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GREEN, YELLOW, AND RED PIGMENTS IN SOUTH AMERICAN PAINTING, 1610–1780

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ABSTRACT—A multidisciplinary team of chemists and art historians from the University of Buenos Aires and the National Council of Scientific and Technological Research (CONICET) has examined the green, yellow, and red pigments used in a collection of 29 paintings from the highlands of Peru in the Andean region during the colonial period (1610–1780). The results described in this paper are a continuation of previous research on blue pigments found in the same corpus (*JAIC* 38 [1999]: 100–23). The results show how the artists from the big workshops of Cusco and the cities of the Alto Peru (the highlands of Bolivia and N.W. Argentina) followed the recipes for color preparation included in the technical treatises written by Spanish painters. Once again, the figure of Mateo Pisarro, an artist active in the Puna of Atacama at the end of the 17th century, emerges as an exceptional investigator of color-rendering problems.

TITRE—Les pigments verts, jaunes et rouges dans la peinture sud-américaine (1610–1780). RÉSUMÉ— Une équipe multidisciplinaire, formée de chimistes et d'historiens de l'art de l'Université de Buenos Aires et du Conseil national de recherche scientifique et technologique (CONICET), a analysé les pigments verts, jaunes et rouges employés dans un ensemble de 29 peintures de la période coloniale (1610–1780), et provenant du haut plateau de la Bolivie et du nordouest de l'Argentine (l'Altiplano) dans la région des Andes. Les résultats décrits dans cet article font suite à une recherche au préalable sur les pigments bleus, que l'on peut retrouver dans le même corpus (*JAIC* 38 [1999]: 100–23). Les résultats démontrent de quelle manière les artistes, qui ont œuvré dans les grands ateliers de Cuzco et des villes de l'Altiplano, ont suivi les recettes de préparation des couleurs que l'on retrouve dans les traités techniques écrits par les peintres espagnols. Une fois de plus, Mateo Pisarro, un artiste actif dans la puna de l'Atacama à la fin du XVIIe siècle, fait figure exceptionnelle de par son investigation sur le problème du rendu des couleurs.

TITULO—Pigmentos verdes, amarillos y rojos en la pintura suramericana de 1610 a 1780. RESUMEN—Un equipo multidisciplinario de químicos y de historiadores del arte de la Universidad de Buenos Aires y del Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) examinó los pigmentos verdes, amarillos y rojos utilizados en una colección de 29 cuadros del Alto Perú que datan del periodo colonial (1610–1780). Los resultados descritos en este articulo son la continuación de la investigación hecha anteriormente sobre los pigmentos azules

encontrados en las mismas obras (*JAIC* 38 [1999]: 100–23). Los resultados muestran cómo los artistas de los grandes talleres de Cusco y de las ciudades del Alto Perú (las ciudades en la región andina de Bolivia y el noroeste de la Argentina) siguieron las recetas para la preparación de color encontradas en los tratados de pintores españoles. Una vez mas, la figura de Mateo Pisarro, un artista activo en la Puna de Atacama a finales del siglo XVII, se destaca como un investigador excepcional de los problemas que se presentan al querer lograr colores específicos.

1 INTRODUCTION

The aim of the present work is to extend the study of the colonial Andean palette following the same guidelines used in our earlier work on blue pigments (Seldes et al. 1999). In the first part we were able to correlate the historical data and the results of chemical analysis. The data refer to the uses of several blue pigments (indigo, azurite, smalt, Prussian blue, and their mixtures) mentioned by the Spanish theorists of the Baroque period (e.g., Vicente Carducho, Francsico Pacheco, Antonio Palomino de Castro y Velasco) and their application in South American colonial paintings of the 17th and 18th centuries. It was found that most workshops of Cusco and the cities of the highlands of Peru (whose production was an important part of the study) closely followed the recipes for obtaining blue hues quoted by the authors mentioned above. An outstanding example was identified from a group of paintings attributed to Mateo Pisarro (active final third of the 17th century and beginning of the 18th century). Pisarro worked in the Puna of Atacama (northwest of Argentina, south-west of Bolivia, and northeast of Chile) for a landowner, Juan José Campero, marquis of Valle de Tojo, at the end of the 17th century. He produced a considerable number of paintings for churches and chapels dispersed over the marquis's possessions. Pisarro showed exceptional skill and originality in the search for special tints of chromatic intensity when looking for visual effects. These talents led him to experiment with smalt pigment and its mixture with azurite for making blue. Pisarro's aesthetic invention relied on that alchemy, while his European counterparts preferred the expressions and symbolic enigmas of iconographic subtleties.

