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ARTÍCULOS

A Technical Study of the 1531 *Huexotzinco Codex* Using Macroscopic Examination and Multimodal Imaging

Un estudio técnico del Códice de Huexotzinco *de 1531 mediante examen macroscópico e imágenes multimodales*

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Abstract
The paintings of the 1531 *Huexotzinco Codex* underwent a technical study to shed light on the manufacture and use of its materials by Indigenous artists. The non-invasive techniques of macroscopic examination and multimodal imaging allowed for an in-depth investigation of the paper supports and paints of the eight *Codex* paintings and elucidated the painting methodologies and material preferences of the Huexotzincan scribes. The study also provided insight into the possible standardization of artists' materials used in the production of Mesoamerican codices.
Keywords: *Huexotzinco Codex*, Mesoamerican codices, tribute lists, amate, maguey, pigments, microscopy, multimodal imaging

Resumen
Las pinturas del Códice de Huexotzinco *de 1531 se sometieron a un estudio técnico para arrojar luz sobre la fabricación y el uso de sus materiales por parte de artistas indígenas. Las técnicas no invasivas de examen macroscópico e imágenes multimodales permitieron una investigación profunda de los soportes de papel y las pinturas de los ocho cuadros del* Códice *y también mostraron las metodologías pictóricas y las preferencias materiales de los escribanos huexotzincas. El estudio también proporcionó información sobre la posible estandarización de los materiales de los artistas utilizados en la producción de códices de Mesoamérica.*

Palabras clave: Códice de Huexotzinco, *códices mesoamericanos,* matrícula de tributos, *amate, maguey, pigmentos, microscopía, imágenes multimodales*

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Introduction

The *Huexotzinco Codex* is one of the earliest pictorial manuscripts created by Indigenous artists in the decade after the fall of the Mexica (Aztecs) to the Spanish. Presented in the 1531 legal case that Hernán Cortés brought against three members of the First Audiencia of New Spain (present-day Mexico) (Library of Congress 1974, 49), it offers insight into the artistic practices employed by Indigenous scribes.

The *Huexotzinco Codex* consists of eight pictographic paintings on Indigenous papers and 79 sheets of European papers of testimony written in Spanish. Huexotzincan scribes created the paintings, whereas the written documents were produced by the Spanish trial clerk. In the trial, Cortés accused the members of the First Audiencia of demanding excessive tribute from the Huexotzincans when he was in Spain in 1529-1530. Since the Huexotzincans aided Cortés and the Spanish in overthrowing the Mexica, Huexotzinco, including its tribute, was considered Cortés' property (Noguez 1995, 99). The paintings document the types and amounts of tribute paid by the Huexotzincans to the three Audiencia members, particularly Nuño de Guzmán (Boone 1998, 179-181; 2000, 425; Cummins 1995, 58-59).[1]

The *Huexotzinco Codex* paintings function as a tribute list. Tribute lists produced in the pre-Hispanic eras documented taxes and tributes paid to the Mexica by conquered groups. In the colonial era, tribute lists were produced as historical accounts of tributes made to the Mexica, as depicted in the *Matrícula de Tributos* and the *Codex Mendoza* (Berdan 2014, 171), and also as contemporary accounts of taxes paid to the Spanish by Indigenous groups, as seen in the *Huexotzinco Codex* (Boone 1998, 179).

Until 1925, the *Huexotzinco Codex* was part of the private archive belonging to the descendants of Cortés, the Italian dukes of Monteleone, and was housed in the archives of the Hospital de Jesús Nazareno in Mexico City with other documents related to Cortés and his family. Sometime after 1925, a Monteleone descendant sold the manuscript to the United States book dealer A.S.W. Rosenbach, who then sold it to the philanthropist Edward Stephen Harkness. In 1928, Harkness donated the *Codex* to the

[1] For detailed descriptions of the legal case and the *Huexotzinco Codex* paintings, see Library of Congress (1974); Noguez (1995); Cummins (1995); and Boone (1998, 2000).

Library of Congress where it resides in the Manuscript Division's Harkness Collection (Library of Congress 1974, 50; Noguez 1995, 94).[2]

The content and imagery of the *Huexotzinco Codex* have long been the focus of historical and art historical interpretations. Conservators and conservation scientists, using various analytical tools, have also studied its materials. In the 1980s, Library of Congress Book Conservator Thomas Albro and Paper Conservator Sylvia Rodgers Albro performed the conservation treatment on the *Codex*. The treatment involved separating the paintings sewn within the bound documents, providing a cover for the bound documents, and repairing and individually matting the eight paintings. During the conservation treatment of the *Codex*, Sylvia Albro took pigment and fiber samples from the paintings. Using polarized light microscopy (PLM) she identified two different paper types, amate and maguey (Albro and Albro 1990, 66, 139; 1995, 105), cochineal (in the form of an alum-based lake pigment), carbon black, and the presence of diatoms (microscopic fossilized algae skeletons) in the yellow samples (personal communication).[3] Reexamining those pigment samples using PLM, Albro and Haude identified Maya blue in the late 1990s and Maya green in the early 2000s. The most recent analysis of the *Codex*'s colorants occurred in 2019 using x-ray fluorescence (XRF), fiber optic reflectance spectroscopy (FORS), portable Fourier-transform infrared spectroscopy, and microscopy where the presence of a cochineal lake, an iron-rich orange kaolinite containing iron hydroxides, a unique Maya blue formulation, and diatoms in the yellows were confirmed (Villafana, Haude, and Sartorius 2021).[4]

This article builds on those previous analytical campaigns with a technical study of the *Huexotzinco Codex* paintings using macroscopic examination and multimodal imaging. Scientific point analysis, such as XRF and FORS, provides chemical and elemental information on the micro-level. Macro analysis, such as visual examination by stereomicroscopy and multimodal imaging, enables viewing artifacts as a whole to discover important, non-analytical information. While analytical techniques may identify the

[2] For detailed information about the history, contents, and provenance of the *Huexotzinco Codex*, see Library of Congress (1974); Noguez (1995).

[3] For detailed information about the conservation treatment and analysis, see Albro and Albro (1990; 1995).

[4] For detailed information about the scientific analysis of the *Huexotzinco Codex*, see Villafana, Haude, and Sartorius (2021).

colorants used in a paint layer, macro examination provides insight into an artists' overall painting technique.

This article also contributes to past and present research performed by a diverse group of scholars, conservators, and scientists on Mesoamerican codices in collections in Mexico, Europe, the United Kingdom, and the United States. Recent scientific analysis has provided invaluable data on the materials used in the production of pre-Hispanic and colonial manuscripts. This analysis includes data obtained from the Borgia Group codices by an Italian team (Buti et al. 2018; Domenici et al. 2014; 2019; 2020), from the *Codex Borbonicus* by a group at the Muséum National d'Histoire Naturelle in Paris (Pottier et al. 2018; 2019), and from the *Codex Colombino* by a team at the Universidad Nacional Autónoma de México (Zetina et al. 2014), to name a few. As a technical study, this article relates to research on the maguey support of *Códice* Vol. 757-CA-AH from the Biblioteca Nacional de Antropología e Historia (BNAH) de México (Tirado and Chagoyán 2013), on the amate supports of fifteen codices from the BNAH collection (Vander Meeren 1995), and on the pigments and painting methodology used on the Beinecke Map at Yale University (Magaloni Kerpel 2012).

Methods

The paintings were visually examined, aided with a stereomicroscope. Macroscopic images of details from the paintings were taken with the stereomicroscope (Zeiss SteREO Discovery.V8 stereo zoom microscope, Zeiss AxioCam MRc5 digital camera, Zeiss AxioVision LE 4.8.1 software).

