ask new questions about hand-coloring prints in early modern Europe, refreshing a topic that is too often ignored, or necessarily circumvented, in historical studies on print resources.

HAND-COLORING MAPS IN EARLY MODERN EUROPE: A HISTORY AND ACCOUNTING

Hand-Coloring of Maps

In the wake of Atlantic exploration and circumnavigation of the globe in the late fifteenth and sixteenth centuries, Europeans began realizing a world notably different from medieval geographies. The ancient Biblical conception of the O-T map in Isidore of Seville's *Etymologiae* (c. 600–625) slowly gave way to medieval scholars' application of Claudius Ptolemy's ancient, yet revolutionary, geometric grid of longitude and latitude. Additionally, the rise of the printing press in the mid-fifteenth century began the slow circulation of maps and travel narratives which visually and textually described distant lands as worlds filled with unknown wonder and delight. German cartographer Sebastian Münster's *Cosmographia* (1544) used allegorical maps and illustrated stories to populate geographies unknown to most Europeans with wonders borrowed from ancient legend (Figure 3) (Landau and Parshall

FIGURE 3 Sebastian Münster filled his printed maps and descriptions with fantastical creatures such as monopods, conjoined twins, and a blemmye (headless creatures Roman authors believed to inhabit remote regions of North Africa). Note the cyclops featured in this sixteenth-century rendering of coastal Africa (c. 1554).

1994, 244). Bursting with woodcuts of cyclops, conjoined twins, and the occasional sea monster, Münster presented a world that closely resembled the previous grand narratives of Marco Polo's *Livre des Merveilles du Monde* (c. 1300). By the close of the sixteenth century, printed atlases presented Europeans with new geographic data revealed through extensive global exploration. Abraham Ortelius, map illuminator (*afsetter*, or map colorists) and book publisher by trade, spoke directly to the European desire for more (or, more specifically, user-friendly) cartographic materials in his *Theatrum Orbis Terrarum* (1570).[2] Ortelius assured subscribers that his atlas would allow them to study, as well as display, their knowledge of world geography at home:

> Large charts cannot be opened and inspected easily because of their size. For to speak the truth, those large geographic maps and charts that are folded or rolled up are not ... easy to inspect. And whoever wants to hang them on a wall will not only need a very large house, but even a king's gallery or a theatre. Since I have often experienced this, I began to wonder whether it is possible to redress these inconveniences or possibly remove them altogether. And finally, it seemed that this might be accomplished by what we have done in this book of ours, which I earnestly wish that every student will include among his books. (Broecke 2011, 16)

By the late seventeenth and eighteenth centuries, expansive printed cartographic series by Dutch, French, and English cartographers dominated European markets. Whereas Münster had relied on sea monsters and cyclops, commercial cartographers of the seventeenth and eighteenth centuries enticed viewers with the wonder of geographic variation (Figure 4). In addition to outlining geographic and political borders, accompanying cartouches and perimeter designs of cities, peoples, costumes, and "strange" flora and fauna, provided allegorical (and widely essentialized) narratives about different regions of the world while simultaneously popularizing the four-part continental structure of Europe, Asia, Africa, and America (George 1969, 56–85).[3]

The craft tradition of coloring maps moved relatively fluidly through these stylistic and technological innovations in continental Europe. From the vibrant colored woodblocks of the fifteenth and sixteenth century, and the eventual ascendency of copperplate engraving during the same period, to the haunting chiaroscuro prints of the seventeenth century, color maintained a close connection with the phenomena of print (Thrower 2007; Ehrensvärd 1987; Landau and Parshall 1994; Skelton 1966, 70–75; Brown 1949). Although the quality and quantity of color changed significantly over time, cartographers and print retailers often used hand-coloring to supplement information provided in the printed image. Whereas color applied to printed maps of the

FIGURE 4 Willem Janszoon Blaeu used cities and regional costumes as perimeter designs in his *Africæ nova* (c. 1660).

fifteenth and sixteenth centuries ranged in opacity, the austere and translucent quality of watercolors became the preferred method for applying colors to prints (often termed "washing") in the late seventeenth and eighteenth centuries (Ehrensvärd 1987, 134).

What is less discussed by scholars is the way craft knowledge about hand-coloring slowly disseminated into European households throughout the early modern period.[4] Fueled by the consumer revolution of the urban middle class, as well as a late seventeenth- and eighteenth-century impulse to observe, classify, and compare foreign geographies, popular "how to" manuals on hand-coloring maps at home circulated in several countries throughout western Europe. Interestingly, the increase in manuals that advocated domestic coloring coincided with a notable conservatism in the use of color in cartographic prints by retailers. Some historians go so far as to argue that color dropped out of favor with the advent of the printing press. This theory suggests that printers and cartographic retailers viewed color as a hindrance to observing the crisp black lines of copperplate engraving and thus kept color to a minimum (Dackerman 2002, 13). John Harthan succinctly dismissed the use of color as early as the fifteenth century, noting "With the invention of printing . . . colour largely vanished for the best part of four centuries" (Harthan 1997, 7). Maps supposedly paralleled this austerity, and color became a less essential part of cartographers' vocabulary (Skelton 1966, 19-20). It was not until the advent of chromolithography in the nineteenth century that the incorporation of color into prints and maps saw an appreciable upswing in popularity.

