

A Microscopical Investigation of Pigments and Technique in the Cézanne Painting “Chestnut Trees”

by Marigene H. Butler

Editors’ Note: In this second article by Marigene H. Butler, the methods and techniques described in her first, basic article are applied to an actual painting. The original article was presented at the First Annual Meeting, American Institute for the Conservation of Historic and Artistic Works, Inc., May 31-June 2, 1973, at the William Rockhill Nelson Gallery of Art, Kansas City, MO. This article, and others at the time, consisted of a compilation of mimeographed paper stapled together, which did not have wide distribution. We are, therefore, pleased to make this invaluable information available to a wider audience, as a template for the identification of paint pigments, and the investigation of painting technique.

The Cézanne painting *Chestnut Trees* (1) was examined in order to learn as much as possible about how it had been created. The information sought included what pigments had been used, how they had been combined to produce the various design tones, and how the paint had been applied, both to model form and to create the recession of planes in space.



This investigation began by using a low power stereomicroscope to study the brush work, handling of paint, and variety of tones used in the design area. Samples were then taken from 20 different tones of paint (2), the paint particles were dispersed, mounted in Aroclor® 5442 (3) (refractive index 1.66) and identified using a polarizing microscope. Identifications were made by using characteristic optical and physical properties. The optical properties included relative refractive index, isotropy and anisotropy, birefringence, and type of extinction. The physical properties included color in plane polarized light and between crossed polars, degree of transparency or opacity, size, shape, surface texture, cleavage, fracture, homogeneity, and degree of agglomeration. Pigment particle size ranges were measured and the percentages of pigments in a mixture were estimated by volume. Apochromatic objectives were found to be essential for studying these samples, especially for seeing the identifying properties of pigment particles because they most frequently fall into a very low 0.5-10 μm range. One sectional fragment was taken from the painting and mounted in viscous Aroclor 1260 for the purpose of measuring typical paint layer thicknesses.

Pigments Used in the Painting and Their Identifying Optical and Physical Properties

Eight pigments were found to have been used in this painting: lead white, vermilion, chrome yellow, iron oxide yellow earth, emerald green, viridian, ultramarine, and bone black.

Lead white was used as the priming material and appeared in nearly all of the paint tones. In both priming and paint layers it occurs in 1-12 μm particles, much larger than are usually found in paintings. When identifying lead white, it is useful to have in mind the fact that crystals of basic lead carbonate are in the hexagonal system and are therefore uniaxial. Thus they have two refractive indices and are anisotropic. Because of their relatively high birefringence, (-)0.15, related to their particle sizes, smaller particles glow with bright white to straw yellow first-order interference colors, and larger particles show various second-order colors when viewed with polarized light. The frequent agglomerates have a pearly-pink cast. In plane polarized light, particles are transparent to translucent, colorless to white, with tannish-gray tones. The irregularly rounded particles can sometimes be seen at 1000X to be thin scales or tabular with hexagonal shapes. As a component of pigment mixtures in this painting, lead white ranges from 5 percent or 10 percent in the yellow-green grass tones to 40 percent of the dark red tone, 60 percent of the yellow building tone, and 40 to 80 percent of various sky tones. Large white agglomerates are visible at 16X, especially in the sky tones. When some of these were crushed, they turned out to be lead white with areas of zinc oxide particles, identifiable by their very low birefringence, (+)0.02, and refractive indices above 1.66. This was confirmed by electron microprobe x-ray analysis. It is possible that the agglomerates of lead white and zinc oxide were formed during the manufacturing process.

Vermilion is also present in nearly every pigment mixture, but usually only a few particles, one percent to five percent. Exceptions are the dark red tone with 30 percent and the mauve tree tone with 20 percent. These red crystals of vermilion, which also are in the hexagonal system, are likely to be rhombohedral, thick tabular, or prismatic with perfect prismatic cleavage and uneven subconchoidal fracture. With refractive indices well above 1.66 and a high birefringence of (+)0.33, these crystals are most readily recognized by the yellow-to-orange colors of smaller particles and the orange-red of larger particles in polarized light. Vermilion differs from the other inorganic red pigments in its polarization colors and in the rounded prismatic shapes of its particles which have very irregular surfaces and appear to glow with a bright, orange-red light which tends to mask the conformation of the surfaces. As a further test for identification, particles of mercuric sulfide will round off when heated on a slide over an alcohol lamp. If heated to 583°C, they sublime and droplets of

mercury will collect on the coverglass. However, with practice and comparison with particles of the same size in reference standards, this confirmation is rarely needed for identification of particles in a dispersed crushing.

