Abstract Tambo Colorado is one of the most impressive archaeological sites in the Southern Peruvian coast, because of its stunning architecture, its extraordinary pictorial decoration, and its strategic location in the section of the Great Inca Road.

The Research Project Tambo Colorado considers necessary to conduct a comprehensive analysis encompassing nature of the materials (archaeometric analysis) as well as a proper understanding of their conservation status of its architecture. In this regard interdisciplinary research provides the necessary tools to achieve these goals. For this reason our team is integrated by archaeometrists, engineers, conservators and archaeologists. Due to of this transdisciplinary approach, one of the main objective is the study of painting technology developed by the craftsmen of the site. The first results obtained, thanks to an analytical strategy combining observation and elemental and structural analysis (colorimetry, SEM-EDS, XRF, XRD and SXRD), allow us to identify the coloring materials used. These data enabled to reconstruct the operational chain followed to elaborate the murals (since the pigments extraction to the making of the murals) but also to consider and develop a suitable surfaces conservation plan.

Graphical Abstract

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Statement of significance

The nature that surrounds us supplies very diverse colours. In this colourful universe, the South American Man always looked for matters capable of generating durable hues in his daily life. Using colouring materials of organic and mineral origins on several media, he passed on polychrome vestiges to us, records of his life, his faiths, his society and his world. Today, through the archaeometrical study of the pre-Hispanic mural paintings in Peru we try to understand these ancient civilizations without writing system. The case study of the Inca site of Tambo Colorado is part of this thematic and illustrates the interest of the use of a multidisciplinary methodology to develop archaeological and conservation issues.

Keywords Mural painting, Archaeometry, Peru, Conservation, Inca
1. Introduction

1.1. The site of Tambo Colorado

The site of Tambo Colorado is located on the South coast of Peru, on the right bank of the Pisco valley, at 35 km of Pisco, on the road that joins the Andes to the principal one on the coast (Morris, 2004) (Fig. 1). Also known under the name of Pucallacta or Pucahuasi (from puca that means red in Quechua), it forms one of the most impressive archaeological sites on the South coast of Peru, with an impressive raw earth architecture, its extraordinary pictorial decoration and its strategic location on the Qhapaq Ñan, the Great Inca road. All these characteristics are closely linked to the role that the site had in the Inca conquest of the coast. Despite its importance, this complex was never protected and was exposed to many phenomena that altered its preservation.

It is admitted that the site was built following the order of the Inca Pachacutec around 1460 A.D. It was built as a residence for the Inca nobility and military troops during the long and difficult conquest of the Chincha, Mala y Huarco reigns. In fact, the long Inca expansion process on the South coast resulted in long battles (Urteaga, 1939). Tambo Colorado’s architecture reflects this phenomenon: the plan is without any doubts Inca, with huge volumes and sophisticated decoration. The rich polychromy of the site was aimed to produce a visual impact but it also demonstrates the influence of local coast architecture with some openwork friezes and decorated entablatures. Its architectonic drawing is typical Inca style (end of the 14th century - 1532) (Fig. 2): a huge central place in trapezoid shape with perimeter walls decorated with niches, and one ushnu. Around this square there are two sectors: the first one located in the North is composed of inhabitation zones and inside squares richly decorated with red, white and yellow mural paintings. The second area, south of the square, was partially destroyed by the river. It also shows inhabitation zones but with less polychromy than the rest of the complex (Fig. 2). All the investigations led by the archaeological mission focused on the north side of the complex: the Northern Palace I (Fig. 3).

Tambo Colorado keeps both Inca special architectonic features, markers of its splendor and its determining and strategic role on the South coast, during a process of conquest extremely long and hard that faced the most powerful pre-Hispanic empire of the

Figure 1  Map of the Qhapaq Ñan the roads grid crossing the Inca territory (© PRTC)

1 Regional cultures of the South coast of Peru contemporary to the Incas.
2 Quechua word used to define a platform located on the central square and on which the Emperor or the local rulers realized ceremonies (McEwan, 2006).
Andes. Even though it has been neglected, Tambo Colorado always generated admiration from the visitors. So after the Spanish conquest, while all the important Inca centers are abandoned, Tambo Colorado, thanks to its location, its adapted residential layout and its impressiveness continue to attract the travelers who during their stay on the site would carve many graffiti.

