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Introduction

1 Four archaeological Andean painted textiles were investigated to learn more about the materials and manufacturing techniques used in their creation. The textiles are in the collection of the National Museum of the American Indian, Smithsonian Institution (NMAI). They are attributed to Peru but have minimal provenience. Research and consultations with Andean textile scholars helped identify the cultural attributions of three of the textiles as Chancay style fragments (figs. 1, 2 & 3) and one as a Middle Horizon style textile (fig. 4).

2 All four textiles are plain-woven cotton fabrics with colorants applied to one side. The colorants are referred to as paints because they appear to have been applied in a paste form. They are embedded in the fibers on one side of the fabrics and most appear matte, suggesting they contain minimal or no organic binder. Some of the brown colors, however, appear thick and shiny in select areas as if they do contain an organic gum or resin. These thicker brown colors are most prominent on the three Chancay-style fragments where brown outlines separate colored shapes. It is possible that these lines are a resist material that prevented colorants from neighboring areas from bleeding into each other. Overall, the linear designs on the Chancay style fragments appear carefully applied, while colors on the Middle Horizon style textile are more freely applied in a looser style.

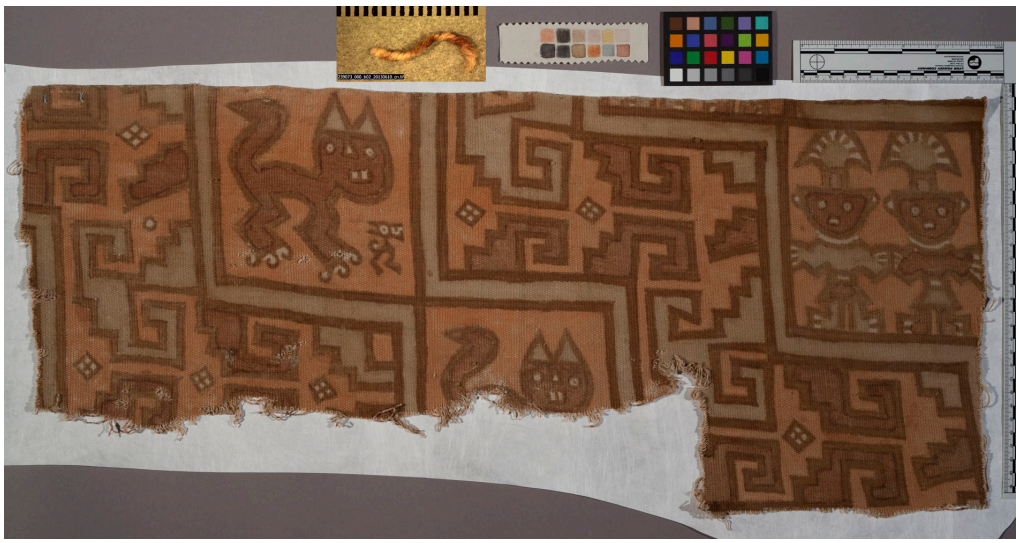

Figure 1 – Chancay style fragment. NMAI 23/9073. Image by Keats Webb, courtesy of the Museum Conservation Institute. Inset image of yarn that was analyzed with µFTIR, µXRD, and LC-MS.