Chrome yellow occurred in four samples, ranging in quantity from 10 percent in the yellow sky and tannish grass tones, to 60 percent in the yellow grass, and 100 percent in the deep yellow grass tones. These translucent monoclinic crystals of lead chromate, with refractive indices above 1.66, occur as minute 0.5-1 μm spheres and 2-5 μm rods and are most readily identified with crossed polars when they show grayed-yellow to bright-yellow colors.

Particles are pleochroic with alpha and beta orange-red and gamma blood red, but because they are so small, at 1000X in plane polarized light their pleochroism can barely be seen to change from bright yellow to orange as the stage is rotated. Particles often form loose agglomerates which are an orange-yellow. In the tones containing only 10 percent of chrome yellow, it was necessary to use the 100X/1.30 oil planapochromatic objective in order to distinguish these particles from the remainder of the crushing. With crossed polars, the rod-shaped particles then were visible.

Iron oxide yellow earth occurs in seven samples, ranging from a few particles, one percent in the dark-red or blue mountain tones, 15 percent in the yellow building, and 30 percent in the medium blue-green grass tone. The yellow earths consist of the mineral goethite whose crystals belong to the orthorhombic system and have refractive indices greater than 1.66. Two types of particles are present in these samples. The larger ones, up to 9 μm , appear to be isotropic except for occasional anomalous birefringence due to impurities. In plane polarized light, these occur as irregularly rounded nodules or fused agglomerates of a translucent, brownish-yellow color. Also present in several samples are 0.5 μm oval particles which are most readily seen between crossed polars when they flicker with pale to bright first-order colors.

Emerald green, a pigment which is especially intriguing visually, turns up in nearly every tone, ranging from a few particles in the yellow sky and dark red tones to 30 percent in the mauve sky tone, 50 percent in the blue-green grass tone and 75 percent in the medium-yellow grass tone. This pigment is copper acetoarsenite with refractive indices above 1.66. Uncrushed particles, 8-15 μm in diameter, appear to be radial in structure and usually have a dark spot at the center, causing them to resemble a doughnut. When these are crushed, they separate into several dozen rounded or wedge-shaped flakes. In plane polarized light, the thin flakes are transparent and nearly colorless, while the translucent, intact particles show pleochroism, changing from pale yellow-green to a grayed blue-green as the stage is rotated. With crossed polars, the thin flakes show first-order gray to white colors and intact spheres glow brightly with a creamy yellow to yellow-green to gray-blue. Undulose extinction is evident as the stage is rotated and flickering dark areas move irregularly across particle surfaces. Also present in these samples and in reference standards of emerald green are 9-12 μm fused agglomerates of 0.5 μm transparent birefringent particles with refractive indices above 1.66. The precise composition of these particles has not yet been determined. When thin emerald green particles are mixed with other pigments in a sample they can be hard to distinguish. Using slightly uncrossed polars to see the green color or fully crossed polars to see the undulose extinction is usually helpful.

Another green pigment, viridian, or transparent chromium oxide, with refractive indices above 1.66, occurs as five percent of the dark gray of the trees, 10 percent of the medium yellow-green grass, and 40 percent of the dark green grass. In plane polarized light, these transparent to translucent particles are pale to deep watery aqua-green, depending upon their thickness. With crossed polars, thin particles show first-order gray to white colors and thicker areas are green. As particles are rotated, undulose extinction causes light and shadow areas to flicker irregularly across their surfaces. Particles in this painting are large, 6-45 μm , and tabular, often present in jagged blade-like fragments with irregular shapes and fractured edges.

Ultramarine blue is the only blue used in this painting. Its translucent particles are in the cubic system and therefore are isotropic. Its surest identifying characteristics are its isotropism, its deep purple-blue, and its refractive index which is lower than 1.66. These 3-10 μm particles are very likely artificial ultramarine, judging from their irregularly rounded shapes, rough surfaces, fairly uniform sizes, and dark color. In samples from this painting they occur singly, never in agglomerates. Ultramarine particles are present in nearly every tone sampled, ranging from two to 15 percent in the dark red, yellow, and green tones, to 30 percent in the gray-blue grass, and 35 percent in the blue mountain tones.

Finally, a very few particles of bone black are present in the brown and mauve tree tones. These opaque particles of charred bone have irregular shapes and jagged edges and range from 3-10 μm . It is significant to note how little black pigment Cézanne used in this painting.