The eight *Codex* paintings, recto and verso, were imaged in broad bands across the ultraviolet (UV) to visible (VIS) to infrared (IR) spectrum. The subsequent images were processed using Adobe Photoshop. The imaging and post-processing methods are detailed in an internal manual describing the adaptation of these techniques for the Conservation Division at the Library of Congress (Digital Imaging Workflow for Treatment Documentation) and have been previously described in detail (Villafana and Edwards 2019). The manual is based on guides used by conservation professionals for the photographic documentation of cultural heritage (Warda et al. 2011; Dyer, Giovanni, and Cupitt 2013). Imaging modes with their respective filters and light sources are described in Table 1. Photography was conducted with a Nikon D700 camera, modified to remove its internal IRblocking filter, and a CoastalOpt UV-VIS-IR 60mm lens. False color modes are specific processing techniques that combine two images using RGB and grayscale channel substitution (also noted in Table 1).

Table 1
IMAGING MODALITIES INCLUDED IN THE STUDY

Mode	*Filter(s)*	*Transmittance (approximate)*	*Radiation/Light Source*
Visible-Reflected	PECA 916 PECA 918	400-750 nm 380-700 nm	North Light High-Intensity Discharge (HID) copy light (2)
Visible-Raking	PECA 916 PECA 918	400-750 nm 380-700 nm	North Light High-Intensity Discharge (HID) copy light (1)
Visible-Transmitted	PECA 916 PECA 918	400-750 nm 380-700 nm	NoUVIR Fiber Optic System with CLE Design Limited Fiber Optic Light Sheet
Infrared (IR)-Reflected	PECA 910	850-1000 nm	North Light High-Intensity Discharge (HID) copy light (2)
Near-Ultraviolet (UVA)-Reflected	PECA 900 X-Nite BP1	250-400 nm 300-650nm	UV Systems Triple Bright II LW370 (2)
	Photographs Used		*Channel Substitutions*
IR-Reflected False Color	Visible + IR-Reflected		G to B; R to G; IRR to R
UVA-Reflected False Color	Visible + UVA-Reflected		G to R; B to G; UVR to B

Source: the authors

MATERIALS

Paper

One aspect that makes the *Huexotzinco Codex* especially unique is that its eight pictographic paintings were executed on two different paper substrates, amate (*amatl*) from the inner bark of fig trees (Figures 1, 4, 6, and 7) and maguey (*metl*) from the inner fibers of agave plants (Figures 2, 3, 5 and 8). While several manuscripts on amate from the pre-Hispanic and colonial eras have survived, only eight Mesoamerican codices have been identified on maguey, including the *Huexotzinco Codex* (Tirado and Chagoyán 2013, 10). The existence of two paper types in equal amounts within the *Huexotzinco Codex* presented a unique opportunity to investigate the production of Indigenous Mesoamerican papers.

In the pre-Hispanic eras, amate was the preferred paper of the Mexica who demanded large quantities as tribute from other Indigenous communities they conquered. Pre-Hispanic papermaking villages were scattered across Mesoamerica, and the trees from which amate was made grew in both warm and cool climates, and on various terrain including riverbeds, mountainsides, rocky soil, and valleys (Von Hagen 1977, 37, 71-73). Besides being a tribute product, amate was also available for purchase in the markets (Díaz del Castillo 1963, 206). In addition to being a painting support for Mesoamerican manuscripts, amate had various uses, including as offerings to the gods and adornments of priests' garments during ceremonies (Binnqüist, Quintanar-Isaías, and Vander Meeren 2012, 139).

Maguey, on the other hand, seems to have been used only in Puebla and Tlaxcala for making codices in the sixteenth century, although its origin is thought to be pre-Hispanic (Tirado and Chagoyán 2013, 11). That so few manuscripts on maguey exist is likely due to its region-specific use, destruction at the hands of Spanish clerics, and loss from deterioration. Baltazar Brito Guadarrama, Director of the Biblioteca Nacional de Antropología e Historia of Mexico, said that maguey papers were produced only in Tlaxcala and parts of Puebla because the trees needed for the production of amate did not grow there (personal communication 2021). Since the Tlaxcalans and Huexotzincans were often enemies of the Mexica, it is possible that they produced maguey for use in their own codices (Tirado and Chagoyán 2013, 17; Villafana, Haude, and Sartorius 2021, 12).

Amate was made from the inner bark of trees from the *Ficus* and *Morus* genera of the *Moraceae* family (Lenz 1961, 153-154; Vander Meeren 1997, 71-72). Detailed descriptions of the amate papermaking process include a historical account by the sixteenth-century naturalist Francisco Hernández and recent publications by paper conservator Marie Vander Meeren of the Instituto Nacional de Antropología e Historia of Mexico (INAH). First, limbs were cut from the trees and immersed in rivers or streams to facilitate the removal of the inner bark from the outer bark. The inner bark was again placed in rivers or streams to clean and soften the fibers (Hernández 1942, 249-250; Vander Meeren 1997, 72). The fibers were then laid on a wooden board and beaten with a striated stone.

Maguey was made from the inner fibers of agave plants (Lenz 1961, 154; Tirado and Chagoyán 2013, 11). Various historical sources mention the use of maguey for paper, including the sixteenth-century missionary Fray Toribio de Benavente (Motolinía), the sixteenth-century naturalist Francisco Hernández, and the eighteenth-century historian chevalier Lorenzo Boturini who offered the most detailed description of the production process (Lenz 1961, 70-72; Von Hagen 1977, 42-43). Conservator Carolusa González Tirado and Botanist Gabriela Cruz Chagoyán of INAH offer invaluable insights into possible production methods of this support based on historical accounts and their examination of the BNAH *Códice* Vol. 757-CA-AH. To gain access to the fibers, the leaves of the agave plant were crushed, pounded, or cooked. This enabled the fibers to be separated from the flesh with a basalt scraper, without cutting them. Once removed, a sheet was made by pounding the fibers (Tirado and Chagoyán 2013, 11). Tirado and Chagoyán note that maguey papers have a smooth, almost glossy surface, and offer two possibilities for this: the fibers were pounded only with a smooth stone, or the fibers were first pounded with a striated stone and then burnished with a smooth stone to flatten, or erase, the striated texture (Tirado and Chagoyán 2013, 12). Presumably, maguey papers were made similarly to amate papers by pounding the fibers on top of a wooden board.

The eight *Huexotzinco Codex* paintings are on individual flat sheets of paper, in keeping with the format commonly used for tribute records (Berdan 2014, 252). At first glance, the paper supports of all eight paintings appear similar with regard to size, color, surface characteristics, and method of manufacture. Interestingly the sheets are close in size, and include larger sheets and smaller sheets, referred to as full and half respectively. There are two full and two half amate sheets, and one full and three half maguey sheets. What distinguishes the half sheets is that they all have one straight, cut edge, suggesting they were trimmed from larger sheets. In addition, they are roughly half the dimensions of the larger sheets. All of the edges of the full sheets, on the other hand, are uneven. The full amate sheets are nearly square whereas the maguey sheets are rectangular. One area of difference between the two paper types is their relative thickness. The average thickness of the amate papers is 0.37 mm and the maguey papers is 0.44

mm.[5] In addition, the maguey sheets are more uniform in their thickness compared to the amate sheets. The specifics of the papers for each painting are detailed in Table 2.