One of the first researchers that studies the site is Bandelier in 1893, to realize plans and take pictures.
few years later, in 1901, Max Uhle stays a month and half in Tambo Colorado where he takes a set of photos and plans (Wolfgang, 1999). Then Harth-Terré in 1928 draws a detailed plan of the complex offering eight different areas where he mentions pre-Inca structures among them one has a religious vocation, a temple with an altar, a principal building, a residential structure for chasquis and quipuqmayoqs3, an inhabitation area for the people and an observation tower (Urteaga, 1939). The following year Urteaga leads an expedition with the Geographic Society of Lima during which he makes plans of the friezes and decorated walls. Engel proposes the first chronology in 1957, and he determines three periods of occupation: Paracas Caverna (700 B.C.), Nazca Monumental (600 A.D.) and Pre-colonial Posterior (1400 A.D.) based on the study of 3000 ceramic fragments collected during a surface exploration. In 1970, the archaeologist Pezzia makes a guide, the “Archaeological and Pictographic Map of the Ica’s Department”, in which he makes a description of the site, offering different functions to the sectors based on the archaeological data (Pezzia Assereto, 1970). During the last decade, the investigations essentially focused on the political and symbolical importance of the site. Morris, in 2004, explains that Tambo Colorado presents the characteristics of an Inca palace based on the description found in Murua’s Chronicle (Murua, 1946) and the comparison with other sites and an architectonical analysis. Finally, Protzen and Morris publish in 2004 an article reevaluating Tambo Colorado’s polychromy. They suggest the existence of fourteen layout patterns executed according to the social hierarchy of the architecture. The mural painting would in this way play the role of visual indicator to communicate the socio-political status (Protzen and Morris, 2004).

1.2. Tambo Colorado’s polychromy
Tambo Colorado’s mural polychromy is outstanding, not only by its degree of preservation but mostly by its recurrence as every wall of the Northern Palace I is decorated. All the panels consist in mural paintings made on a raw earth support and on a sporadic way on stones in the occasional areas where this material was used (base of some walls or intern faces of niches and windows). These characteristics make this site an example of mural polychromy unique in the Andean zone but also in the American continent.

The chromatic range is limited with the use of three basic colors that are the white, the red and the yellow, applied in monochrome surfaces for the white or in alternating horizontal strips for the three tints (Fig. 4). This pattern is stated with two colors (white and red or red and yellow) on two to three strips, and three (white, red and yellow) on three to six strips. A superficial observation allows noticing the existence of repainted part on some areas with two or three pictorial layers on top of each other. In one single room, the recinto 47 (Fig. 3), the decoration made on the northern wall consists in a succession of triangles inserted of horizontal lines. The whole was executed with the help of a way diversified palette including the white, red and yellow but also black and a set of secondary tints (grey, brown, or pink for instance) probably obtained by mixing (Fig. 5).

Despite the extraordinary characteristic of the vestiges, we do only have few data about the material and techniques used by the Inca craftsmen to make these paintings. The only reference concerns the analysis of three samples (white, yellow and red) at Laboratories of the Research Department of the Cerro de Pasco Corporation in La Oroya and in the Chemistry Laboratory of the Universidad Peruana Cayetano Heredia in Lima.

3 The chasquis were royal envoys of the Inca Empire, while the quipuqmayoqs are economical managers experts of quipu, registering system of checking and measuring goods.
painting. To proceed to the identification of the raw material to the completion of the mural expression in Tambo Colorado leaves to suppose the existence of an important organization around this crafty activity.

One of the objectives of the Projet de Recherche Tambro Colorado⁴ thus concerns the study of the pictorial technology used by the Inca craftsmen painters on the site to attempt to recreate the “chaîne opératoire” elaborated and followed from the extraction of the raw material to the completion of the mural painting. To proceed to the identification of the material and techniques used and of all the steps of the creating process we gave advantage to an analytical approach applied on the site then in laboratory according to a precise experimental methodology. To develop this objective, our research also focused on two pigments deposits located thanks to an aerial exploration and then a pedestrian one, at 300 m north on a sector we called “Cantera” (13°42′.94″ S - 75°49′.46″ O) and at 1300 m southwest (13°42′.35″.57″ S - 75°50′.25″.40″ O) of the archaeological complex. The proximity with the site as well as the presence of red, yellow and white pigments’ veins, allowed suggesting that the pre-Hispanic craftsmen used these as mines. Their study will allow developing these questions about the origin of the material.