Cézanne's Technique in *Chestnut Trees*

Table I, which lists the pigments, proportions, and particle sizes of the twenty samples, shows an interesting fact. Sixteen of these samples contain lead white, vermilion, emerald green, and ultramarine, but the proportions of each of these pigments are varied, creating differences from tone to tone. For example, the dark red tone includes these four pigments with a high 30 percent of vermilion. The aqua sky tone is 40 percent emerald green. The mountain blue tone is 35 percent ultramarine, and the mauve tree tone is high in both ultramarine and vermilion. These subtle variations of the same pigment combination perhaps help to explain the harmony between all of the tones used in the painting.

One sectional fragment was taken (see Table I) and it was difficult to find an area for this purpose where two layers of paint overlapped each other. Usually one tone was placed next to another tone without any overlapping areas. For example, the wall was painted up to the edge of the tree trunks and the tones did not overlap one another. This placing of different tones next to each other without mixing is used particularly in the foreground and the resulting hard edges give the tree trunks, for example, a solidity that serves to bring them forward in space. Similarly, grass tones in the foreground are painted with separate, short strokes and no blending of adjacent tones. In contrast, the mountain and the trees against the sky have their edges softened by brushing a wet tone into the adjacent wet tone. This gives the illusion of distance and causes the mountain, for example, to fall back in space.

Wet on wet suggests a rapid technique and other evidence for the fact that Cézanne must have painted rapidly, wet paint into wet paint, includes the fact that at low magnification the beginnings or ends of brush strokes such as the tree branches, blend into sky tones beneath them. Sometimes the tree tones are painted over the sky; other times the sky is painted over the edges of branches.

The building at the right is another example of this with some blending of adjacent tones which softens the color area, again causing it to recede into the distance. The sky contains at least four tones, blue, aqua, yellow, and mauve, but their variety is minimized by brushing the edges of adjoining tones, wet into wet, into each other; thus the sky tones hold their place in the distance.

Conclusion

The investigation of the materials and technique of Chestnut Trees revealed that Cézanne used eight pigments—a fairly large number. The eight pigments were readily identified with the polarizing microscope by studying their optical and physical characteristics and comparing them with reference standards when needed. By using four of these pigments, lead white, vermilion, emerald green and ultramarine, in varying quantities in nearly every tone, he achieved a harmony of subtle tonal relationships throughout the painting. By placing these varying tones adjacent to one another, sometimes mixing wet paint into wet paint at their edges and sometimes not, he defined the landscape with a recession of planes in space.