However, even if retailers and cartographers were restricting their use of excessive color or privileging lighter washes in retail settings, this theory is too simple to explain the high circulation of map coloring instructions or the increase in resources for educating the public on how to create pigments at home. Despite austerity in retail settings, domestic coloring manuals encouraged individuals to purchase uncolored printed maps to personally hand-color in order to save the purchaser from the inevitable mark-up of shop-coloring or hiring a professional illuminator.[5] Most early modern authors argued that pre-coloring was not only more expensive, but robbed the purchaser of the process of critical inquiry into geography and the opportunity to engage in a creative and educational pastime. Author Henry Peacham noted the usefulness of coloring in the *Art of Drawing* (1606), imploring young men and women "to exercise your Pen in Drawing and imitating Cards and Maps: as also your Pencil in washing and coloring small Tables of Countries and places, which at your leisure you may in one fortnight easily learn to do; for the practice of the hand doth speedily instruct the mind, and strongly confirm the memory beyond anything else" (Hardy 1970, 6). The popular art manual *Albret Dürer Revived* (1685) offered instructions on how to draw, trace, and color a range of birds, beasts, fowl, landscapes, and ships, as well as "several maps and pictures" (Jenner 1685, 24). Richard Blome's *Gentleman's Recreations* (1686) similarly argued that map coloring was a superior way to engage those with even the meanest capacities to the subject of geography, suggesting that the practice of coloring prints was as educational as the result was visually pleasing. "The practitioner may be able for their better illustration to put them into apt and fitting colors, as well for distinctions sake, as the delight of the beholder" (Blome 1686, 217). Other manuals suggested that because the practice of coloring maps was both entertaining and educational, the activity was uniquely suited to women and children. Seventeenth-century art manual *Academia Italica* (1666) explicitly encouraged women to color maps, stating that women could be as "ingenious as men" if they put their minds to drawing and coloring: "but I confess they [women] have not so many helps, therefore I could wish that they, as well as men, would use this book until they know how to get a better [understanding]" (Lillicrap 1666, 15). By the eighteenth century, the practice of map coloring was so common that in *Handmaid to the Arts* (first published in 1758), Robert Dossie noted that "the art of washing maps [is] of more general use; and requires no apology for holding a place in the work" (Dossie 1758, xiii). His later elaboration on the specifics of coloring printed maps indicated that the educational objective of the activity had not changed, noting that "...the intent of coloring them [maps] being to distinguish the visions of the maps with respect to countries, districts, &c." (329). Francisco Martinez' *Prontuario Artistico* (1788) similarly outlined the usefulness of drawing and coloring maps and prints for the education of Spanish children (*la juventud Española*), advocating youth to learn how to outline the four continents and their cartographic iconography in order to represent any map, object, subject, or idea in their studies at home (*delinear*, or *expresar algun* [sic] *mapa, objecto, asunto* [sic] *ó idéa*) (Martinez 1788, 106).

The enterprise of washing (or watercoloring) was commonly associated with "amateurs" during the seventeenth and eighteenth centuries. On the subject of washing maps, the author of *Excellency of Pen and Pencil* (1688) noted "If any ingenious spirt that delights in picture, and hath not time or opportunity to study to be a proficient in Paining in oyl or limning, I would advise him to practice this, which is very delightful and quickly attained" (Anon. 1688, 108). Popular late seventeenth- and eighteenth-century Dutch engraver William Goeree agreed, noting "one often sees that to paint prints is to corrupt prints, unless it is does not move a little closer to the Art of Painting, we have . . . added something here and there throughout [this manual] concerning the painting with watercolors" (Stijnman and Savage 2015, ix). The association between watercoloring and nonprofessional engagement with hand-coloring survived well into the eighteenth century. In Constant de Massoul's late eighteenth-century treatise on painting and composition, he noted "It is in Aquarel [sic], or Water Colours, that the greatest number of amateurs begin to study the effect of colours, and this style of painting is an introduction to all others" (Massoul 1797, 107).[6]

Hand-Coloring of Other Print Types

Color was also essential to areas of study that were outside of—though fundamentally adjacent to—the subject of cartography. For example, contemporaneous natural history illustrators made clear the singular utility of color in acquiring knowledge through printed images. Famed ornithology illustrator Eleazar Albin noted the necessity of colors in observing natural variation in his lavishly illustrated *Natural History of Birds* (1731–1738). Although Albin warned against those who attempt to "outdo" the colors of nature, he emphasized the extreme utility of coloring: "I need not put the Reader in mind how lifeless bare Descriptions only of Birds are, without the Representations of them in their proper Colours . . . therefore it is, that I have taken such Pain, to be so very exact in the most lively Representation of them in their beautiful Colours" (Albin 1738, preface). Mark Catesby's *Natural History of Carolina, Florida and the Bahama Islands* (1771) espoused a similar affinity for coloring natural history prints, stating that "illuminating Natural History is so particularly essential to the perfect understanding of it, that . . . ever a clearer Idea may be conceived from the Figure of Animals and Plants in their proper color, than from the most exact description without them" (Catesby 1771, vi–vii). In an early nineteenth-century revised edition of German geologist Abraham Gottlob Werner's *Von den äußerlichen Kennzeichen der Foßilien* (*On the External Character of Fossils*, 1774), translator (and horticulturalist) Patrick Syme spoke to the innovation of Werner's eighteenth-century classificatory color system for fossils, noting "it is singular, that a thing (color) so obviously useful, and in the description of objects of natural history and the arts, where color is an object indispensably necessary, should have been so long overlooked" (Werner and Syme 1814, 5).

Manuals that advocated for coloring natural history prints (often paired with map coloring) gave similar instructions for coloring at home. For example, in addition to instructions on map coloring, author William Salmon included a visual primer for drawing and coloring "exotic" animals in his comprehensive art manual *Polygraphice* (1675). Salmon argued the natural subjects of foreign lands were "not hard to be laid in colors," especially if one has "a living pattern before your eyes." However, if practitioners were relegated to the vague primer provided in the *Polygraphice*, it was best to be "well acquainted with their shape and action ... [and] show the landscape of the country natural to that beast" in order to add appropriate realism to the image (Salmon 1675, 29).