2. Materials and Methods

2.1. Archaeometric study in situ

The first phase of our research took place on the site itself with two sets of measures: colorimetric and elemental. Thus the testing started with a study of the whole pictorial layers of the Northern Palace I with a colorimeter Minolta CR-300⁵. Due to the diameter of the light beam emitted by the device (1 cm) each point of measure was determined according to the state of preservation and the homogeneity of the pictorial layers. On each zone, three successive analysis were made and averaged, then translated in the form of chromatic coordinates used in chromaticity diagrams Xy (CIE 1931) and L*a*b* (CIE 1976). The measures were reproduced on the same points during the second field season, at one-year interval, to attempt to follow the evolution in time of the pictorial layers, without the intervention and after application of preservation treatments. Thanks to the calculation of the ΔE value using the coordinates L+a*+b*⁶ these modifications were quantified as well as their degree of perception⁷ (Hunt, 1995). There are 76 points on 29 rooms that were followed during the two first years of research. The effectiveness and the inputs of this protocol could be evaluated thanks to the work led since 2002 on similar vestiges on the site of Huaca de la Luna in Trujillo on the North coast of Peru (Wright, 2008).

In a second time, a set of analysis by X-ray fluorescence (XRF) was led on the painting of the Northern Palace I, allowing the acquisition of 69 measures⁸. These were done with a device Bruker Tracer III-SD with the following parameters: 45 kV, 11.30 μA and a time of acquisition of 180 seconds. These measures enabled to determine the elementary composition of the whole archaeological pictorial layers.

2.2. Sampling and experimental laboratory strategy

The study in laboratory was possible thanks to the realization of a sampling on the archaeological mural paintings of the Northern Palace I (28 samples: 11 reds, 8 whites, 6 yellows, 1 black, 1 grey and 1 brown) (Table 1) and on the two natural pigments deposits (5 samples: 2 reds, 3 whites, 2 yellows and 1 black). In light of the field results, which first conclusions are developed below, principally strengthened the use of mineral materials, a precise experimental protocol combining observations and elementary and structural analysis methods was determined. In a first time, the samples were the object of a XRF analysis at Laboratorio de Arqueología of PUCP in Lima, with the help of the same device and with the same parameters than on the field, in order to verify the preliminary results and to obtain data about the geological materials. One of the objectives also concerned the highlight of “trace elements” – geological markers – to work on the questions of the origin of the minerals. This step also enabled the selection of different material collection chosen for new analysis: thirteen samples (5 archaeological and 8 geological ones) were analyzed by X-ray diffraction in a conventional configuration (XRD) and then synchrotron (SRXD) then eight by Fourier transform infrared spectroscopy (FTIR) and then three (archaeological) were observed and analyzed by scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM-EDX) (Table 1).

⁴ Archaeological mission established according to a quadrennial plan started in 2013 that receives financing from the Advisory Commission of Archaeological Abroad Research of the French Ministry of Foreign Affairs and International Development (MAEDI) and logistical support from the French Institute of Andean Studies (IFEA) of Lima.

⁵ Collaboration with the Proyecto Arqueológico Huacas del Sol y de la Luna in Trujillo.

⁶ ΔE=√((L+1-L-1)+(a+1-a-1)+(b+1-b-1))

⁷ If ΔE < 1: evolution no perceptible to the naked eye; ΔE > 2-3: evolution perceptible to the naked eye; ΔE > 3: evolution very perceptible to the naked eye.