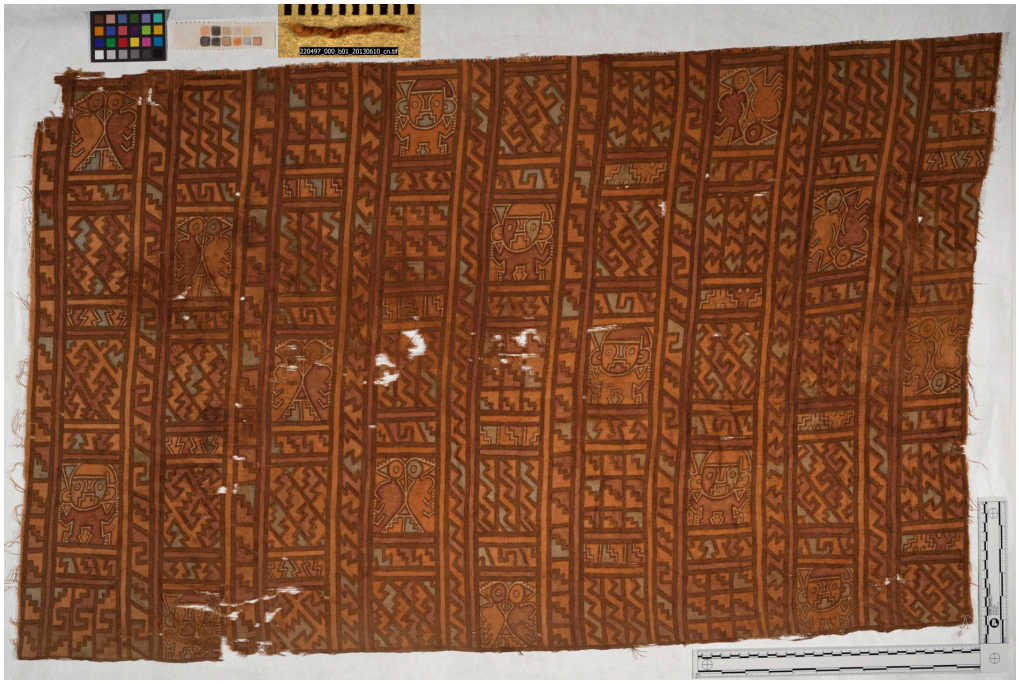

Figure 2 – Chancay style fragment. NMAI 22/0497. Image by Keats Webb, courtesy of the Museum Conservation Institute. Inset image of yarn that was analyzed with µFTIR, µXRD, and LC-MS.

Figure 3 – Chancay style fragment. NMAI 23/9038. Image by Keats Webb, courtesy of the Museum Conservation Institute.

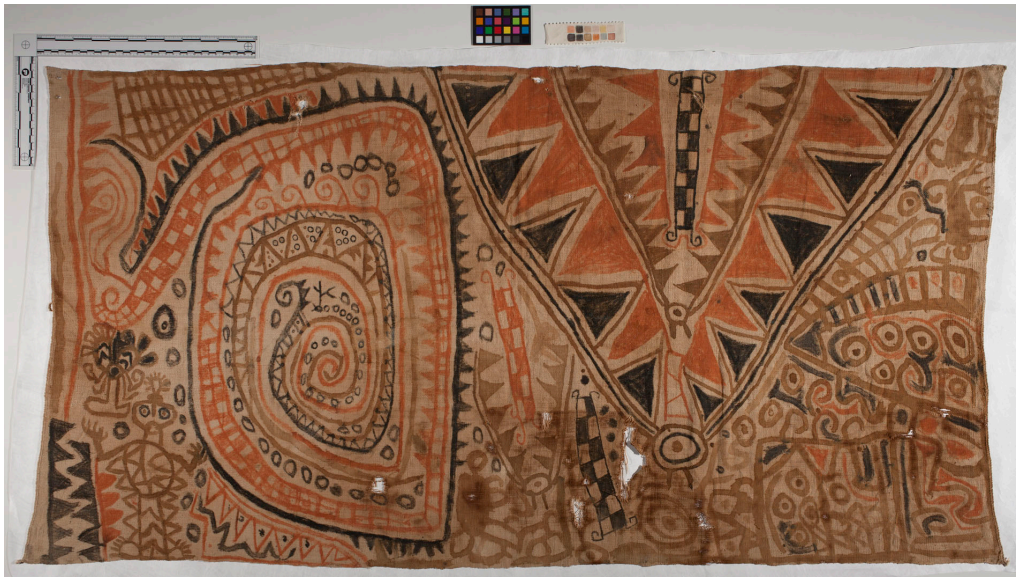

Figure 4 – Middle Horizon style textile. NMAI 23/9040. Image by Keats Webb, courtesy of the Museum Conservation Institute.

Background

3 The complex iconography and sophisticated technology of Andean archaeological textiles have long been important to Andean tradition bearers, archaeologists, art historians, textile artists, and many others. The weaving techniques, execution, and diverse styles of Andean textiles are testaments to the extraordinary skills of the artists who made them and the great value that was placed on textiles in Andean cultures. To date, the majority of scholarly works about archaeological Andean textiles have focused on iconography, fabric structure technology, and dye technology.