Map coloring similarly challenged owners of geography prints to add an additional layer of active observation by exploring geographic details, including: political borders, variations in flora and fauna, and differences in custom and dress.[7] An eighteenth-century treatise on the construction of maps and globes confirms the singular preoccupation with evocative imagery: "Tis in the geographer's power to make his MAP very entertaining to the Curious, and by delineating the Natives at their Sports or Devotion, their King in State; the various Fish, Beasts, Fowls, and the like, instead of other Flourishes, give us at one View, as in a Picture, both the Geography and History of a Country" (Green 1717, 155). Such cartographic imagery (often clumsily) grouped peoples, animals, and plant life within specific geographic locations; spaces that could be observed and cross-referenced with the provided coordinates or with geographically restricted views (Schmidt 2002, 347–369). Acting as a framework, the printed black lines worked in tandem with watercolors that highlighted, complimented, and shadowed, but never obscured, the printed lines. This allowed practitioners to explore "natural" differences represented in the cartouches, borders, and interior illustrations of cartographic prints. J. B. Smith's *The Art of Painting in Oyl* (1701) also included watercolor recipes which would evoke what he called the "true nature" of a cartographic scene. Smith challenged domestic colorists to clarify difference through color, noting that those "who delight in the knowledge of maps, whereby being colored, and several divisions distinguished one from the other by colors of different kinds, so give a better idea of the countries they describe, than they can possibly do uncolored" (Smith 1701, 88). To accomplish this, Smith outlined specific color mixtures for demarcating political boundaries, cities, and environmental features designed to aid in investigation during, and reflection after, the coloring process. For example, on the subject of political borders, Smith noted:

> take notice of the several divisions in a map which distinguish one kingdom from another, one country from another, which are known by certain lines, or rows of pricks, or points of several sizes and shapes agreeable to the divisions they are to denote. As for instance, Portugal is distinguished from Spain by a row or large points, or pricks, and the provinces of that kingdom, or shires, as we call them in England, are distinguished one from another by lines of lesser points or pricks. Now if you were to color the kingdom of Portugal do thus, first with a small camel hair pencil in a ducks quill, colour over all the hills with the large prick line that divides it from Spain with the tincture of myrrh very thin.

On coloring human subjects, Smith proceeds with similar attention to detail, stating as follows:

> ....[colour] the hair of men or women with tincture of myrrh, or if black, with half water half common ink, or with burnt Umber; the flesh of Women and boys with a very little of tincture of cochineal, in a large quantity of water, and garments either with thin green shadowed with thicker, and with the tincture of cochineal made thin with water, and shaded with the same colour thicker, and thin Bice, and shade.

Smith concluded his instructions with an encouraging note to aspiring practitioners of map coloring, stating that "if a man does spoil half a score maps in order to get the knack of colouring a map well . . . there's no man that is ingenious [that] will grumble at it" (Smith 1701, 96). As a guide, Smith encouraged domestic colorists to have pattern of a "good workman" to emulate. For this, Smith noted that the Dutch "are esteemed the best."

FROM COPPER GREEN TO CYANUS FLOWERS: INVESTIGATIVE RESULTS

It was with this complicated historical landscape in mind that we moved into the technological analysis of the pigments in Dutch map maker Fredrik de Wit's late seventeenth-century atlas (Figure 5). The series comprised a total of 28 double-paged maps bound in contemporary vellum, a range consistent with similar de Wit compilations from the period. One of the most active map sellers of the period, de Wit retailed everything from atlases to nautical charts for a range of patrons throughout Europe. Historian Marco Van Egmond notes de Wit's atlas compilations could be "subdivided into a small *Atlas*

FIGURE 5 Fredrik de Wit, *World Map* (late seventeenth-century printing).

with thirty to fifty maps, a somewhat larger *Atlas* with approximately 100 maps and a large *Atlas* or *Atlas maior* with 130 to 160" (Egmond 2009, 45). Additionally, all maps in the Library of Congress' version of the de Wit (1680) atlas were colored, ranging from light washes to opaque coatings. The atlas also contained marginalia by eighteenth-century Venetian bibliophile, Soranzo di Giaco, who signed an introductory flyleaf in 1722 and made several, largely inconsequential, notes on the map of America. Thus, the de Wit maps realized all the desired parameters for further analysis: (a) it was a popular, widely circulated cartographic rendering from our targeted time period, (b) the color appeared curiously inconsistent, and (c) its marginalia and subsequent absorption into the rare books collection at the Library of Congress suggested movement through time and space.

We began our technological identification of pigments in the de Wit atlas through the use of a technique called X-Ray Florescence (XRF) (Figure 6).[8] Due to its noninvasive, *in situ* chemical analysis, XRF is a well-established practice in many museums and conservation centers and is often involved in projects on pigment identification and historic preservation throughout the

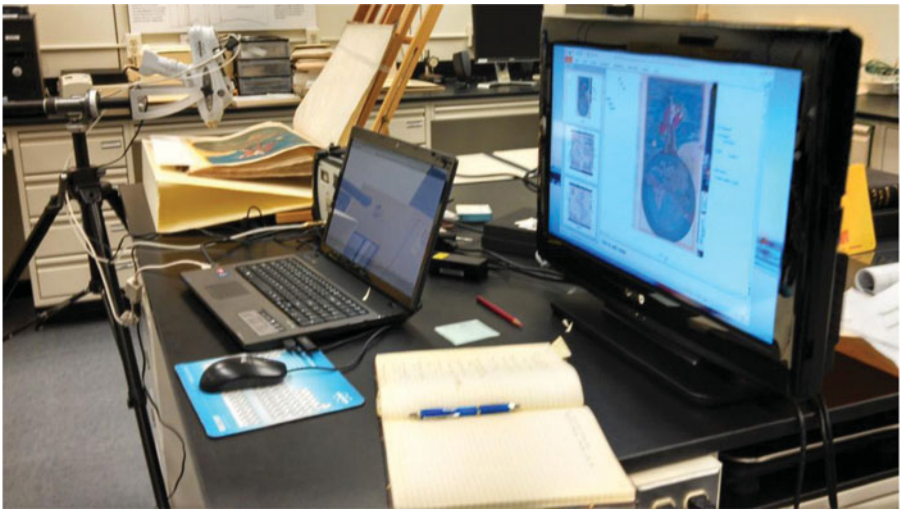

FIGURE 6 Preparing to take an XRF reading of de Wit's Frontispiece with a portable XRF in the Preservation, Research, and Testing Division (PRTD) Lab at the Library of Congress.