Table 2
DIMENSIONS AND THICKNESSES OF THE EIGHT *HUEXOTZINCO CODEX* PAINTINGS

Painting	*Paper Type*	*Height and Width*	*Full or Half*	*Thickness*
I	amate	45 cm × 46.2 cm	full sheet	0.37 mm
II	maguey	26.9 cm × 41.8 cm	half sheet	0.47 mm
III	maguey	52 cm × 20.3 cm	half sheet	0.42 mm
IV	amate	23 cm × 44.5 cm	half sheet	0.29 mm
V	maguey	41.5 cm × 52.7 cm	full sheet	0.43 mm
VI	amate	43.2 cm × 43.4 cm	full sheet	0.38 mm
VII	amate	46.4 cm × 25.2 cm	half sheet	0.45 mm
VIII	maguey	26.7 cm × 40 cm	half sheet	0.43 mm

Source: the authors

Maguey and amate papers were both made by flattening softened plant fibers into sheets with various tools. At first glance, the amate and maguey substrates of the *Huexotzinco Codex* look the same, and evidence of a similar manufacturing process is visible on both paper types, including the presence of parallel, striated marks made by the pounding stones (Figure 9) and well-defined outer edges made by folding the supports onto themselves (Figure 10). Close examination, however, revealed distinct differences in tone, surface characteristics, and fiber distribution of the two substrates.

[5] Thickness measurements were taken in six random areas on the edges of all eight paintings using a Mitutoyo Quick Mini Digital Thickness Gage. The measurements were taken in blank spots on the papers of single thickness only, thus avoiding painted areas and folded edges of double thickness. The thickness of each painting was obtained from the average of the six measurements. The average thickness of the amate and maguey papers was then obtained from the thickness measurements of the four amate sheets and the four maguey sheets.

The amate supports (Paintings I, IV, VI and VII) are light tan in color and relatively thin. The fiber distribution throughout the sheets is not uniform which gives the amate papers a lacy appearance and contributes to their overall limpness. The maguey supports (Paintings II, III, V, and VIII) are off-white in color and moderately thick. The fiber distribution is dense making the sheets opaque and rigid, especially compared to the amate sheets. The transmitted light images in Figure 9 show the thin, lacy quality of the amate compared to the denseness of the maguey.

Detailed views of the two paper types using the stereomicroscope are shown in Figure 11. Both the amate and maguey are slightly yellow in color, but the maguey appears brighter and shinier. The amate fibers look like a web of intersecting fibers oriented in different directions, with thin, hollow areas readily visible. The maguey fibers, on the other hand, appear dense and matted together.

While the surface texture of the amate sheets appears similar on both sides, raking light shows smooth areas on the rectos but not the versos. These smooth areas may indicate that one side of the sheet was burnished with a smooth stone (Figure 12). Visually the maguey papers appear smooth on their rectos, but textured on their versos with visible marks from the pounding stones. This supports the second hypothesis by Tirado and Chagoyán (2013) where the fibers were first flattened with a striated stone and then burnished, at least on one side, with a smooth stone. Raking light images of maguey show long parallel fibers on the rectos and striated pounding marks on the versos (Figure 12). The long parallel fibers shown in raking light match the description by Tirado and Chagoyán (2013, 12) of the parallel orientation of the fibers in the paper supports as having the same orientation of the fibers inside the leaves of agave plants.

Across all eight *Huexotzinco Codex* paintings, the way in which the paints interact with the surface of the amate and maguey papers is similar, and the painted edges are defined and show no evidence of feathering or blurring. This is surprising given that the amate sheets are thinner and rougher in texture than the maguey sheets. There are areas, however, where the paints penetrated through to the versos on all four amate and one of the maguey sheets. The paints that penetrated the supports include black, purple, gray, and red in some instances (Figure 13). The cause of the penetration is likely due to dilution of the paints in order to achieve a specific visual appearance.

Colorants

Recent analysis revealed a consistent paint palette across the *Codex* paintings, even though they were executed on two different substrates. The palette consists of black, gray, purple, red, orange, yellow, green, and blue from the identified colorants carbon black, cochineal, orange kaolinite, Maya green, and Maya blue (Villafana, Haude, and Sartorius 2021). Unfortunately, there is scant information about the production and distribution of pigments. Historical sources mention that pigments came in the form of cakes, or tortillas (Sahagún 1981, bk. 11: 239) and were available for sale or trade in the markets (Cortés 1843, 113; Díaz de Castillo 1963, 206).

The colorants on the *Codex* paintings are vibrant. Since the paintings were protected from light-induced damage by being sewn between the documents in the bound manuscript, it is possible that the vividness of the colors has not changed significantly since the paintings were made. The black, blue, green, orange, and yellow paints appear mostly opaque whereas the red, gray, and purple areas appear as transparent washes.

Under magnification using the stereomicroscope, all of the colorants have a similar granularity, appearing somewhat coarse. Most of them have inclusions of other particles and clear crystals that are slightly larger in size. Given that the colorants are coarsely ground, the presence of inclusions is not surprising. While the granularity of all the pigments is similar, the orange appears slightly coarser and the red slightly finer.

To the naked eye, the red looks like it was applied as a wash; however, examination with the stereomicroscope revealed that it was originally applied as a thick, opaque layer. In many red-painted areas, the paint has been abraded leaving only the stained red fibers, especially strong in Painting IV where the red paint penetrated to the verso (Figure 13). As cochineal is a dye, its application to the paper supports readily stains the paper fibers. The cochineal seems more delicate than the other colorants because it has more areas of loss due to abrasion and it offsets, or rubs off, more readily onto adjacent areas of the sheet, especially on Painting VII. The orange, yellow, green, and blue paints are opaque, and completely cover the amate and maguey fibers. In areas of abrasion and loss, the color is still visible, however, the fibers do not appear stained as is the case in the red areas.

As previously mentioned, the color palette is consistent across the paintings. However, close examination revealed the use of two different green hues and two or three yellow hues. The green on Painting V is blue-green in color whereas the green on Painting III is yellow-green (Figure 14). Recent scientific analysis revealed no distinct difference in the greens on these two paintings, as both are comprised of Maya blue and an unidentified yellow colorant (Villafana, Haude, and Sartorius 2021, 11). Differing proportions of blue and yellow in the admixtures of the two greens likely resulted in the different hues. The yellows on Painting III are different, as confirmed by analysis that showed the yellow of the Rabbit glyphs contains cochineal and the yellow of the Flower glyphs does not (Villafana, Haude, and Sartorius, 2021, 10-11). In the stereomicroscope images, the Rabbit glyph yellow appears more orange than the bright yellow of the Flower glyph (Figure 14), which is consistent with the analytical findings of red cochineal mixed with the yellow colorant. Across Painting V the various yellows appear the same, and somewhat more muted in color than the yellows from Painting III (Figure 14).

Multimodal imaging shows how the colorants of the *Huexotzinco Codex* paintings respond in different spectral modes, as seen in the details of Painting III (Figure 15). In the infrared-reflected (IRR) image, the colorants do not absorb near-infrared radiation (either transparent or reflecting), which is typical of organic colorants (and is consistent with the previous findings). The only colorant on the paintings that does absorb near-infrared radiation is the orange, identified as inorganic orange kaolinite (not shown here). The ultraviolet-reflected (UVR) image shows that the colorants respond to ultraviolet radiation in different ways. While they respond differently in UVR, the even quality of the clay component of the blue, green, and yellow colorants is apparent compared to the mottled red lake. The presence of clay components in the blue, green, and yellow colorants was identified in the previous study (Villafana, Haude, and Sartorius, 2021, 8-11). The infrared false color (IRRFC) and ultraviolet false color (UVRFC) modes further reveal differences seen in IRR and UVR. For instance, in IRRFC the pink areas show paints that contain blue colorants. In UVRFC, the blue colorants remain blue, the yellow colorants appear pink, and thus the green colorants appear purple. The red colorant appears yellow in IRRFC and dark blue in UVRFC.