This second part of our study focuses on 29 paintings selected from the corpus of 106 works that we studied in the first part. Those 29 works of art belong to the Cuscan and Alto-Peruvian schools of painting or were painted by Mateo Pisarro, with one exception—*Virgin with Baby Jesus* (painting 3.1.1) in an altar at the Yavi chapel—which probably came from Flanders to South America in the 17th century. The results describe the practices of colonial times used to obtain green, yellow, and red hues in painting. The main hypothesis was, once again, the remarkable performance of Mateo Pisarro when dealing with pigments other than blue: viz., green, yellow, and red tints. Pisarro's originality led us to examine a particular

relationship between him and Melchor Pérez Holguín (second half of the 17th century), a great master of the Potosinian school who also obtained brilliant results in the field of color rendering. Market conditions in South American colonial cities were considered a main force in the process of artistic production, not only from masters of traditional workshops in Cusco but also from Mateo Pisarro himself.

A brief description of the Cusco and Alto-Peruvian schools of painting in colonial times follows. According to the guidelines established by three Italian artists active in the viceroyalty of Peru at the beginning of the 17th century—Bernardo Bitti (1548–1610), Angelino Medoro (1547–ca. 1630), and Mateo Pérez de Alesio (ca. 1545–ca. 1616)—Cuscan painting followed the manner of the High Renaissance until 1650. In the second half of the 17th century, local painters such as José Espinosa de los Monteros (second half of the 17th century), the Indian Basilio de Santa Cruz (active 1661–1700), and the mestizo Diego Quispe Titos (1611–1681?) in Cusco, and Mechor Pérez Holguín in Potosí (Bolivia) introduced and adapted to Andean society the Baroque style that they knew mainly from copies of Spanish canvases and engravings produced in the Flemish, French, or Italian workshops, all of them spread by trade throughout the entire Spanish American territory. During the 18th century large series of works were produced in an almost industrial fashion by artists such as Marcos Zapata (second half of the 18th century, active 1748–1764), Basilio Pacheco (middle of the 18th century), Diego de Aliaga (second half of the 18th century) in Cusco, or Gaspar de Berrío (second half of the 18th century) in Potosí. All developed and standardized the characteristics of the Andean Baroque style: dynamic compositions, emphatic expressions in faces and gestures, light and shadow effects, and a rich palette.

It is important to point out a non-European variable that could have influenced the artistic reception of Native viewers of Christian religious painting in colonial times: the symbology of colors in the Inca and other pre-Columbian civilizations of the Andean regions. In pre-Hispanic South America, the color red, as well as blue, green, and yellow, were symbolically associated with the Inca himself and the gods. For the Native population, the bright and glittering, well-defined colors in the clothes and headdresses of noblemen were a symbolic manifestation of holiness and an expression of social inequalities, domination, and political, economic, and military power.

2 METHODOLOGY

2.1 TECHNICAL ANALYSIS OF PIGMENTS

The 29 works studied were part of a restoration and preservation project undertaken by the Fundación TAREA of Buenos Aires. Both qualitative and quantitative methods were used for the analysis of the pigments. In some cases, chemical microscopy studies were carried out on cross sections or on unmounted samples. The specific microchemical tests used for each pigment are described in each pigment's section. A scanning electron microscope (PSEM 500) equipped with an energy dispersive xray detector (EDX-4) was used for inorganic microanalysis. It was operated at 30 kV with diffusion pump vacuum in the mode of secondary electrons. The samples were coated by sputtering with a thin (less than 80 Å) layer of gold.

X-ray diffraction (XRD) was performed on a Phillips diffractometer (PW 1050), with copper radiation and nickel anticathode with different voltages for each spectra, depending on the sample. Tandem mass spectrometry (MS-MS) for the detection of indigo was performed on a ZAB hybrid spectrometer (Micromass, Manchester, UK) (BeqQ), filtering the molecular ion of indigo with B (magnetic sector), colliding with helium in the second, field-free region, and analyzing the fragments with E (electrostatic sector).