Library of Congress. Most fundamentally, an XRF machine is a spectrometer that evaluates chemical signatures in materials in any given substrate, in our case, paper. Once a target is established, an XRF machine sends an X-ray beam into the targeted area to "excite" the present electrons. The XRF detector then articulates the energy signature of that particular sample location. As elements have unique energy signatures, the energy that bounces back from the sample can be visualized as a spectrometric "peak" in attendant software, allowing for identification of the elements present in the sample.

Inorganic-Based Pigments Used in Hand-Coloring

Conclusive interpretation of pigments using XRF requires literacy in both chemistry and history. For example, vermillion (HgS), a historic pigment made with mercuric sulfide, will reveal signature peaks of mercury (Hg) and sulfur (S). However, cadmium red (CdS, CdSe), composed of cadmium sulfoselenide, will reveal peaks of cadmium (Cd) and sulfur (S), and often selenium (Se). The distinction between the two reds is important for the purpose of periodizing color. Vermillion (or cinnabar) has been in use since late antiquity, emerging in Europe in the early eighth century with the Islamic settlement in Iberia in 711. In contrast, cadmium red did not find its way onto European artists' palettes until around 1890 and was not widely used or distributed until well into the twentieth century. Further complicating the matter, early modern artists seldom used only one pigment in the process of hand-coloring, complicating XRF interpretation. The colors represented

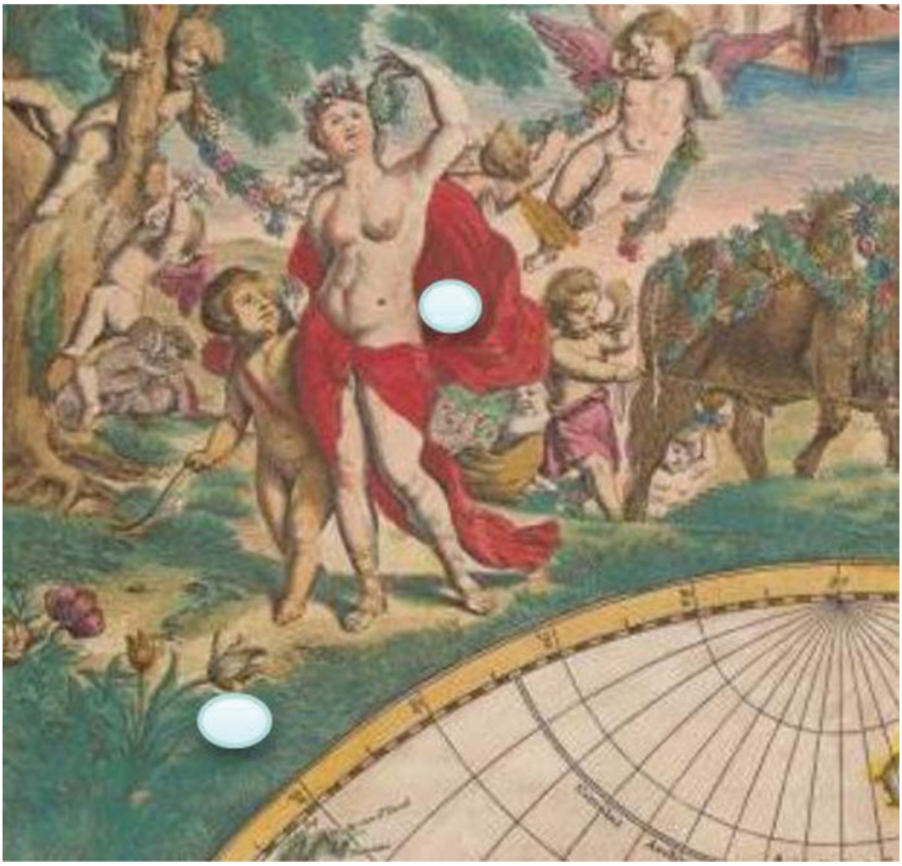

FIGURE 7 Red and blue-green XRF target points on de Wit's world map.

in most prints are mixtures, adjusted for desired hues or combined with cheaper pigments for frugality. One of the most common colors to extend was red. To maintain the hue of the more expensive pigment, early modern artists often mixed red lead into vermilion to mitigate the expense and to extend the color. An XRF sample reading for this common mixture will render peaks for both vermillion (HgS) and red lead (Pb_3O_4), as well as possible contamination from a touching color. Thus, a correct interpretation of a vermillion-red lead mixture relies on both a scientific background in chemistry, as well as a historic knowledge of artists' practices during a given time period.

XRF evaluation of targeted points within the frontispiece and six maps within the de Wit atlas revealed a wide range of period-appropriate inorganic pigments. For example, Figure 7 above shows two (out of twenty-four) pigment targets in de Wit's world map. First, there is the red drapery on the figure of a bare-chested woman with a floral crown. Then second, there is the blue-green flora immediately under her feet. Figure 8 below provides