4 Andean painted textiles contain iconography and woven fabrics that are similar to unpainted textiles, but few studies have been published on the materials and techniques used to create them. This study builds on three previous technical studies on Andean painted textiles. Saltzman *et al.* used spectrophotometry to identify shellfish purple in Paracas textiles.[1] Smith used X-ray fluorescence spectroscopy (XRF) and polarizing light microscopy to identify iron-based pigments, carbon black, and lead-based pigments on Late Intermediate Period textiles that are probably from the central coast of Peru.[2] Boucherie used optical microscopy, Raman spectrometry, scanning electron microscopy with energy dispersive spectroscopy, Fourier transform infrared spectroscopy (FTIR), and high-performance liquid chromatography (HPLC) to analyze colorants in Nasca painted textiles, identifying carbon black, iron oxides, gesso, indigo, a copper-containing blue mineral (possibly azurite), and cinnabar.[3]

5 The current study applies a range of techniques, which are primarily non-invasive, to characterize colorants on the four painted textiles at the NMAI. The project aims to correlate materials and artistic processes identified through analysis with the attributed cultures and geographic regions. This will ultimately inform understanding of indigenous materials and processes and shed light on understudied textiles in NMAI's collection.

Methods

Non-invasive investigative techniques

6 Two types of photo documentation techniques were applied. First, images of the textiles were acquired using sections of the electromagnetic spectrum between long wave ultraviolet and near infrared by switching various band pass filters on a modified digital single-lens reflex camera, capturing characteristic absorption, reflection, or emission of radiation of the materials in the textiles. Second, one of the textiles was imaged with reflective transformation imaging (RTI) to produce images that highlight its three-dimensional and reflective qualities.[4]

7 X-ray fluorescence spectroscopy (XRF) analysis, which involves exciting materials with X-rays to determine their elemental composition, was used to detect elements that could be characteristic of mineral pigments or dye mordants used in the painted textiles.

8 Fiber optics reflectance spectroscopy (FORS) is a technique in which a material (typically a colorant) is illuminated through a fiber optic probe and the reflected light is captured and measured to produce a characteristic reflectance spectrum for the material. Spectra were compared to known reflectance spectra to identify the composition of colorants.

9 Reflectance Fourier transform infrared spectroscopy (FTIR) measured the reflectance of infrared radiation by a sample to determine its molecular makeup. This technique was used on the surface of the textiles, while micro-destructive FTIR analysis (see below) was used for analyzing colorants on detached yarn fragments using a microscope.

Analyses requiring sampling

10 Analyses requiring samples were executed on previously detached yarn fragments that appeared to be from two of the textiles (figs. 1&2). The original locations for these fragments are unknown, as they were detached before the start of the project ; however, microscopic examination of the fragments suggested that they were associated with the objects. Emphasis was placed on distinguishing between and characterizing mineral pigments and organic dyes, as well as characterizing the thick and shiny material present in fine brown outlines on both fragments. When possible the same sample was used for the following three techniques.

11 Micro X-ray diffraction (μXRD) measures the diffraction of X-rays in very small samples of crystalline solids. It was used to identify crystalline materials, such as most mineral pigments.

12 Fourier transform infrared microscopy (μFTIR) measures the absorbance of infrared radiation by a very small sample to determine its molecular makeup. The μFTIR has the advantage of analyzing samples of the colorants without interference from the fabric substrate.

13 Liquid chromatography-mass spectrometry (LC-MS) is a technique used for dye identification, in which dyes are extracted from a fibrous substrate before they travel through a liquid chromatography column. Different molecules from the dye travel though the column at different rates. Upon exiting the column, the molecules enter a diode array detector (DAD) where their transmittance spectra are recorded before the molecules enter a mass spectrometer (MS), which records their molecular weights. The combination of time in the chromatography column, reflectance spectrum, and molecular weight can identify organic dyes.

Results

14 Imaging revealed indigo in three of the textiles. Images taken with the 660nm & 735nm filters were subtracted from one another using “Difference” mode in Adobe Photoshop, resulting in black and white images (fig. 5) that highlight blue colorants on two textiles (figs. 2 & 3) and the black colorant on one textile (fig. 4). This technique highlights indigo, which absorbs radiation strongly at around 665nm but reflects it at 735nm.