Multimodal imaging can also aid in revealing what is beneath areas covered by opaque paint, such as Painting V where the black underdrawing in some of the feathers becomes apparent in IRR (Figure 16).

Inks

All eight paintings have inscriptions in Spanish on their versos and Painting VI has an inscription on its recto.[6] The Spanish court scribe Alonso Valverde penned his rubric and the number of the paintings in brown ink (Figure 17) to mark the order as they were presented as evidence at the trial (Noguez 1995, 103; Library of Congress 1974, 51). The versos of Paintings I and VIII have longer, more descriptive inscriptions written in gray ink (Figure 17), presumably penned by Valverde as well (Noguez 1995, 103). Multimodal imaging aided in distinguishing the brown inscriptions as iron-gall ink and the gray inscriptions as a carbon-based ink. In Figure 17, the brown inscriptions do not absorb near-infrared radiation in IRR and appear red in IRRFC, which is typical of iron-gall ink, while the gray inscriptions do absorb near-infrared radiation as expected of carbon-based inks (Havermans, Abdul Aziz, and Scholten 2003, 89-90).

Painting methodology

Macroscopic examination provided immediate insight into the painting methodology of the *Codex* paintings. First, an opaque, slightly shiny black paint was applied to the paper substrates, delineating the design on all eight paintings. Colored paints were then applied inside the black frame lines on seven of the eight paintings. Painting VI is the only painting that lacks color and thus contains only black-delineated imagery. There are exceptions where the black lines were painted over areas of color. In Painting IV, which is painted only in black and red, the black frame lines were applied on top of the red lines in the vertical flag glyphs (Figure 18). Other instances of black lines applied on top of other colors include the green-painted areas of the quetzal feathers in Painting V and the multicolored maize granary in Painting VII (Figure 18).

To create different colors, the scribes mixed paints before applying them to the papers and also superimposed colors on top of each other. It appears that the green and some of the purple paints were made by mixing two different colors (blue and yellow, black and red respectively) before being

[6] For transcriptions of the inscriptions on the versos of the *Huexotzinco Codex* paintings, see Library of Congress (1974); Noguez (1995).

applied to the amate and maguey supports. A few of the purple-painted areas clearly show superimposition of red over black. Looking at the pictographs of the bags of chia seeds, the way in which they were painted varies between paintings in both execution and color, as well as within a single painting (Figure 19). The chia bags in Painting I are painted with a purple wash that is an admixture of red and gray. The chia bags in Painting II are painted with a gray wash, lacking red entirely. While in Painting VIII, two of the bags are painted with an admixture of red and gray and one bag is painted with a superimposition of red over gray. Similarly, some of the adobe bricks in Paintings I, II, and VIII are painted with a stand-alone gray wash, a purple wash from an admixture of red and gray, and with a superimposition of a red wash over a gray wash. These differences in painting the chia bags and the adobe bricks may be an indication of individual preferences and techniques employed by the various scribes, or intentional uses of color. In addition, it is possible that multiple scribes contributed to a single painting given the variation of techniques within Painting VIII.

Discussion

As a group, the eight *Huexotzinco Codex* paintings give the impression that they were made at the same time by several scribes working together in a workshop. Aspects of the paintings that point to a workshop setting include the different artistic hands across as well as within individual paintings, the uniformity of the paint palette across the paintings, the types of paper, and the size of the sheets.

The *Huexotzinco Codex* paintings appear to conform to a Nahua Indigenous artistic convention with regard to the painting technique and the use of a primarily organic paint palette. There are exceptions, as previously mentioned. The use of the orange kaolinite pigment is certainly an exception. Given that its texture has a granularity similar to the other colorants, it is likely that the orange pigment was an Indigenous product and not a Spanish import. While the reason for the use of this one inorganic pigment is unknown, it is present on five of the eight paintings and was used to paint a variety of objects, including ceramic vessels (some containing liquidambar), wooden beams, turkey eggs, elongated stones, and the walls of a maize granary (Noguez 1995, 103-117). Similarly, on the *Matrícula de Tributos* and the *Codex Mendoza*, ceramic vessels, wooden beams and planks, and food storage bins were painted orange. Perhaps the use of orange to paint these specific objects on tribute lists was a pre-Hispanic scribal convention that continued into the sixteenth century, and that the orange kaolinite pigment was what the Huexotzincan artists had on hand.

Another interesting finding from the technical study is the presence of different green and yellow hues. These differences may have resulted from artistic preferences or even separate paint palettes of the individual scribes. However, the imagery on which the different hues appear may point to intentional uses of color. For instance, quetzal feathers, highly esteemed in Mesoamerica (Noguez 1995, 110; Magaloni Kerpel 2014, 21), appear on Painting V as individual feathers and as a green band in the frame around the image of Mary and Jesus. It is possible that a specific green hue, in this case a blue-green one, was deemed necessary to convey both the significance of quetzal feathers as a precious article of tribute and as a luxury artist material used to adorn the Madonna and Child. Similarly on Painting III, the cochineal-derived red was possibly added to the yellow paint for the Rabbit glyphs to set them apart from the Flower and Reed glyphs painted with yellow, especially since the Rabbit had "underworld cosmological concepts" associated with it (Noguez 1995, 107).

The use of maguey as a paper support in the *Codex* is puzzling, especially since amate was the preferred paper of the Mexica. As codices on maguey papers are rare, it is unknown if they were available in the markets like amate papers and pigments. The use of maguey in the *Codex* may have been intentional and was possibly supplied by a particular scribe. On the other hand, if the supply chain for amate was broken in the colonial era, as suggested by Barbara Mundy (personal communication 2021), the use of maguey was likely necessary for the completion of the paintings. Interestingly the two most colorful and heavily pigmented paintings, III and V, are on maguey papers. While this might have been accidental, the thick maguey paper with its smooth surface was likely more satisfying to paint upon than the thin, slightly rougher amate. The thickness of the maguey likely provided a better support for heavily applied paint. In addition, the use of maguey for these two paintings may point to an artistic preference for a particular support on which to apply larger amounts of paint.

Despite the difference in surface textures of the amate and maguey papers, the paints did not blur or feather on either of them. One possible reason is that gypsum, identified in the amate sheets of Paintings I, IV, and VI (Villafana, Haude, and Sartorius 2021, 3) acted as a filler to prevent feathering of the paints. The gypsum in these sheets may have functioned similarly to gelatin-sized European papers by sealing the amate so that the water-based paints easily flowed on the surface when applied and dried with well-defined, non-blurred edges. The use of gypsum in the *Codex* may also point to a continuation of pre-contact Indigenous artistic conventions where codices of amate and animal skins were coated with a white preparatory layer of either calcium sulfate (gypsum and/or anhydrite) or calcium carbonate on which paints were applied. Calcium sulfate was identified on the *Codex Cospi* from central Mexico (Domenici et al. 2018, 133) and the *Codex Colombino* from southern Mexico (Zetina et al. 2014, 127), while calcium carbonate was found on the Mayan *Codex Madrid* (Buti et al. 2014, 171-172; Domenici et al. 2014, 102).

It is also possible that the surface of the paper was sealed by natural adhesives released during the pounding of amate fibers (Vander Meeren 1995, 5) that prevented the paints from feathering. As gypsum was not identified in the maguey papers, the density of the agave fibers and the smooth surface of the sheets likely inhibited the blurring of the paints.