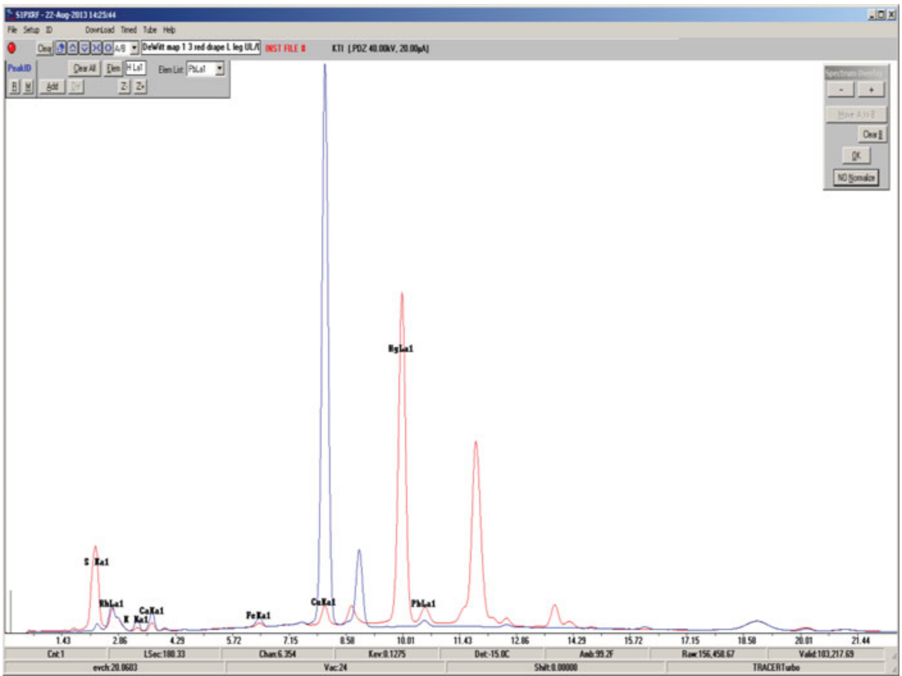

FIGURE 8 Compressed XRF results for the above red and blue-green target points. The red pigment (featured here as red peaks) reveals the presence of both mercury (Hg) and sulfur (S), as well as smaller peaks of lead (Pb). This reading is a strong indication that the colorists used a mixture of vermillion (HgS) and red lead (Pb3 O4). The blue-green pigments have a very high copper (Cu) peak, indicating the use of a common copper-based pigment such as copper green or azurite (blue bice).Though these two readings are consistent with pigments used in early modern Europe, analysis of reds and blues in other sections of the atlas revealed the use of modern pigments. Red samples in de Wit's map of America revealed traces of cadmium (Cd), an indication of Cadmium red lithophone, which was not in use until the early twentieth century. Additionally, the blue hues in the same map of America revealed the presence of tin (Sn), suggesting the use of cerulean blue, which was introduced only in the nineteenth century.

the XRF interpretation for these two points. The blue-green target read high levels of copper (Cu), suggesting the use of a copper-based pigment, likely copper green or azurite (often termed blue bice in manuals). However, the unique blue and green hue does not exclude the possibility that the artists used a mixture of copper green and an organic yellow, a conclusion that could not be reached with XRF readings alone. The red drape demonstrated high peaks in mercury (Hg) and sulfur (S), as well as minor peaks of lead (Pb), strongly suggesting the aforementioned common practice of mixing of vermillion with small amounts of red lead to extend color.

XRF analysis on several colored maps in Richard Blomes' seventeenth-century cartographic compilation *Geographical Descriptions of the Four Parts of the World* provided a contemporary comparison for the de Wit results.

Based on the work of well-known seventeenth-century French geographer Nicolas Sanson, *Geographical Descriptions* was sold by subscription only. The compilation rolled off London printing presses c. 1670 at the price of 30 shillings, unless a patron wished for enlarged prints or maps "illustrated in proper colours" (Clapp 1933, 373). With some notable exceptions, which will be discussed later, the inorganic pigments found in Blome's *Geographical Descriptions* suggested that the colorist maintained a similar palette to the de Wit compilation. XRF readings of fifteen color targets in Blome's world map revealed the presence of vermillion (HgS), red lead (Pb_3O_4), and azurite (blue bice or copper blue) ($2CuCo_3$, $Cu(OH)_2$).

The majority of the pigments identified in both the de Wit compilation and Blome's *Geographical Descriptions* remained faithful to seventeenth- and eighteenth-century instructions for hand-coloring maps. Instructions for hand-coloring, especially hand-coloring at home, included everything from how to best lay color on printed images to methods for procuring all necessary materials for coloring, including brushes, porringer or earthen pans, shells, and of course, pigments. Most manuals offered a rather predictable palette for watercoloring, including inorganic pigments such as red lead, vermillion, azurite (or ultramarine for the more wealthy practitioners, displaced by Prussian blue in the early eighteenth century), and a few organic lake pigments. J. B. Smith, the aforementioned author of the *Art of Painting in Oyl* (1801), anticipated a timid practitioner, a common theme in coloring manuals. Smith encouraged readers to familiarize themselves with dissolving pigments in gum water and how to formulate particular "tinctures" such as French Verdigris, Liquor of Myrrh, and Blue Bice in order to color "according to the nature of it [images in the map]" (Smith 1701, 107). Despite such specific instructions, the practice of procuring pigments remains a complex subject, as purveyors, supply lines, and manufacturing nodes changed over time.[9] As new pigments such as American indigo (seventeenth century) or Prussian blue (eighteenth century) entered European markets, pigments underwent fierce competition for prominence. By the late seventeenth and eighteenth centuries practitioners could, in theory, acquire pre- or unmixed colors in color shops or at a "druggist" (apothecary), or endeavor to make colors at home using both organic and inorganic materials. Evidence suggests that by the late seventeenth century shops selling color were already struggling to keep up with demand. The author of *Academia Italica* lamented that the popularity of the practice of coloring had exceeded the ability of retailers to provide appropriate materials, sometimes to the detriment of the print itself: "colouring prints, and maps, is of common use, and much practiced by the gentry and youths, who for want of knowledge therein, instead of making them better, quite fowl them . . . because they know not how to make several colours that are of greatest use in colouring of maps, and prints, nor can the colour shops fit them with them [proper pigments], for that they have them not, nor know how they should be made" (Lillicrap 1666, 15). Extant printed

FIGURE 9 De Wit, *Political Borders (Europe)* (1680). Although never repositioned, political borders were the most likely to have several competing colors.

catalogs also indicate the heightened demand for smaller quantities of pigments, presumably for novice practitioners. For example, *A Compendium of Colors* (1797) provided "hints for purchasing" colors at a local market, including a detailed pricelist which indicated that shops selling legitimately mixed[10] pigments should offer a choice of either an ounce of pigment for "cheap,"[11] an ounce already mixed with an appropriate binder for a higher price, or an entire bladder for triple the cost of cheapest metric.[12] This list included a host of inorganic pigments, such as blue bice, verdigris, carmine, verditer, and vermillion. The catalog also embraced a significant amount of organic pigments, including ocher, brazilwood, indigo, and Avignon berries (yellow or buckthorn berries) (Anon. 1797, 2–81 passim).