Copper resinate appeared transparent and viscous green under the optical microscope, and it did not show evidence of particles. The small amount of sample available prevented exact identification of its components by gas chromatography–mass spectrometry, but oil or protein could be excluded and the presence of signals like terpenes similar to those of some conifers could be observed. The presence of copper was determined by SEM, in addition to microchemical tests using rubeanic acid (Plesters 1956). Feigl's procedure (Feigl 1958, 80–82) was also used to determine the presence of copper by catalyzing the iron thiosulfate reaction through the presence of copper ions. None of the aforementioned methods was useful for detecting the acetate group.

Among the analytical criteria used for the identification of malachite are solubility and effervescence in cold 3N hydrochloric acid (HCl) and in concentrated nitric acid (HNO3) (Gettens and FitzHugh 1993), performed on the cross sections. A test for copper in malachite using rubeanic acid (Plesters 1956) was performed on the samples. When a solubility test in ammonia was performed, the solution turned deep blue, indicating a copper-ammonia complex. SEM elemental analysis indicated in all cases the presence of copper as a sole component or sometimes with minor impurities such as lead, silicon, calcium, aluminum, or iron.

Orpiment was identified where SEM results indicated the presence of arsenic (As) and sulfur (S). Some microchemical tests were also performed. The pigment was soluble in 3N hydrochloric acid, giving off hydrogen sulfide, and in concentrated nitric acid, giving off arsenic. It was also soluble in sulfuric acid and in 4N sodium hydroxide (Plesters 1956).

Vermilion was identified where SEM results indicated the presence of mercury (Hg). The pigment was not affected by dilute or concentrated nitric acid, hydrochloric acid, or sulfuric acid. It was also unaffected by 4N sodium hydroxide.

Red earth pigments such as hematite were identified from the presence of iron (Fe), detected by SEM analysis.

To identify carmine lake, a small sample was hydrolyzed and analyzed by thin-layer chromatography (TLC) on acetylcellulose according to the procedure described by Masschelein-Kleiner and later compared with results obtained for a genuine sample of carminic acid (Masschelein-Kleiner 1967; Masschelein-Kleiner and Heylen 1968).

Red lead was indicated by the presence of lead in SEM analysis. Some microchemical analyses were also performed, such as insolubility in 4N sodium hydroxide and solubility in dilute acids.

2.2 PIGMENT REFERENCES IN ART-HISTORICAL LITERATURE

Available references on the pigments (apart from blue) used in colonial South American art refer to *cardenillo* (verdigris), *coravari* (chrysocolla), and earths for green hues; *génuli, jalde* (orpiment), and saffron for yellow hues; *grana de México* (cochineal from Mexico) or *magna, achiote*, vermilion, minium, dragon's blood, and red earths for red hues; and white lead for white hues and lights, as well as ochers, earths, and ivory black for shadings. Understanding pigment nomenclature has been problematic. Undoubtedly due to transcription errors from the original sources, changes in terminology, and the wide range of materials used during this period, some differences have been identified. Thus, Mesa and Gisbert (1982, 267) refer to "Castilian colors" imported from Spain, based on a 1581 contract in which the master gilder Juan de Ponce was commissioned to gild the retable of the Church of Our Lady of Mercy in Cuzco (Cornejo Bouroncle 1960, 161–64). They quote a phrase from this document that mentions "genolis en borlazar con bermellón," which we understand as referring to *génuli, azarcón* (red lead), and vermilion.

Specific treatises and manuals, such as Carducho's ([1633]1979), Pacheco's ([1649]1990), Palomino's ([1723]1988), and Manuel Samaniego y Jaramillo's (Vargas 1975) offer a broader palette including a wide range of hues as well as recipes and recommendations for mixing and applying pigments. Pacheco mentions mountain green (a copper ore that results in a light green hue, which may be related to malachite), earth green, and *verdacho* (also used by Palomino)—all of them

derived from mineral sources. Among other pigments used during this period, red lead (in Spanish, *azarcón*) is also mentioned. It is a burnt lead oxide, orange-red in color, and also known as minium or Saturn red. This color was considered by Palomino ([1723]1988) among the "false colors" because the colors shifted and became duller as the paint dried (literally,"when drying it casts out crusts which strip away all gentleness from the painting" [135–36]). Another such pigment is the *encorca*, mentioned by Pacheco and Palomino as "Flanders' *encorca*," which yields a dark yellow hue.