Another aspect that contributed to a paper's readiness for painting was the physical preparation of its surface. As previously shown, both the amate and maguey papers in the *Huexotzinco Codex* have one side that is smoother than the other side. Burnishing the papers with smooth stones (Hernández 1942, 250; Von Hagen 1977, 36; Tirado and Chagoyán 2013, 12) flattened and polished the fibers to create a suitable painting surface. Interestingly, Von Hagen mentions that heated stones, or "flat-iron shaped planches" were used to polish the surface of amate "to create a non-blotting surface" (Von Hagen 1977, 64-65; Weidemann 1995, 712). Regardless of the method for burnishing the paper, it appears that the scribes in the Huexotzinco workshop preferred painting on the smoother side of the amate and maguey papers.

While this is a hypothesis based on a small group of paintings, the relative uniformity of pigments and papers of the *Huexotzinco Codex* may point toward a standardization of materials made and used by Indigenous artists. With regard to the pigments, the similarity of their texture, or granularity, may reflect a particular quality preferred by scribes for painting. The use of full and half sheets of similar dimensions, regardless of whether they were maguey or amate, may be an indication of standard sheet sizes for flat manuscripts, like tribute lists.

Conclusion

The technical study of the *Huexotzinco Codex* paintings offered valuable insights into the practices of Indigenous scribes, and also revealed that there is much still to discover. Looking at the paintings as they pertain to the locality of Huexotzinco highlighted the practices of the scribes from that region of Puebla. There is a relative uniformity of the materials used to make the paintings, which may be indicative of the artistic traditions of a group of scribes or a particular workshop. Viewing the paintings more broadly, however, may point toward a standardization in the production of pigments and papers used for codices.

The study of *Huexotzinco Codex* shows both the continuation of and certain deviations from the typical scribal traditions, such as the use of maguey. While codices on maguey are rare, it is likely that more exist than have been recorded to date. In fact, it is possible that some Mesoamerican manuscript supports identified as amate are actually maguey. The only way to determine if maguey was more widely used and if there was a standardization of materials used in the production of Mesoamerican manuscripts is to the perform more technical studies on extant pre-Hispanic and colonial Mesoamerican codices.

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Mary Elizabeth Haude es restauradora de papel en la Biblioteca del Congreso en Washington, D. C. Tiene una maestría en Bibliotecología y Ciencias de la Información con un certificado avanzado en Conservación de la Universidad de Texas en Austin. Su investigación se centra en los materiales utilizados en la producción de códices mesoamericanos del siglo xvi, con especial atención a los papeles y pigmentos elaborados por artesanos indígenas.

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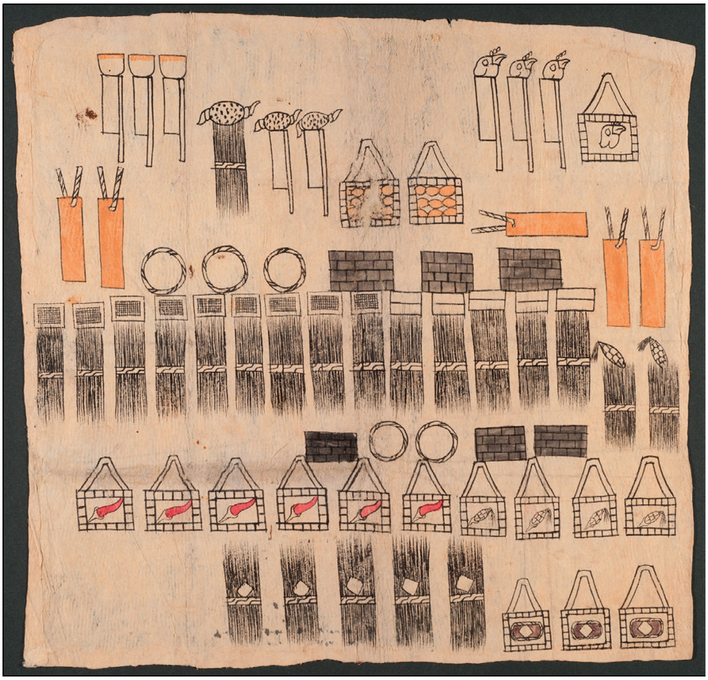

Figure 1. Painting I on amate. Harkness Collection, Manuscript Division, Library of Congress. Photography: Mary Elizabeth Haude

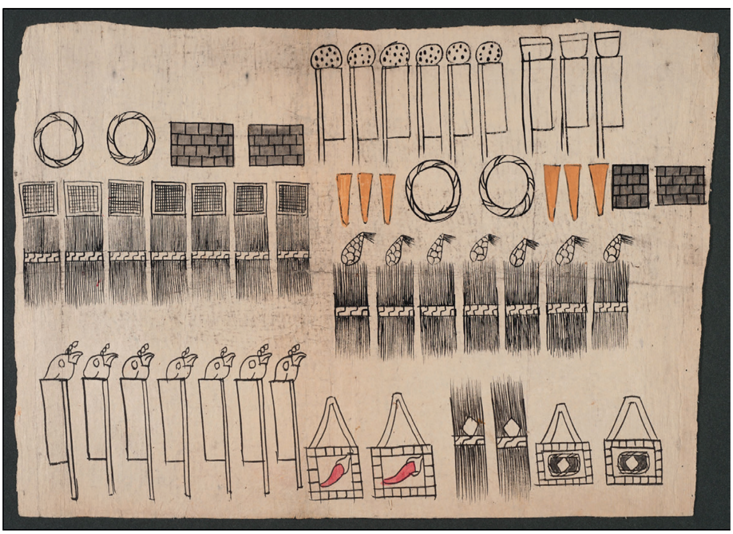

Figure 2. Painting II on maguey. Harkness Collection, Manuscript Division, Library of Congress. Photography: Mary Elizabeth Haude

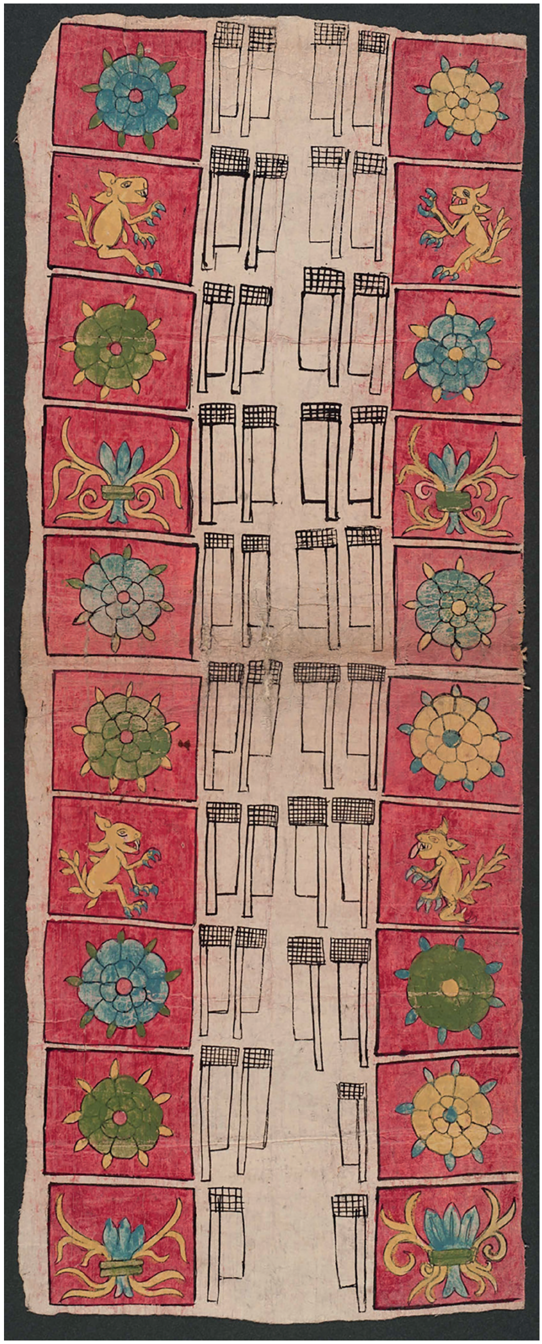

Figure 3. Painting III on maguey. Harkness Collection, Manuscript Division, Library of Congress. Photography: Mary Elizabeth Haude