Despite some fidelity to early modern pigments, the de Wit compilation contained several unmistakable markers of modern color intervention. While analyzing the more discrete coloring techniques in the frontispiece and twenty-eight maps with a high-powered microscope, it became apparent that several maps within the compilation had an original color composed of very light washes but underwent a more recent "touch-up" (Figure 9 above and Figure 10 below) at some point in its history. Interestingly, the secondary color rarely attempted to radically alter the original color. Political borders were often layered with multiple opaque colors atop much lighter washes of the same or similar color. Also, the original pale (likely organic) yellow borders that framed the frontispiece and nearly all subsequent maps had been layered over with a much brighter yellow.

XRF readings of opaque yellow applied to borders, as well as various compasses and cartouches throughout the atlas, consistently revealed substantial peaks of chromium (Cr), indicating the presence of chrome yellow

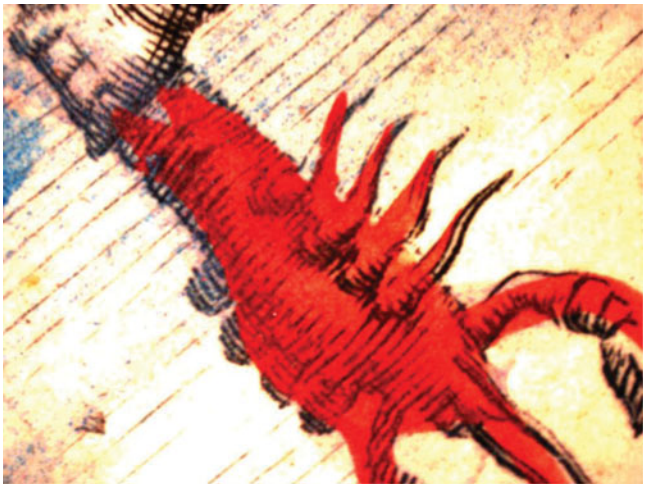

FIGURE 10 De Wit, *Lobster (World)* (1680). An original wash composed of light pink mixed with blue was here "touched up" with an opaque red. This was not the work of shading (which was often considered very important in coloring prints), rather a (likely much later) application of an additional layer of pigment.

($PbCrO_4$), a pigment that was not available in Europe or America until the latter part of the nineteenth century when mining outputs in France and the Shetland Islands encouraged its wider use (Figures 11, 12, and 13). Additionally, the frontispiece of the titan Atlas holding the celestial plane, as well as the maps of Europe and the Americas, demonstrated the presence of cadmium (Cd), sulfur (S), and selenium (Se), a positive match for cadmium

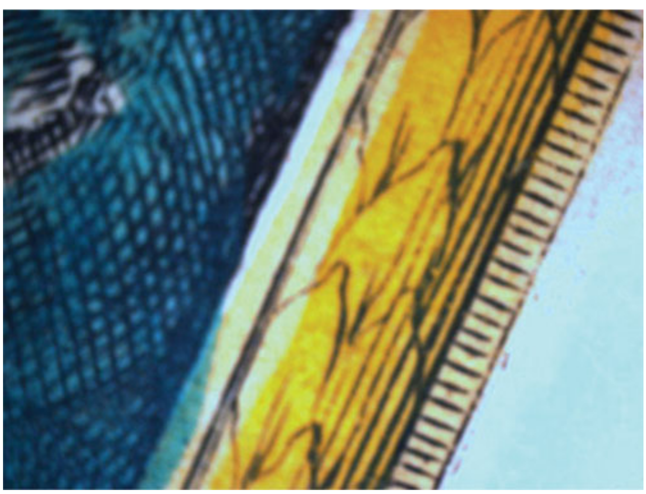

FIGURE 11 De Wit, *Decorative Yellow Borders (World)* (1680). Nearly all borders throughout the de Wit atlas received an additional layer of bright yellow pigment.

FIGURE 12 De Wit cartouche (India) (1680). Another example of the use of chrome yellow.

red (CdS, CdSe) which, as previously mentioned, was not in abundant circulation until the twentieth century. The blues present in both the frontispiece and the map of the Americas also indicated the presence of tin (Sn), suggesting the use of cerulean blue ($CoO\text{-}nSnO_2$), discovered by Andreas Höpfner in Germany only in 1805 and not circulated as an artists' pigment until the 1860s.

Perhaps the most intriguing component of the de Wit compilation, as well as with many other early modern colored prints, are the pigments which could not so easily be identified, in particular organic pigments. In the de Wit atlas, organic pigments were often detected in mixtures,[13] such as a light organic yellow mixed with copper blue or green to create softer hues. Sometimes the colorist used organic pigments without any inorganic mixtures. For example, the bright pink that illuminated gowns in several cartouches was a completely organic colorant. Unfortunately, XRF cannot definitively identify organic pigments without another layer of technological investigation such as Raman spectroscopy, which requires a physical sample of the pigment for identification. Despite current challenges to noninvasive identification, organic pigments in hand-coloring is the current frontier of both historical and technological analysis, and the potential of this research deserves at least minimal elaboration.