There are documents on pigment traffic and how pigments were transported from one place to another. An anonymous manuscript of the 17th century, probably written by a converted Portuguese Jew, gives information on shipments of cochineal (carmine) from Mexico to Peru and also from Guatemala and Nicaragua. This "Memoir of All Kinds of Merchandises Necessary for Peru, Which Cannot Be Obtained Because They Are Not Made in This Country" records powdered cochineal from Valencia and verdigris (Lewin 1958, 121). Several private contracts and inventories were studied, such as the 1581 contract commissioning of Juan de Ponce to gild the retable of Church of Our Lady of Mercy in Cuzco. Other examples are the registrar book of the Church of Yucay in 1679 (Mesa and Gisbert 1982, 268–69); the accounting book of the Chapel of Our Lady of the Rosary in the monastery of Saint Dominic in Quito, dated 1823; and a list of tools and materials inventoried at the missions of Paraguay after the Jesuits were expelled from Spanish territory in 1767 (Ribera and Schenone 1948, 60).

3 RESULTS

3.1 GREENS

Analyses of all green pigments indicated a copper ingredient (table 1). Electron microscopy showed crystals resembling malachite, mentioned in ancient treatises and in documents as mountain green. Chemical tests revealed the specific combinations and proportions that differentiate it from green earths.

3.1.1 Copper Resinate

Six paintings were found to contain copper resinate, and these are listed in table 2. Copper resinate is a compound of *cardenillo* (verdigris) and a vegetable resin, similar to those obtained from some conifers or from copal trees, used as incense by

Native Americans. It is composed mainly of copper salts of resinic acids. Spanish art literature refers to this resin as *grassa* or *grasilla*, also called *sandarac* by the Arabs. It was commercialized in Europe in liquid form, as a powder (dissolved in linseed oil to make a varnish similar to the liquid *vernice* of the Italians), and also in grain form (*vernice in grana*). It is worth mentioning that Spaniards used the green *cardenillo* varnish for coating or making *velature*on a dried base of *añil* (indigo) and white, whereas it was found in some of the paintings of this collection applied directly on the primer layer, a procedure that produces an intense green. Mateo Pisarro used these recipes in his works, experimenting to obtain different hues, as exemplified by his ingenious use of copper resinate as a *velatura* upon an azurite blue for the Virgin Mary's garment in Yavi's *Coronation. Cardenillo* varnish was also known in 18th-century Cuzco workshops: it has been found in the collections from the province of Córdoba (Saint Catherine's and Saint Rose's). It was used for trees as a *velatura* on indigo, though with time it darkened to black. The initial bright color could be appreciated only when the original frame was removed for restoration (Seldes and Bucucúa 1998). Palomino knew it was a very unstable pigment and recommended varnishing it once it dried to prevent its transformation into a dark, dull color. In Quito, Samaniego used it mixed with earth green and *génuli* to make a *velature* on a dried layer of *añil* or black with white. Upon the *velatura*, he reinforced dark hues with black and clear hues with *ancorca*. No such technique was found in our study.

Table .

Painting Number (see table 2)	Location	Analy
1.1.1	dress, Virgin	SEM:
1.1.2	dress, Virgin	SEM:
1.1.3	dark leaf	SEM:
1.1.4	tree	SEM:
1.1.5	cloak, Saint Joseph	SEM:
1.1.6	right angel of the painting	SEM:
1.2.1	dress, angel	SEM:
1.2.2	cloak, Saint Gabriel	SEM:
1.2.3		SEM:
1.3.1	leaf	SEM:
1.3.2	tapestry on desk	SEM:
1.4.1	tree	SEM:

SEM: scanning electron microscopy
GC-MS: gas chromatography–mass spectroscopy
MS-MS: tandem mass spectrometry
Note: Elements in parentheses are minor or in some ca

Results of Pigment Analyses on Green Hues

Virgin of the Rosary of Pomata, at Casabindo (painting 1.1.3 [fig. 1]), is an interesting case because the above-mentioned resin may be found mixed with a