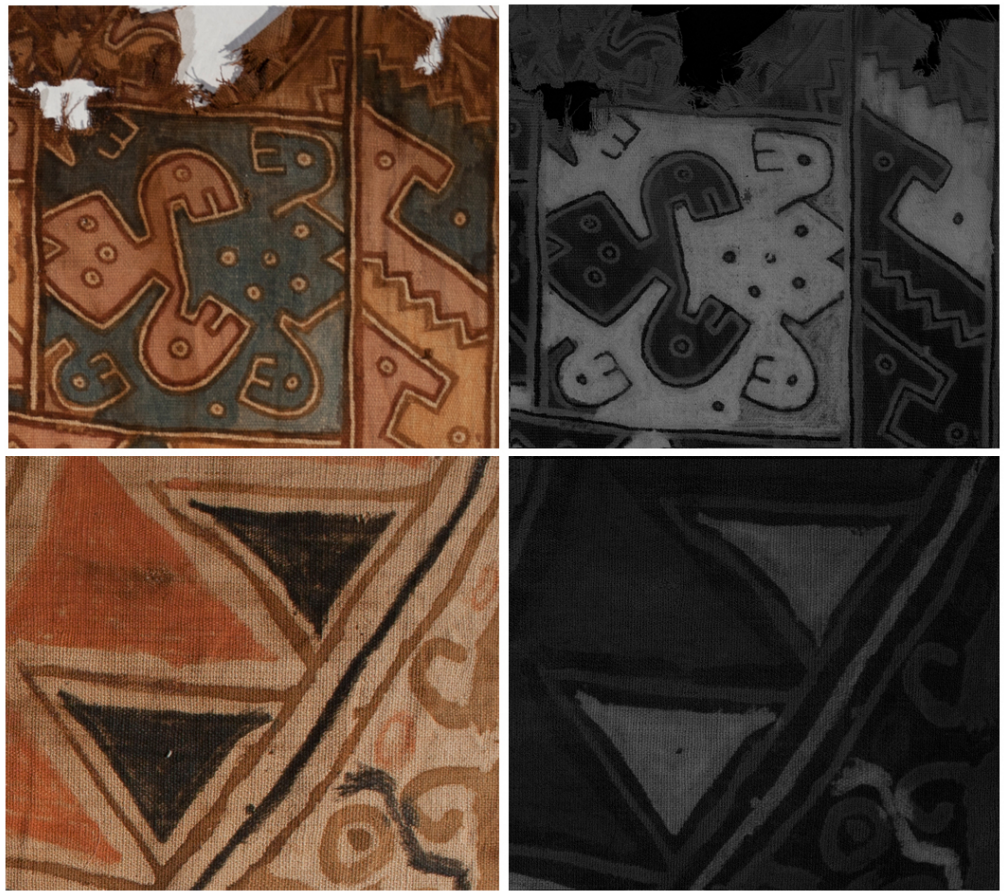

Figure 5 – Details of image subtractions with 660&735nm bandpass filters that highlight the blue and black colors on two textiles (NMAI 23/9038 top, NMAI 23/9040 below). The corresponding normal illumination images are on the left. This technique suggests both of these colors contain indigo.