⁸ Collaboration with the Laboratorio de Arqueología de la Pontificia Universidad Católica del Perú (PUCP) in Lima.
Table 1  Colorimetric results of the 29 archaeological samples from Tambo Colorado’s Northern Palace I and list of the laboratory analyses performed

| Sector               | Room          | Color | Colorimetry 2013 | ΔE 2013–2014 | XRF | XRD/SXRD | SEM-EDS | FTIR |
|----------------------|---------------|-------|------------------|--------------|-----|----------|---------|------|
| Northern Palace I    | 12 Red        | L* = 45,26 a* = 22,05 b* = 24,80 | 3,42         | X              | X   |          |         |      |
|                      | 12 White      | L* = 84,19 a* = 0,65 b* = 11,83 | 3,04         | X              | X   |          |         |      |
|                      | 16 Red        | L* = 46,96 a* = 15,19 b* = 16,52 | 4,94         | X              | X   |          |         |      |
|                      | 16 White      | L* = 71,59 a* = 2,5 b* = 19,71 | 4,98         | X              | X   |          |         |      |
|                      | 16 Yellow     | L* = 64,93 a* = 6,11 b* = 25,4  | 4,49         | X              | X   |          |         |      |
|                      | 23 Red        | L* = 50,5 a* = 17,75 b* = 20,7  | 3,14         |                |     |          |         |      |
|                      | 23 White      | L* = 78,25 a* = 4,23 b* = 14,85 | 3,36         |                |     |          |         |      |
|                      | 23 Yellow     | L* = 57,91 a* = 6,43 b* = 24,16 | 5,32         |                |     |          |         |      |
|                      | 33 Red        | L* = 51,49 a* = 17,91 b* = 22,73 | 1,99         |                |     |          |         |      |
|                      | 33 White      | L* = 77,38 a* = 1,34 b* = 13,06 | 2,49         |                |     |          |         |      |
|                      | 33 Yellow     | L* = 71,04 a* = 5,18 b* = 29,01 | 1,29         |                |     |          |         |      |
|                      | 41 Red 1      | L* = 46,72 a* = 20,11 b* = 26,58 | 3,80         |                |     |          |         |      |
|                      | 41 Red 2      | L* = 50,02 a* = 11,56 b* = 14,99 | 3,66         |                |     |          |         |      |
|                      | 42 Yellow     | L* = 62,83 a* = 9,7 b* = 34,64  | 4,27         |                |     |          |         |      |
|                      | 47 Brown      | L* = 50,89 a* = 4,97 b* = 12,79 | 5,65         |                |     |          |         |      |
|                      | 47 Grey       | L* = 55,3 a* = 2,13 b* = 14,01  | 4,11         |                |     |          |         |      |
|                      | 47 Black      | L* = 44,7 a* = 0,73 b* = 10,31  | 2,95         |                |     | X        |         |      |
|                      | 52 Red        | L* = 48,13 a* = 19,32 b* = 22,4  | 2,26         |                |     |          |         |      |
|                      | 52 White      | L* = 81,47 a* = 0,6 b* = 12,89  | 4,46         |                |     |          |         |      |
|                      | 54 Red 1      | L* = 51,99 a* = 16,4 b* = 20,33 | 2,09         |                |     |          |         |      |
|                      | 54 Red 2      | L* = 50,61 a* = 18,78 b* = 23,48 | 1,95         |                |     |          |         |      |
|                      | 54 White      | L* = 71,9 a* = 3,62 b* = 18,49  | 2,13         |                |     |          |         |      |
|                      | 54 Yellow     | L* = 63,57 a* = 4,59 b* = 20,73 | 1,57         |                |     |          |         |      |
|                      | 60 Red        | L* = 47,26 a* = 20,53 b* = 25,27 | 2,56         |                |     |          |         |      |
|                      | 60 White      | L* = 81,87 a* = 0,27 b* = 14,74 | 0,73         |                |     |          |         |      |
| Eastern              | Red Red       | L* = 51,27 a* = 19,49 b* = 22,99 | 3,16         |                | X   | X        |         |      |
| Perimeter Wall       | Red 2         | L* = 58,45 a* = 13,07 b* = 19,77 | 1,04         |                | X   | X        |         |      |
|                      | White         | L* = 78,15 a* = 3,1 b* = 13,29  | 3,19         |                |     |          |         |      |
|                      | Yellow        | L* = 64,66 a* = 4,3 b* = 30,37  | 1,28         |                |     | X        |         |      |