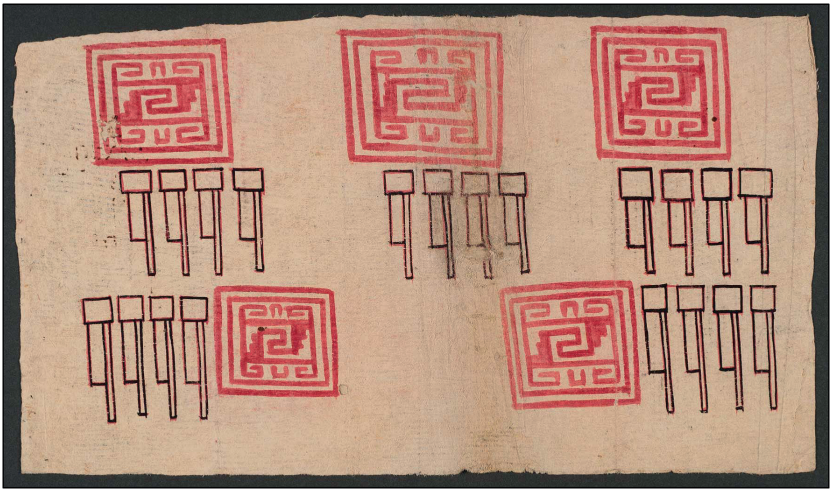

Figure 4. Painting IV on amate. Harkness Collection, Manuscript Division, Library of Congress. Photography: Mary Elizabeth Haude

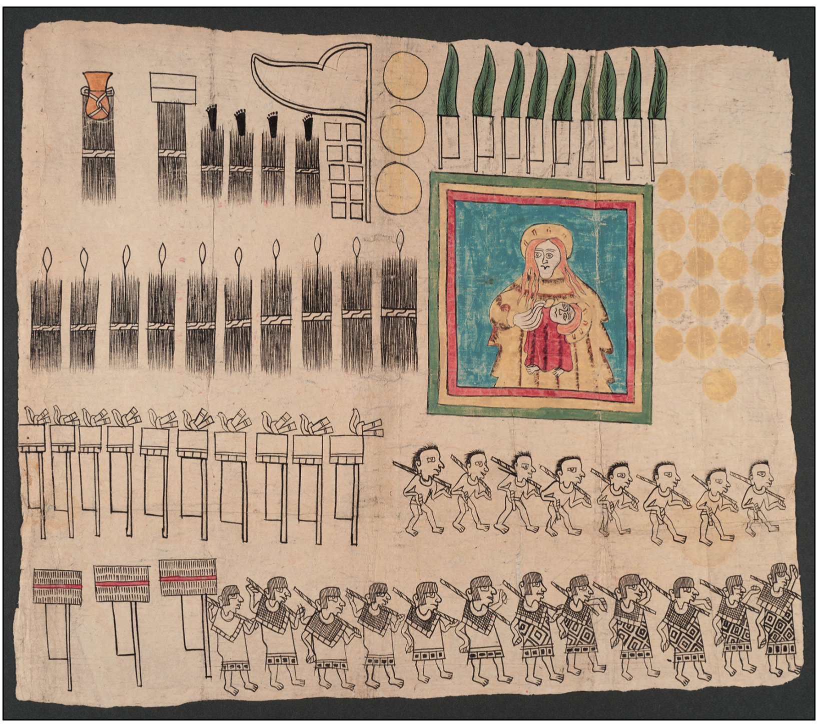

Figure 5. Painting V on maguey. Harkness Collection, Manuscript Division, Library of Congress. Photography: Mary Elizabeth Haude

Figure 6. Painting VI on amate. Harkness Collection, Manuscript Division, Library of Congress. Photography: Mary Elizabeth Haude

Figure 7. Painting VII on amate. Harkness Collection, Manuscript Division, Library of Congress. Photography: Mary Elizabeth Haude

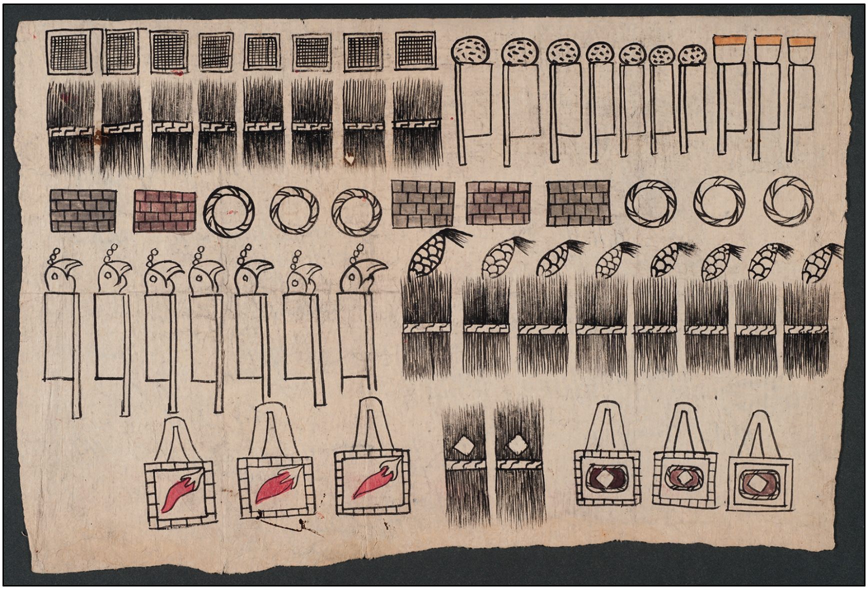

Figure 8. Painting VIII on maguey. Harkness Collection, Manuscript Division, Library of Congress. Photography: Mary Elizabeth Haude

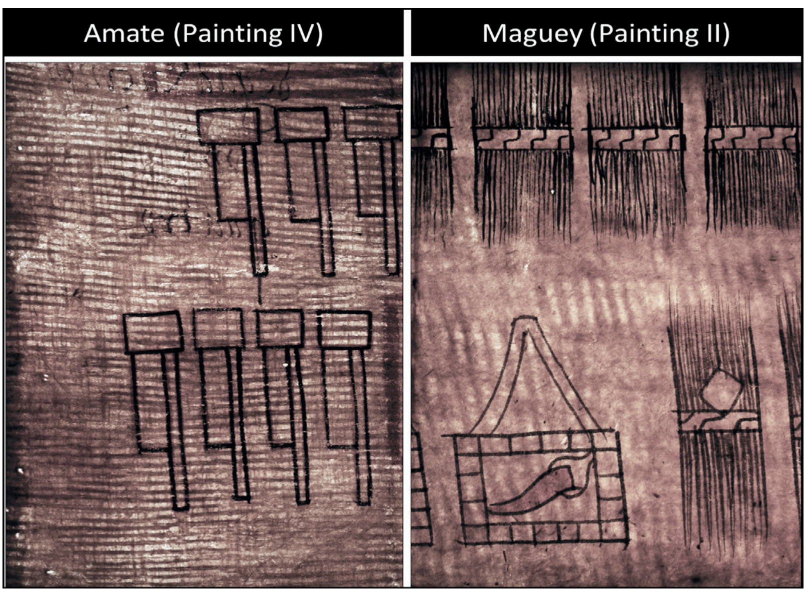

Figure 9. Details of transmitted light images showing the parallel marks made from the striated stones on amate (Painting IV) and maguey (Painting II). Photography: Mary Elizabeth Haude