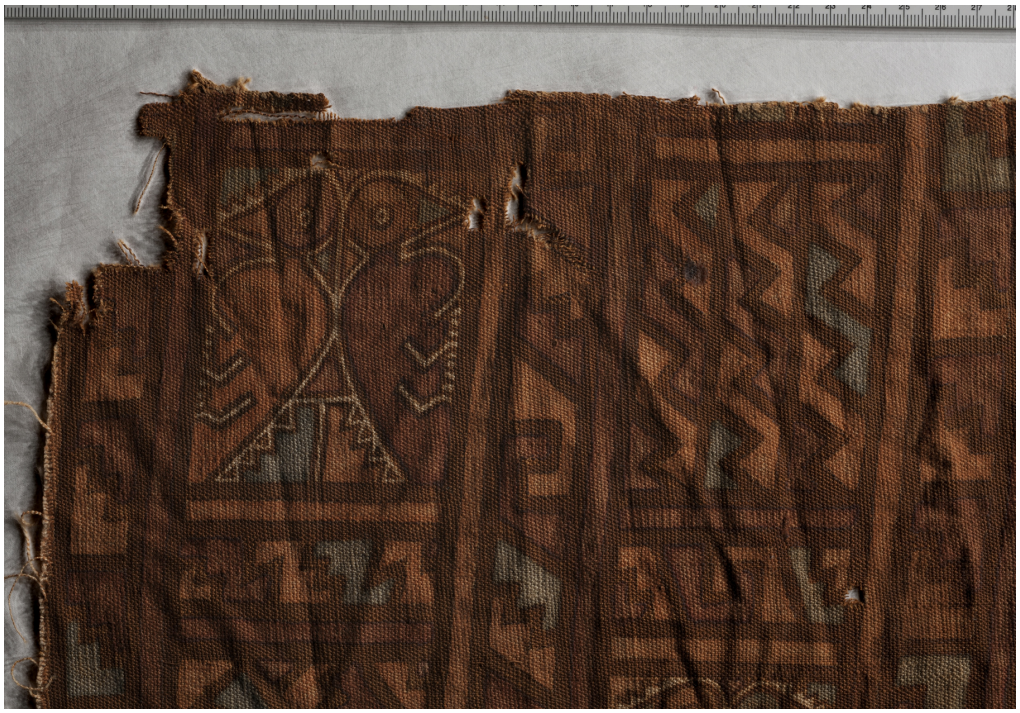

Figure 6 – Detail of RTI image of one of the Chancay style textiles (NMAI 22/0497). This technique highlighted the woven texture and creases in the textile, but not the fine brown outlines that have a slightly shiny appearance.

15 One Chancay style textile was imaged using RTI to highlight its three-dimensional woven texture and creases (fig. 6). RTI did not, however, highlight the reflective and three-dimensional qualities of the fine brown outlines that have a shiny and raised appearance in specular illumination.

16 XRF mapping of red-orange colorants on the textiles in figures 2, 3 & 4 shows high iron, silicon and aluminum content, and XRF mapping of the red-orange in figure 1 showed high iron and silicon content, suggesting the red-orange colorants are iron earths. Some of the browns had elevated manganese content, suggesting that a manganese oxide brown pigment may be present.

17 FORS produced characteristic reflectance spectra from a number of colorants on the textiles. The spectra suggest the following colorant identifications : pink colorant (fig. 3) appears to contain an insect-based red dye (i.e. cochineal), blue (figs. 2 & 3) and black colorants (fig. 4) appear to contain indigo, and the red-orange colorants (figs. 1, 2, 3 & 4) are inorganic reds. FORS was unable to distinguish between organic and inorganic brown colorants.

18 Two methods of FTIR were applied : a handheld reflectance FTIR instrument measured the reflectance of infrared radiation directly from the painted surfaces, without sampling, while infrared microscopy measured the molecular makeup of colorants on detached fragments. This analysis indicated that red-orange colorants (figs. 1 & 2) contain kaolinite, supporting their identification as iron earths. It also confirmed the textile substrates as cellulose, supporting their identification as cotton. Infrared microscopy identified a gum in the brown accretion in the yarn fragment in figure 1.

19 XRD analysis of brown accretions on detached yarn fragments from two textiles (figs. 1 & 2) characterized carbon (a potential colorant) and cellulose from one textile (fig. 2) and NaCl in the other (fig. 1). These results indicate that the colorants on these fragments are primarily non-crystalline, as neither carbon nor salt is likely to be the brown colorant or binding media.

20 LC-MS identified organic dye components in the brown and red colorants on the two detached yarn fragments (figs. 1 & 2). Carminic acid, a primary colorant in cochineal, was present in both fragments. Ellagic acid, a component of tannin-rich dyes, and an unknown red dye were also present in the fragment in figure 2.

Conclusions

21 Non-invasive imaging and analytical techniques provided sufficient data to identify red-orange colorants as iron earths, pink colorants as containing insect-derived dye (i.e. cochineal), blue colorants as indigo, a black colorant as indigo-containing, and the fabrics as cellulose (cotton). Characterization of cochineal, indigo, and cotton, is consistent with materials known to have been used in the Andes in ancient times.[5] Additional analysis may determine if the black indigo is a mixture of indigo with a black pigment.

22 Destructive analysis identified components of organic materials on the detached yarn fragments from two of the Chancay style textiles (figs. 1 & 2) ; these materials included the brown outlines, as well as possible brown and red colors from adjacent color fields. The identification of gum in one fragment (fig. 1) suggests that the brown lines contain a gum ; analysis of additional samples will clarify this result. The identification of carminic acid in both yarn fragments indicates the presence of cochineal on the two Chancay style textiles that also contain red-orange iron earth pigments. Ellagic acid, a component of tannin-rich dyes, was also found in one fragment along with an unknown red dye (fig. 1). Additional research is needed to characterize the unknown dye. Finally, the identification of carbon, cellulose, and NaCl by μ-XRD in the detached fragments supports characterization of the brown colorant accretions as primarily non-crystalline material.