The XRD analyses were realized at the Crystallography Laboratory of the Physics Department at the Universidad Nacional Mayor de San Marcos in Lima. The data was collected using a Bruker D8 Focus powder diffractometer in θ-2θ geometry and CuKα radiation (λ=1,5418 Å). Divergence slits of 1 mm, reception slit of 0.1 mm and soller slits of 2.5° were used to limit the beam to the simple that was mounted on a flat simple holder. The X-ray generator was operated at 40 kV and 40 mA of power and a scintillation detector was used. Data was collected between 4 and 65° with a step of 0.02° and data collection time of 6 seconds per step. The samples which were prepared as powder were then studied by SXRD using beamline 11-BM of the Advanced Photon Source (APS) with an incident wavelength of 0.413841 Å (Lee et al. 2008). The sample powders were loaded in 0.8 mm diameter polyamide capillaries which are spun at 10 Hz during data collection to improve powder averaging. Data was collected using the beamline’s twelve Si(111) analyzer crystals coupled to twelve Oxford-Danysfik LaCl3 scintillators, which were scanned over a 2θ range of 0.8 to 50 degrees, with data points collected every 0.001° 2θ and scan speed of 0.1°/second9. The analysis using XRD and SXRD are very important since they allowed identifying the presence of mineral components complementing the results from the elemental composition acquired through XRF. In addition, they allow obtaining quantitative compositional data using the Rietveld method (Young, 1993) with Bruker AXS Topas program10.

Then it is at Centre de Recherche et de Restauration des Musées de France (C2RMF) in Paris11 that the experiments followed on the preselected material. Infrared investigation was carried out by Fourier transform infrared spectroscopy (FTIR) using a Perkin Elmer Spectrum 2000 spectrophotometer, by near-infrared transmission spectroscopy using a micro diamond cell. Infrared transmission spectra of the samples were recorded in 4000–220 cm⁻¹ range, a resolution of 4 cm⁻¹ and 10 scans. All spectra are presented in transmittance units and baseline corrected. This technique gave us structural information useful to the identification of clays and natural earth often part of coloring mixtures composition. In addition, an elemental analysis by SEM-EDX measurements has been carried out on 3 samples, which identification were not completely known, by using a FEI XL30 CP associated with a Silicon Drift Detector X-MAX 50 and equipped with an AZtec Energy Advanced analytic platform (accelerating voltage 20 kV in a controlled pressure (CP) configuration). The images were made

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9 Phase identification of the samples was performed using the program EVA Copyright © Bruker-AXS 1996-2007.
10 TOPAS User’s Manual. BRUKER AXS GmbH, Karlsruhe, West Germany - DIFFRACPlus; TOPAS/TOPAS R/TOPAS P; Version 3.0; Technical Reference, BRUKER AXS GmbH, Karlsruhe, West Germany.
11 Collaboration with the Research Department of C2RMF, Palais du Louvre, Paris.
Figure 6  SRXD powder diffractogramme on a white sample of the eastern perimeter wall of the Northern Palace I of Tambo Colorado, illustrating the concentration of illite and gypsum responsible of the white color (© PRTC)

Figure 7  X-ray fluorescence spectra of a red and a yellow sample of the mural painting of the Room 33 of the Northern Palace I of Tambo Colorado, illustrating the presence of iron responsible of the color (© PRTC)
combining secondary electrons (SE) (such as Everhart and Thornley detector) and back-scattered electrons (BSE).

The whole analytical methodology established has enabled a complete characterization of the different colors used at Tambo Colorado, as well as the acquisition of new data about the origin of the material and the pictorial techniques used.

3. Results

3.1. Pictorial technique and chromatic range

The observations during the fieldwork allowed to give several remarks about the preparation of the wall support: a first thick and rough layer of heterogeneous granulometry coating applied on the stone or the adobes, then a second coating thinner, then a third one very thin and homogeneous of smoothed granulometry on the surface and finally the paint layer.

The colorimetric study has enabled to show the use of four basic colors for the execution of the paintings in the Northern Palace I: two types of red among them one more orange and the other darker and less saturated in red, a yellow and a white. In addition in the recinto 47, the craftsmen used black and some secondary tones like grey, pink and brown for example (Table 1).