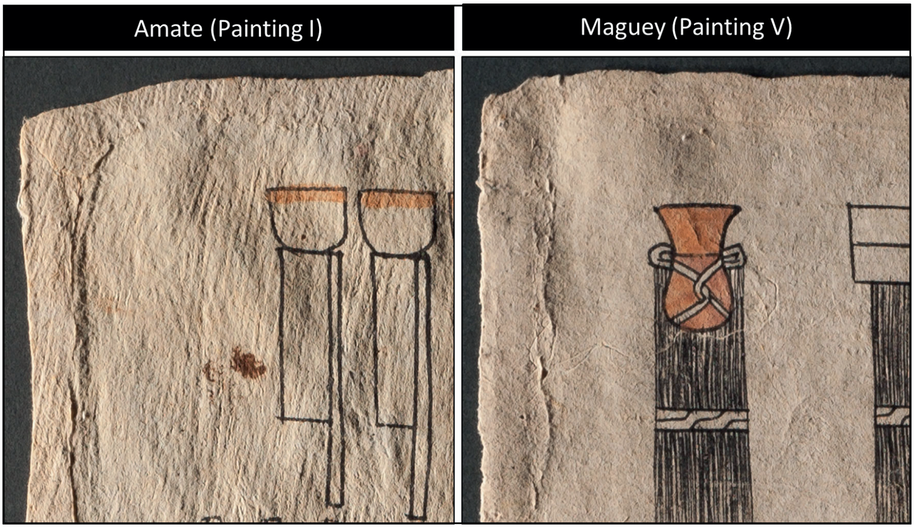

Figure 10. Details of raking light images showing the edges folded over onto the recto of the amate sheet of Painting I and the recto of the maguey sheet of Painting V. Photography: Mary Elizabeth Haude

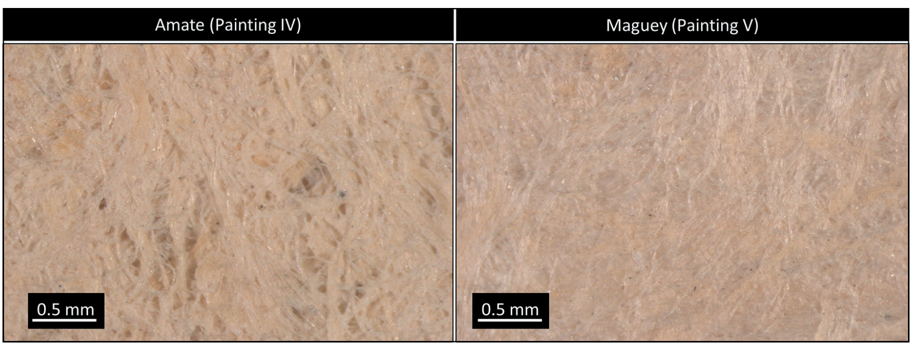

Figure 11. Details of stereomicroscope images of amate from Painting IV and maguey from Painting V. Photography: Mary Elizabeth Haude

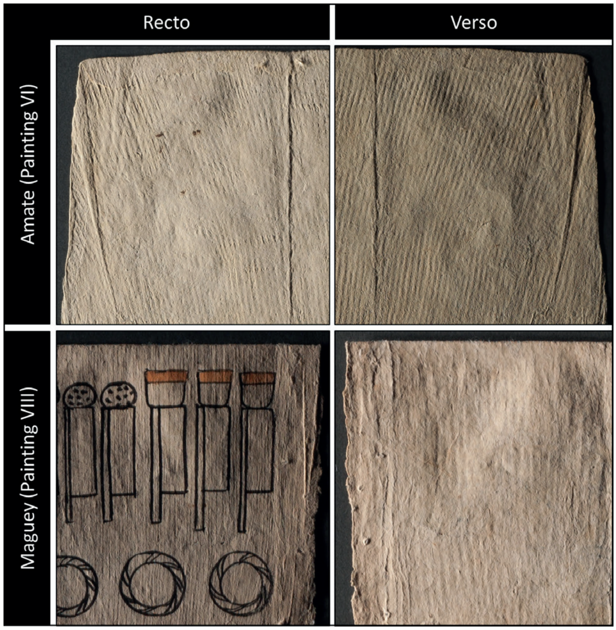

Figure 12. Details of raking light images showing the different surface textures of amate (Painting VI) and maguey (Painting VIII). Photography: Mary Elizabeth Haude

Figure 13. Details of visible-reflected images showing paints penetrating through the paper to the versos: black frame lines on Painting VI (amate), red on Painting IV (amate), gray wash on Painting I (amate), and purple wash on Painting VIII (maguey). Photography: Mary Elizabeth Haude

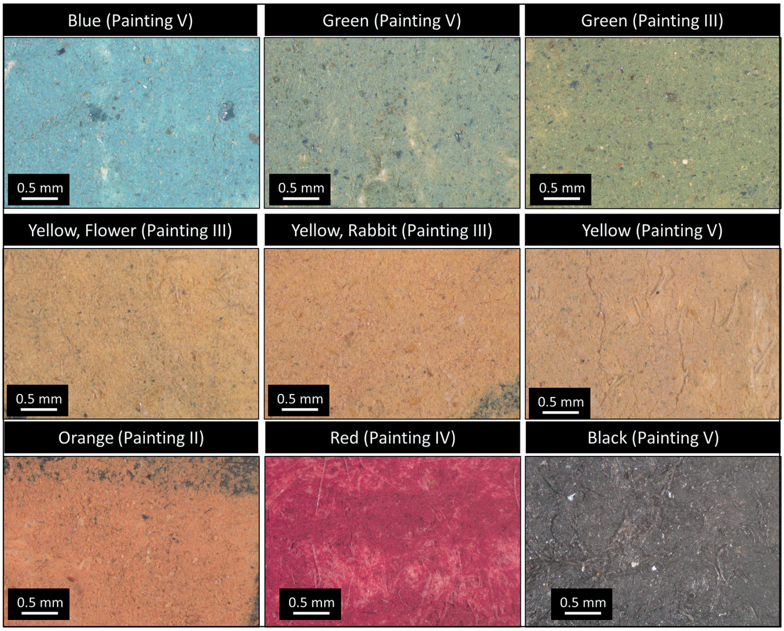

Figure 14. Details of stereomicroscope images of the colorants from Paintings II, III, IV, and V. Photography: Mary Elizabeth Haude