Future work

23 Anticipated future analysis includes characterization of 1) brown accretions from the Chancay style textiles, 2) brown and reddish-brown colorants from all of the textiles, and 3) the black colorant with the indigo component (fig. 4). These samples will be selected from known locations. Additional further research is expected to illuminate the origin of the unknown red colorant that was observed using LC-MS.

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Notas

1 Saltzman *et al.* 1963, p. 244

2 Smith 1986, p. 201-202

3 Boucherie 2009

4 Earl *et al.* 2010; Frey *et al.* 2011

5 Phipps 2010, Cardon 2007, Roquero 2002

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Resúmenes

This project investigates the materials and manufacturing techniques used to create four archaeological Andean painted textiles in the collection of the National Museum of the American Indian, Smithsonian Institution. The textiles are attributed to Peru but have minimal provenience.
Building on previous work by other scholars on similar archaeological textiles, the materials and manufacturing techniques are identified and characterized by observation, documentation, and scientific analysis. Several analytical techniques are used to identify materials with emphasis on distinguishing between organic and inorganic colorants. Non-invasive analytical techniques, including X-ray fluorescence and fiber optics reflectance spectroscopy, as well as ultraviolet and infrared imaging techniques, were used to characterize an insect-derived pink color, blue and black indigo, and red iron earth pigments. Additional analysis with Fourier transform infrared spectroscopy, micro X-ray diffraction, and liquid-chromatography-diode array detector-mass spectrometry led to identification of carminic and ellagic acids on detached yarn fragments.

Analisis tecnico de cuatro telas arqueologicas pintadas de los Andes

Este proyecto investiga los materiales y técnicas de fabricación utilizados para crear cuatro telas pintadas de los Andes en la colección del Museo Nacional del Indígena Americano de la Smithsonian Institution, en Washington DC. Las telas, de origen arqueológico, son atribuidas al Perú y carecen de contexto.
Considerando los trabajos anteriores de otros estudiosos sobre similares textiles arqueológicos, se ha identificado y caracterizado los materiales y técnicas de fabricación mediante la observación, documentación y análisis científico. Varias técnicas analíticas se utilizan para identificar los materiales, con énfasis en la distinción entre colorantes orgánicos e inorgánicos. Técnicas no invasivas de análisis, que incluyen fluorescencia de rayos X y espectroscopía de reflectancia en fibra óptica así como técnicas de imágenes ultravioleta e infrarroja, se utilizaron para caracterizar el color rosa derivado de un insecto, y azul y negro de índigo y pigmentos rojos de hierro. Análisis adicionales con espectroscopía infrarroja por transformada de Fourier, micro difracción de rayos X, y cromatografía líquida con espectrometría de masa de con detector de arreglo de diodos, condujeron a la identificación de ácidos carmínico y elágico en fragmentos de hilo sueltos.

Analyse technique de quatre tissus archéologiques des Andes avec un décor peint

Ce projet étudie les matériaux et les techniques de fabrication utilisés pour créer quatre tissus archéologiques avec un décor peint qui se trouvent dans la collection de la Smithsonian Institution du National Museum of the American Indian de Washington DC. Les tissus sont attribués au Pérou et n'ont pas de contexte.
S'appuyant sur les travaux antérieurs d'autres chercheurs, les matériaux et les techniques de fabrication sont identifiés et caractérisés par l'observation, la documentation et l'analyse scientifique. Plusieurs techniques d'analyse sont utilisées pour identifier les matériaux en

mettant l'accent sur la distinction entre colorants organiques et inorganiques. Des techniques d'analyse non invasives, y compris la spectrométrie de fluorescence X et la spectroscopie visible par réflectance diffuse, ainsi que les techniques d'imagerie dans l'ultraviolet et dans l'infrarouge, ont été utilisées pour caractériser une couleur rose issue d'un insecte, un bleu et un noir d'indigo, et des pigments rouges ferrugineux. Des analyses additionnelles par spectroscopie infrarouge à transformée de Fourier, par micro diffraction de rayons X, et par chromatographie liquide couplée à un détecteur à barette de diodes et un spectromètre de masse ont permis d'identifier des acides carminique et ellagique sur des fragments de fils détachés.

Entradas del índice

Mots clés : tissus peints, Andes précolombiennes, colorants, pigments, analyses non invasives
Keywords : painted textiles, Pre-Columbian Andes, non-invasive analysis, dye, pigment
Palabras claves : telas pintadas, Andes precolombinos, colorantes, pigmentos, análisis no invasivo