The analysis in situ and in laboratory then allowed us to characterize the composition of each of the coloring mixes. The white paint results from the combination of two principal compounds (Fig. 6): one clay, the illite (\((K,Na)\text{Al}_2\text{Fe}_3\text{Si}_4\text{O}_{10}(OH)_2\)) and the gypsum (CaSO\(_4\cdot2\text{H}_2\text{O}\)) also characterized in the red and yellow pictorial layers. These two mixes are actually made of clay and calcium sulfate to which one chromogenic element made from iron oxide is added, red for the red mix in the form of hematite (Fe\(_2\)O\(_3\)) and yellow for the yellow mix in the form of goethite (FeO(OH)) (Fig. 7). The variations in intensity...
and luminosity of the tones noticed thanks to the colorimetric study can be explained by a difference in the concentration of each of these elements. The analysis led on the black pictorial layers showed a composition made from manganese oxide without the ability to precise its mineral form (Fig. 8). It is associated to calcite (CaCO₃), and in variable proportions responsible of the different colors noticed, from grey to black, on the mural painting in the recinto 47.

The results demonstrate that the coloring element, responsible of the perceived color, always matches a pigment, that is to say a product insoluble in the water that is fixed to the object’s surface. These pigments are all from mineral origins and are mixed in proportions responsible to the general color of the mix. While the clays and the iron oxides form are pigments usually found in the pre-Hispanic mural art (Wright, 2008; 2014), the use of manganese oxide for the black is really remarkable. Actually, the only other mention of its use in mural painting in Ancient Peru is certified on the site La Mayanga on the North coast (Donnan, 1972).

These pigments are associated to a second category of products identified as fillers. The filler is an insoluble product in a suspension environment, with weak coloring and opacity powers. It improves the cohesion of the paint, its covering up on the support and its preservation (Petit & al., 1995; Vignaud & al., 2000). It also enables, depending of its nature, to confer an adding shiny surface. In this case it matches to gypsum and calcite. It is associated to the white, red and yellow pigments for the gypsum and to the black for the calcite.

Finally, for the whole pictorial layers, some tracking elements, some markers of geological origin were highlighted: they match to the metallic inclusions of nickel (Ni) and in a lower way of copper (Cu), zinc (Zn), arsenic (As) and yttrium (Y) (Fig. 7). The characterization of these compounds enables to develop problematic about the origin of the mineral material.

3.2. Sourcing the pigment

In order to identify the sources of origin of the mineral coloring material used in the production of the mural paintings in the Northern Palace I, we proceeded to the analysis of the samples of geologic pigments collected on two open-air deposits next to the site. The data obtained thanks to the experiments XRF and XRD/SXRD were then compared to the data acquired on the archaeological pictorial layers.

The results of the characterization indicate first that the red samples result from the combination of iron oxide (hematite), gypsum and illite, added to a noticeable concentration of mineral salt (halite, NaCl). The yellows are essentially made of iron oxide with illite and gypsum. The white samples come from two deposits: on the first one (from where were sampled the reds, yellows and black) the chromogen elements are illite and gypsum (with a high concentration in halite) while on the second site of extraction the gypsum is the main component. Finally the black mineral is essentially made of iron oxide (in the form of hematite) to which are associated again the gypsum and the illite.

In a second time, thanks to the XRF analyses, it was possible to detect trace elements on the two studied deposits: metallic inclusions in type of nickel, copper, zinc, arsenic and yttrium for the deposit located north of the complex and inclusions of nickel for the one located south-west.

Therefore these first data indicate that the red, yellow and white pigments are available locally as the similarities of the composition between the natural pigments of the deposit north of the complex and the archeological pictorial layers show it. The similarity between these two sets of pigments and trace elements tends towards demonstrating that the area called “Cantera” matches to the extraction site of the coloring material used by the Inca craftsmen of Tambo Colorado. The unique difference lies in the concentration of salts noticed on the red and white samples that could be the result of an exterior pollution as the samples were made on surface which means a possible contamination. The only pigment that wasn’t identified locally matches to the black which characterization indicates a composition based of iron oxide and not manganese.