Organic Pigments and Their Uses

Extant textual evidence of coloring with organic distillations during the late seventeenth and eighteenth centuries is remarkable. The kaleidoscope of colors that can be extracted from (or by) organic materials such as honey,

FIGURE 13 Reference pigment samples used for verification of chrome yellow. Samples are part of ongoing studies on document preservation in the PRTD labs at the Library of Congress. Chrome yellow featured on the second-to-last line.

urine, and animal blood had been trade knowledge of medieval painters and dyers for centuries. Early modern coloring manuals that advocated for coloring at home attest to the survival of this craft tradition well into the eighteenth century. Authors encouraged domestic colorists to be curious and experimental in their quest for a complete color palette, which usually included some variation of seven fundamental colors: white, black, red, green, yellow, blue, and brown. An organic palette was not only more economical, but it was also considered safer. Inorganic pigments such as azurite can cause severe skin allergies, while vermillion, orpiment, and verdigris can be toxic if inhaled by a careless practitioner. Manuals sometimes offered words of warning to new practitioners. When explaining how to mix a "good Green of Verdigrises," for washing maps, the author of *Academia Italica* (1666) noted "let the cloth come over both nose and mouth, for this color and several others is unwholesome, and therefore keep them out of the body as much as you can" (Lillicrap 1666, 15). When similarly explaining

FIGURE 14 Buckthorn berries (also termed Avignon berries, yellow berries, or French berries). At different points of maturation, buckthorn berries provide a range of colors. Several seventeenth- and eighteenth-century authors encouraged their use, particularly for translucent green and yellow washes.

how to prepare verdigris, J. B. Smith suggested "to stop your nose, and hold a bunch of fine linen in your mouth to breathe through, else the subtle powder of the verdigris will be apt to offend" (Smith 1701, 98). Despite his endorsement of inorganic pigments for map coloring, Richard Blome also betrayed concern over their use, noting "I forbear to speak of verdigrises, orpiment, and several others, as being unnecessary, or dangerous, by reason of their unnatural quality" (Blome 1686, 217).

As an alternative, manuals offered organic solutions which altered or harnessed the extractive quality or natural color of everything from animal and human extracts to wild flora. These included aging sheep's blood for red, harnessing the acidity of vinegar or urine to extract various colors out of copper pots or dyed materials, or using a combination of manure and egg to create gold leaf. The most prized organic "tinctures" (often termed "natural colors") were those distilled from flowers, herbs, or roots. As their transparent consistency did not obscure the quality of the printed line, Richard Blome noted the usefulness of these pigments for prints in general, and maps in particular.

> There are yet omitted diverse other colours, such as saffron (which are very good to be used) besides some others, which are extractions from flowers, juice of herbs, or roots, which by reason of their cheapness are esteemed fitter for those that wash prints and maps . . . yet of these, or the like extractions, from flowers, herbs, though they be esteemed, of so small value, nevertheless they are exceedingly pleasant (if rightly

FIGURE 15 Common cyanus flower as described in *Arts Companion*.

> extracted). There are also colours which proceed from berries, as bay berries, French-Berries, that make a good yellow. Other colours that are made of woods, as Brazil, Log-wood, and the like, which make good reds. (Blome 1686, 217)[14]

Though Blome suggested that organic colors were “of lesser value,” medieval art manuals had long sung the praise of fruits and flowers in the coloring process. Ranging from ordinary buckthorn berries to “exotic” saffron harvested from the stamen of the crocus flower in the Middle East, flora had the capacity to either enrich or supplement a color palette if garnered at the proper point of maturation and saturated with the correct mordant (Eamon 1980, 204–205) (see Figure 14 on the previous page). For example, on the subject of translucent organic colors for washing printed maps, the author of *Excellency of Pen and Pencil* noted that yellow berries (buckthorn berries) steeped in alum water (aluminum potassium sulfate) overnight yielded a “fair yellow to wash.” The text goes on to describe how ground logwood steeped in beer and vinegar and set over a soft fire to boil will yield a transparent purple if mixed with alum powder to raise the color (Anon. 1688, 111–112).

Some authors challenged practitioners of watercoloring to use locally grown flowers to substitute for more expensive pigments. Supposedly borrowing from a (likely seventeenth-century) manuscript copy of Robert Boyle’s experiments on colors, the author of *Arts Companion* (1749) offered instructions on how to collect cyanus flowers for a "beautiful blue" that could rival ultramarine in watercoloring[15] (see Figure 15 above). In addition to its economy, the author emphasizes the unique availability of the cyanus flower, noting: "what I admire it for the most is, because the chief of the ingredients it is composed of, may be easily had during four of the summer months [roughly May through August] . . . [and] abounds in almost every cornfield; Children may gather it, without hurting anything" (Anon. 1749, 88–89). Noted as one of its many benefits, the blue color could be extracted immediately from the flower, requiring none of the drying or curing often essential for extracting colors from a flower's pedals or stamens. The extraction process for cyanus flowers was simple. Rubbing or pressing the flower while still fresh would extract the deep blue juice which, based on the author's supposedly three year experiment, would not fade. Adding alum to the blue juice in order to raise the color would create "a lasting transparent blue, of as bright as staining colour as you would desire; and in my Opinion . . . not inferior in beauty to ultramarine" (89). In his closing remarks on the subject of the spectacular blue yielded from the cyanus flower, the author opined: "How valuable are the many things we daily trample under foot" (90).

CONCLUSION

Despite unexpected results, my collaboration with preservation scientists in the PRTD labs at the Library of Congress demonstrates the potential of partnerships between the humanities and STEM fields. The project began with the goal of comparing the pigments used in early modern maps with hand-coloring suggestions in coloring manuals from the same time period. Only through collaboration did these questions become much larger, eventually leading to more profound inquiries into color authorship and historical authenticity in hand-colored prints. Even though identifying the chemical signatures that signaled modern color intervention in the de Wit atlas often demanded our full attention, the process of inquiry into its coloring layers revealed something much more profound. Our collaborative analysis unfolded the compilation's remarkable journey, one which bridged several continents and included multiple stewards.

This knowledge is essential not only for questions of authenticity and historic preservation, but for beginning to understand the (too often obscured) historical circumstances that have influenced the archive of hand-colored prints. The potential of XRF analysis is to close this gap in knowledge; to reveal layers of movement and intervention. Future studies using similar scientific inquiry will be necessarily collaborative. STEM experts are essential in providing requisite knowledge about subjects ranging from new technologies to processes of contamination, topics rarely addressed by humanities scholars. At the same time, historians must continue to critically analyze, periodize, and contextualize the texts which reveal the purpose of color in early modern era prints.