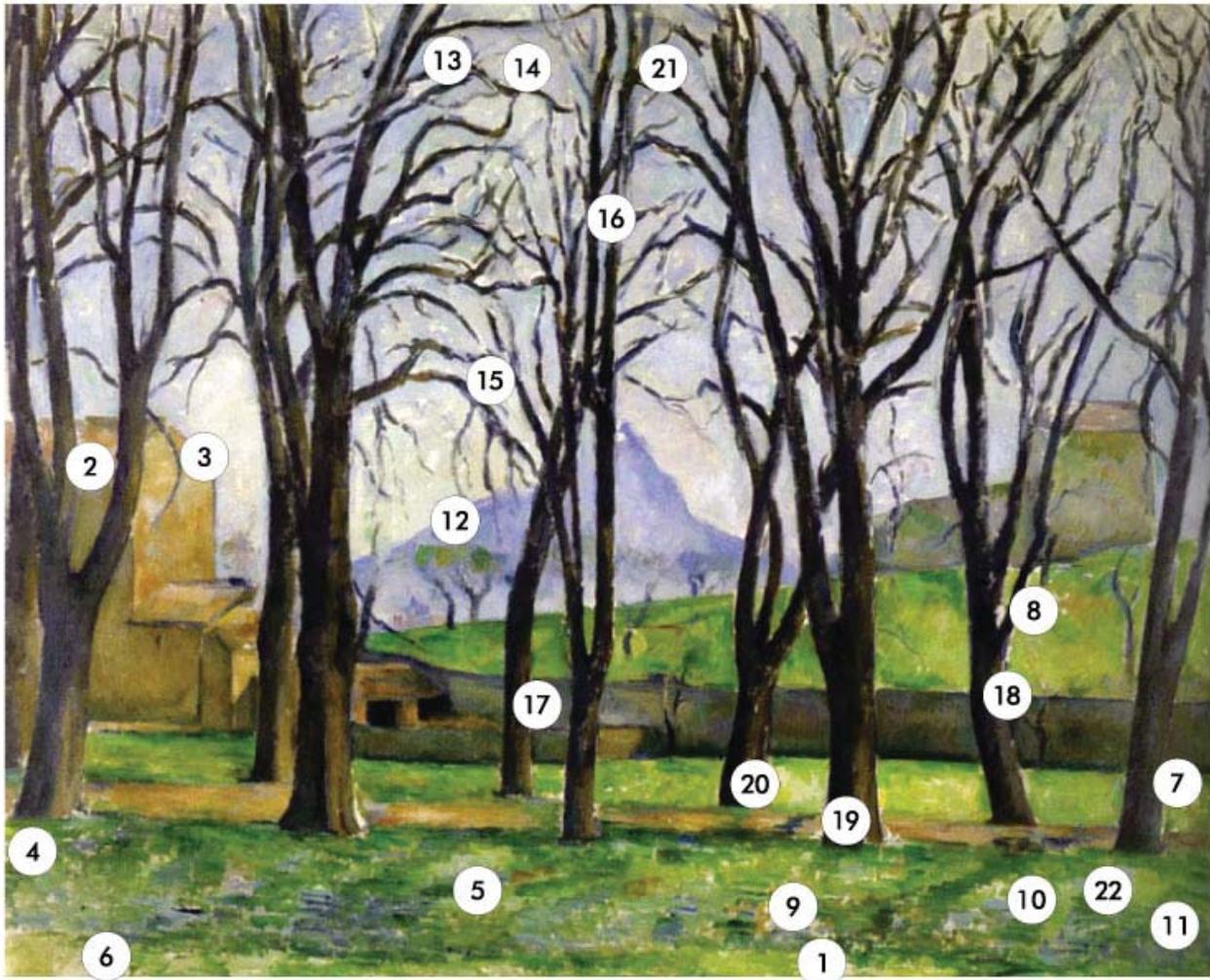
A great deal has been learned from this investigation about how Cézanne created one of his paintings. Hopefully this information will be augmented by applying these techniques to the examination and identification of materials in other paintings by Cézanne. (Note: In 1984, the materials and techniques used in 10 paintings from the last three decades of Paul Cézanne's career were examined by the author; see reference #4.) Such a fund of information provides an understanding of the materials involved which both enhances the conservation treatment of his paintings and aids in distinguishing his work from possible imitations.

Table I.

See the following page for an on-painting diagram, or key, showing the locations of samples 1 through 22 referenced in this table.