These results also allow understanding that the illite and the gypsum and then the iron oxides, the illite and the gypsum are encountered naturally associated. Then it is allowed to think that the composition of the archaeological pictorial layers results from a natural mix and not an anthropogenic one. In the same way, the gypsum forms a geological natural filler associated to the white, red and yellow chromogen.

4. Discussion

The whole archaeometric study enabled to acquire new data about the pictorial technology developed by the craftsmen painters of Tambo Colorado. It was possible to characterize the coloring mixes made with the help of different “ingredients” such as the pigments and the fillers, all of mineral origins.

The analysis made didn’t allow highlighting the organic binder intended for blending the mix and for favoring the adherence on the support. However, the FTIR experiments revealed absorption bands (to 1089 cm⁻¹ and 1605 cm⁻¹) characteristics of polysaccharides (Bondetti, 2014). It is likely that these organic compounds match the presence of vegetable gum which function in the mural paintings of the pre-Hispanic Peru was confirmed in previous investigations (Wright, 2008). An extensive study with chromatographic techniques for instance, and the realization of a reference sampling with local gums and resins possibly used, would allow to develop new perspectives in this totally unexplored field.
The study about the origin of mineral material allowed suggesting a local origin of the red, white, and yellow pigments probably extracted from the area called “Cantera” north of the archaeological complex. The importance of this result has led to an archaeological excavation on this sector from the second field season of the project in 2014. The first objective was to understand the method of extraction and the preparation of the coloring raw materials used in mural painting, theme without previous investigation in the whole Andean zone.

Besides, the use of the black pigment made from manganese is exceptional in the pre-Hispanic mural art. However, the use of this material in the ceramic decoration is confirmed in Peru on Nazca vestiges (1–750 A.D.) (Vaughn & al., 2005), and Late Moche (700–850 A.D.) and Wari (500 / 600–1000 A.D.) ceramic fragments on the Ayacucho area in the South cordillera (Solar Velarde, 2011; Dollwetzel, 2012). As Tambo Colorado is located in one of the communication ways of the Inca Empire linking Cuzco to the coast and going through Ayacucho, it is allowed to think of a distant origin for the black pigment. This would then show circulation of the coloring material at the scale of the Inca territory, as argue other examples such as Pachacamac, south of Lima, where remarkable and unusual pigments were characterized in offerings context (Wright & al., 2013).

This principle of circulation of the material allowed approaching the notion of trades of “savoir-faire”. Actually, the pictorial technology developed at Tambo Colorado is very similar to the one that used Inca craftsmen painters on the whole territory, or the ones from previous civilizations (Wright, 2008; 2014). Then this similarity shows some kind of handover of knowledge on the whole Peruvian territory and through time.

Finally, the colorimetric results and the acquired data on the pictorial layers of the Northern Palace I complete the preservation works led at the same time by the research project. These ones applied not only to the architecture but also on the painted surfaces and the relative conclusions to the material composition and to the production techniques allowing to adapt the treatment used to increase their efficacy (Pacheco & al., 2014). Also, even though there is little distance to the protocol applied, the first conclusions of the colorimetric study enabled to show a very visible and a very fast deterioration on some painted zones (ΔE ≥ 2–3) reinforcing the emergency of pursuing the preservation works (Table 1).

5. Conclusions

The archaeometric works led on the mural paintings of Tambo Colorado have once again demonstrated the interest of using an analytical methodology to develop archaeological and conservation issues. The new characteristic of the obtained results enables to contribute to the understanding of the Inca handicraft and more particularly of the craftsmen painters at the origin of the extraordinary mural decorations. The investigations about the pigments deposit located north of the complex allow to acquire new clues about the materials’ origin but also on their extraction and their preparation methods. These results are important because for the pre-Hispanic societies, without writing system, mural art took up a particular place and formed a real mean of communication. But, despite the importance of this artistic expression for these civilizations its actors remain unknown. Thus every new data enables to recreate the “chaîne opératoire” developed as well as its spatiotemporal evolution and to apprehend the craftsmen of the past. Finally, the implications in preservation increase the interest in such methodology to make durable and to pass on a unique and exceptional global heritage.

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Conflicts of Interest

The authors confirm that there are no conflicts of interest.

Author Biography

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