As we discovered, there is also exciting research on the horizon. Though XRF now allows scholars to cautiously identify inorganic pigments in hand-colored prints, noninvasive approaches to analyzing organic pigments will lead to similarly innovative research opportunities. When combined with XRF results, these studies will provide a more complete view of the way Europeans interacted with the world around them during the early modern period. This study has revealed that colorists used a range of inorganic pigments in map coloring. However, positively identifying organic coloring recipes, such as those outlined in *Arts Companion*, which encouraged colorists to scour local fields to find both new and common flora for water-coloring, would complement our knowledge of the way Europeans utilized their natural resources. This research also has the potential to reveal the way Europeans internalized the extraordinary amount of knowledge available in print. As practitioners of hand-coloring illuminated the green palm leaves of Africa's cartouches or colored the feathers on headdresses in the Americas, they (for better or worse) became armchair travelers in the wider world. Thus, as modern scholars and cultural heritage institutions work together to learn more about the use of color in prints, we are also uncovering the mechanisms for acquiring knowledge in and about early modern Europe.

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NOTES

1. The first portable XRF machine emerged in the 1980s and the use of XRF in museums has been steady since the early 2000s. Due to the efforts of preservationist and conservators, data on pigment composition has become a well-traversed subject for those interested in art history, as well as the intersection of art and science. These include lengthy studies in artists' pigments, including Feller et al. (1986–2007) and Eastaugh et al. (2004). The high-profile application of XRF on early modern prints is

less common, with some recent notable exceptions, such as (Primeau 2003, 49–80 and 271–278). For a more technical study, see Castro et al. (2008)

2. Abraham Ortelius' *Theatrum Orbis Terrarum* received wide acclaim throughout Europe. It is estimated that over 8,200 copies were sold of some 35 editions.

3. Also, for a very strong analysis of the emerging metageographical frameworks of the early modern period, see (Lewis and Wigen 1997).

4. Artisanal knowledge and the marketplace for leisure in the early modern period, particularly the prevailing assumption about where and how to acquire knowledge outside a university or apprenticeship is a subject which deserves far more attention. Historian Pamela Smith has argued that textual knowledge among European intellectuals was slowly supplanted by more active forms of knowledge acquisition as early as the sixteenth century. Popularized by figures such as Francis Bacon who argued for applied methods of empiricism, the emphasis on experimentation led to an increased prestige of those who labored with their hands (artisans) as opposed to those who relied solely on textual knowledge. In particular, European intellectuals began studying how artisans supposedly unlocked the mechanics and productive power of nature by manipulating natural processes such as metals and chemical compounds. Pamela Smith notes that "artisanal knowledge was tacit, no language that could convey experiential knowledge existed, and, while scholars were experts with words, texts, logic and disputation, they did not have much of an idea about how to approach the things and materials of nature, nor of how to go about doing and making." Contrasting traditional textual pursuits, artisanal knowledge relied heavily on didactic pictures and objects, a division which encouraged a more active engagement with the natural world. See (Smith 2008, 130).

5. The most comprehensive work on coloring manuals in England remains (Harley 1970). Though extremely thorough, Harley's analysis fails to incorporate works that fall outside of the scope of artists manuals, but still include coloring instructions, such as (Bate 1634).

6. De Massoul's work was most certainly unoriginal. It borrowed heavily from contemporary treatises without recognition. For more on this see (Lowengard 2006, 1–10).

7. Historian Benjamin Schmidt has rightly noted both the prominence of Dutch cartography during this period of educational geography. Schmidt argues that Dutch maps emphasized variety in world geography in order to appeal to a pan-European audience. This process created cartographic renderings of a world "not infrequently described as 'strange,' somewhat paradoxically as 'novel,' or more prosaically as 'marvelous.' It burst with social, cultural, and natural bric-a-brac." For this argument, see (Schmidt 2002, 357).

8. XRF results cannot offer definitive readings on organics pigments, thus XRF is often paired with other technologies for a more robust analysis of pigments. These include Ramen-spectroscopy, NMR (nuclear magnetic resonance) to assess impurities or anomalies in substrates, polarized light microscopy (PLM), and scanning electron microscopy (SEM). Though a combined approach is preferential, XRF is often the primary method of analysis due to its qualitative potential and non-destructive, noninvasive quality.

9. For more on this subject, see (Cannon, Kirby, and Nash 2010).

10. The high demand for pigments by the late seventeenth and eighteenth centuries meant that there was significant concern over the quality of pigments matching the retail price.

11. "Cheap" is here noted as a few shillings.

12. Full bladders were traditionally reserved for profession use.

13. As organic elements do not have the same type of signatures as inorganic pigments, an XRF result for a test point which contains only an organic pigment will have no peaks. This indicates the use of an organic pigment, but cannot render the information necessary for a full identification. If an organic pigment is used with an inorganic one, only the chemical signatures for the inorganic pigment will register. For example, buckthorn berries mixed with copper green to create a light green wash will only register a copper peak. Thus, several test points which contained unique (usually lighter) hues were likely a mixture of both organic and inorganic pigments. However, as mentioned above, there were several test points where the colorists used only the organic pigments for a lighter effect.

14. Blome's opinion on organic pigments the challenges of retailing the practice of coloring prints at home. This strategy included marketing not just instructions for coloring, but also the specific materials that would minimize expense and possible damage to a household. Professional painters and illuminators were taught in studios through apprenticeships, and they worked with large, bulky canvases. Working with pigments was also messy, and oil paints stain easily. Light washes (watercolors) composed of organic materials would, in theory, limit damage to a home interior.

15. These directions reside under the heading of "watercoloring instructions" for painting in miniature. The authors section on "illuminating prints" notes that "all the colours used to shade the whites [white paper prints] may be found in the following directions" (Anon. 1749, 73).

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