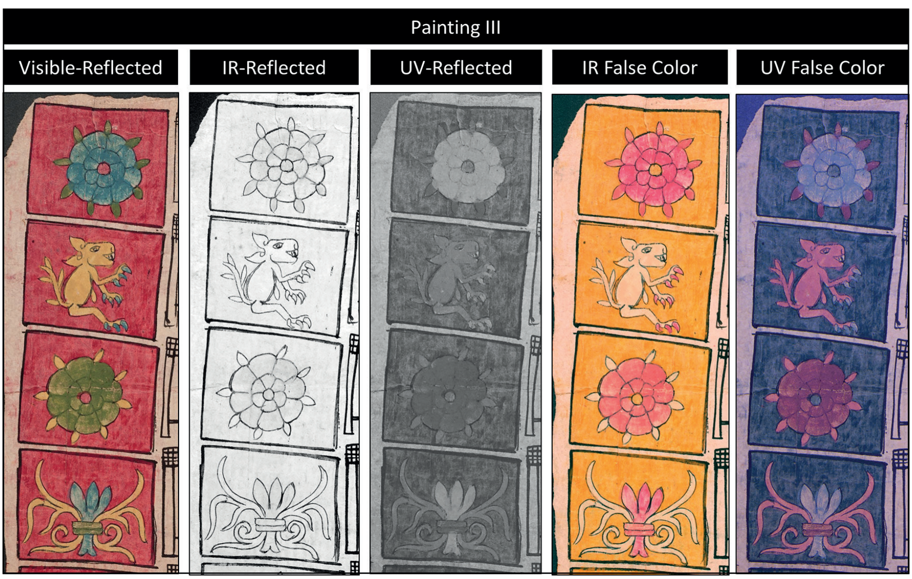

Figure 15. Details of Painting III showing the responses of the colorants in different spectral modes. Photography: Mary Elizabeth Haude

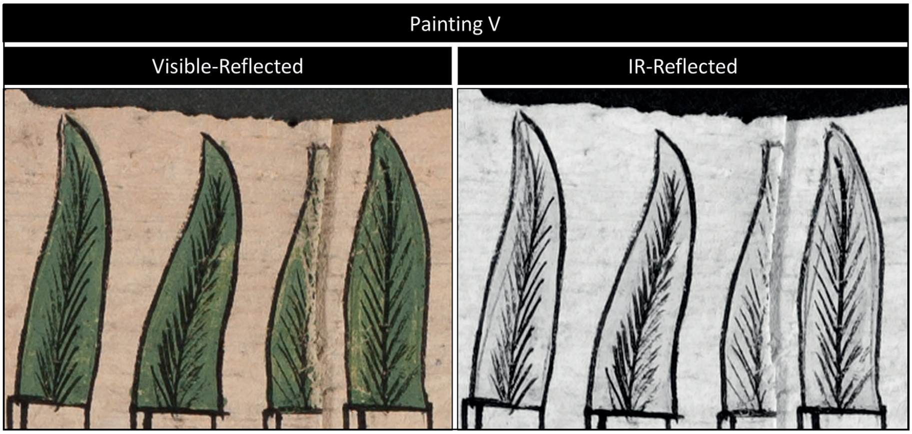

Figure 16. Detail of Painting V showing how the underdrawing in the left-most and right-most quetzal feathers, covered by the green paint in the visible-reflected image, is revealed in the infrared-reflected image. Photography: Mary Elizabeth Haude.

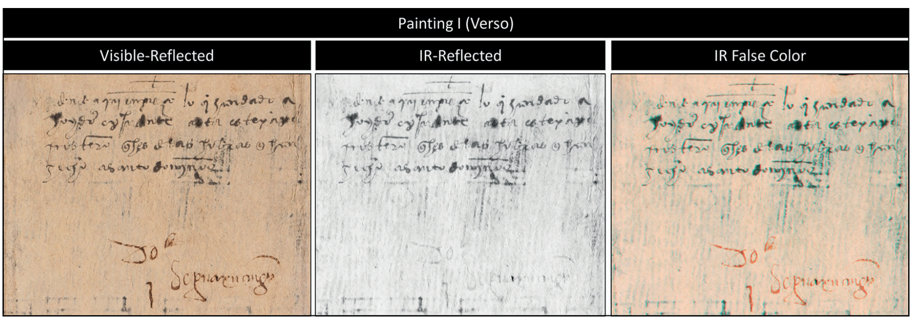

Figure 17. Details of the verso of Painting I showing how the brown iron-gall ink inscription at the bottom and the gray carbon-based ink inscription at the top appear differently in the infrared-reflected and infrared false color images. Photography: Mary Elizabeth Haude

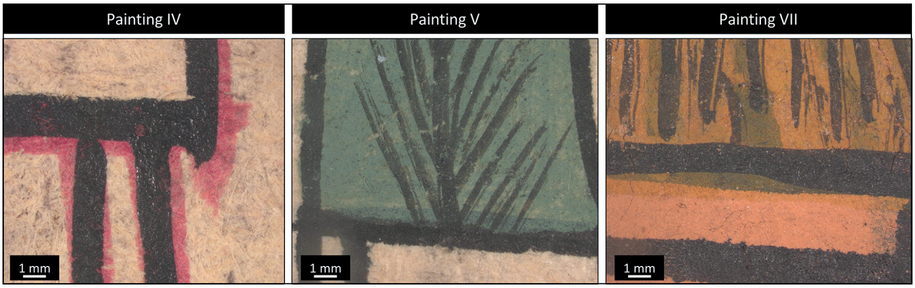

Figure 18. Details of stereomicroscope images of black frame lines painted on top of other colors. Photography: Mary Elizabeth Haude

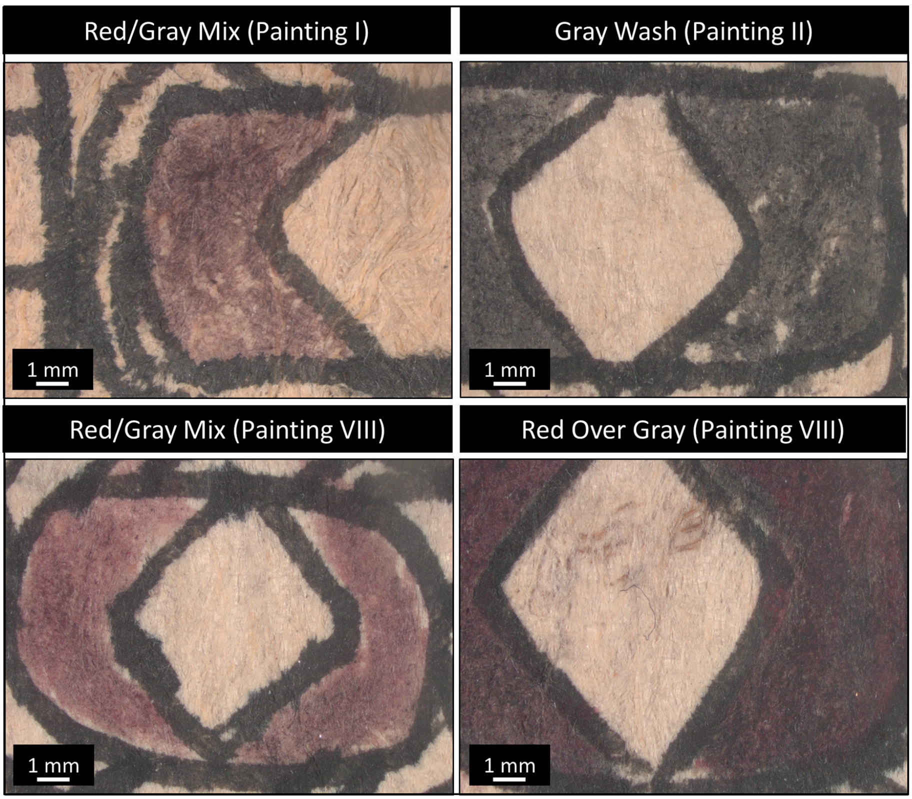

Figure 19. Details of stereomicroscope images of bags of chia showing an admixture of red and gray in Painting I, a gray wash in Painting II, an admixture of red and gray and a superimposition of a red wash over a gray wash in Painting VIII. Photography: Mary Elizabeth Haude