Sample Reference Number	Samples: Crushings Location in Meters	Pigments	Particle Size Range in Micrometers*	Estimated Percent (Volume)
1	Priming h. 0.230 w. 0.601	Lead white	1 – 12	100
2	Dark Red h. 0.380 w. 0.078	Lead white Vermilion Yellow earth Emerald green Ultramarine	1 – 6 2 – 8 4 4 – 6 3 – 6	40 30 1 14 15
3	Yellow, building h. 0.384 w. 0.155	Lead white Vermilion Iron oxide yellow earth Ultramarine	1 – 10 2 – 6 2 – 4 2 – 6	60 15 15 10
4	Dark green grass h. 0.098 w. 0.043	Lead white Vermilion Emerald green Viridian Ultramarine	1 – 15 3 15 6 – 45 2 – 4	30 2 15 43 10
5	Medium yellow-green, grass h. 0.027 w. 0.100	Lead white Vermilion Emerald green Viridian Ultramarine	1 – 5 3 3 – 18 30 3	10 1 75 10 4
6	Yellow-green, grass h. 0.084 w. 0.355	Lead white Vermilion Emerald green Ultramarine	1 – 6 3 7 – 12 3	5 2 90 3
7	Yellow, grass h. 0.170 w. 0.854	Chrome yellow Emerald green	0.5 – 5 8 – 10	60 40
8	Deep yellow, grass h. 0.290 w. 0.745	Chrome yellow	0.5 – 5	100
9	Tannish, grass h. 0.072 w. 0.581	Lead white Vermilion Iron oxide yellow earth Emerald green Ultramarine	1 – 10 3 0.5 – 2 6 2 – 4	90 1 5 2 2
10	Gray-blue, grass h. 0.084 w. 0.747	Lead white Vermilion Iron oxide yellow earth Emerald green Ultramarine	1 – 9 4 1 – 2 6 – 15 3 – 10	48 1 1 20 30
11	Medium blue-green, grass h. 0.170 w. 0.854	Lead white Vermilion Iron oxide yellow earth Emerald green	1 – 3 3 0.5 – 2 8 – 10	15 5 30 50
12	Blue, mountain h. 0.342 w. 0.343	Lead white Vermilion Iron oxide yellow earth Emerald green Ultramarine	1 – 9 4 6 – 9 6 2 – 6	60 1 2 2 35
13	Aqua tone, sky h. 0.673 w. 0.333	Lead white Vermilion Emerald green Ultramarine	1 – 5 2 – 4 16 8	40 10 40 10
14	Mauve gray, sky h. 0.668 w. 0.370	Lead white Vermilion Emerald green Ultramarine	1 – 12 4 – 6 8 2 – 8	75 5 5 15
15	Yellow tone, sky h. 0.449 w. 0.375	Lead white Vermilion Chrome yellow Emerald green Ultramarine	1 – 6 4 2 – 3 6 3 – 5	60 10 10 10 10
16	Blue, sky h. 0.547 w. 0.443	Lead white Vermilion Emerald green Ultramarine	1 – 12 2 – 3 6 3 – 12	80 4 1 15
17	Gray, wall h. 0.211 w. 0.402	Lead white Vermilion Emerald green Ultramarine	1 – 10 4 – 6 8 – 12 3 – 6	55 5 20 20
18	Mauve, trees h. 0.230 w. 0.725	Lead white Vermilion Emerald green Ultramarine Bone black	1 – 12 1 – 5 8 2 – 8 3	40 20 8 30 2
19	Dark gray, trees h. 0.140 w. 0.617	Lead white Vermilion Emerald green Viridian Ultramarine	1 – 4 3 – 8 8 – 10 4 – 15 2 – 8	30 5 30 5 30
20	Brown, trees h. 0.162 w. 0.551	Lead white Vermilion Iron oxide yellow earth Emerald green Ultramarine Bone black	1 – 4 1 – 6 1 – 8 8 2 – 4 10	35 20 8 25 10 2
21	Large white particles, sky tones h. 0.665 w. 0.480	Lead white Zinc oxide	1 – 12 0.5 – 4	50 50
Sample Reference Number	Samples: Sectional Fragments Location in Meters	Layers	Layers thickness in Micrometers*	
22	Grass h. 0.090 w. 0.795	Priming Green layer Blue layer	72 – 80 8 – 24 24	

* 1 micrometer (µm)
= 1/25,000 inch



Acknowledgement

The author wishes to acknowledge Mr. Alfred Jakstas, Conservator, for suggesting and promoting the use of the polarizing microscope in the conservation laboratory of The Art Institute of Chicago; Dr. John Maxon, Associate Director of the Art Institute, for supporting the microscopy program; and Mr. John G. Delly of McCrone Associates, Inc. for advice and encouragement in furthering the use of the polarizing microscope in conservation of works of art and for their constructive criticism of this paper.

References

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3. Aroclor is a registered trademark of the Monsanto Chemical Company.
4. Butler, M. H. An Investigation of the Materials and Techniques Used by Paul Cezanne, *American Institute for Conservation: Preprints, 12th Annual Meeting*. 20-33 (1984). Available online: <https://www.mccrone.com/mm/investigation-materials-technique-paul-cezanne/>

About the Author

Marigene (Mrs. Daniel K.) Butler has enjoyed a long and distinguished career as paintings conservator, microscopist, and conservation administrator. From 1978 until her retirement in 1997, Mrs. Butler served as Head of Conservation at the Philadelphia Museum of Art (PMA). Over these nearly two decades, she established the PMA's conservation department and oversaw its development. Through her efforts, it became one of the leading conservation laboratories in the nation, making substantial contributions in conservation training and scientific research, as well as providing outstanding care for the museum's extensive collections.



An AB graduate in Art History from Mount Holyoke College, Mrs. Butler apprenticed for two years in paintings conservation with Elizabeth H. Jones at the Fogg Art Museum, Harvard University. She continued training in this specialty for another two years under Alfred Jakstas at the Art Institute of Chicago; and remained at the institute for a subsequent five years as Assistant, and then Associate, Paintings Conservator with responsibilities both for the treatment of paintings and the identification of their materials with the polarizing microscope. After training in polarizing microscopy with Walter C. McCrone, she developed a course *Polarized Light Microscopy for Conservators*. She taught elements of it while a teaching consultant in microscopy at the graduate conservation programs of the University of Delaware and New York University.

Prior to joining the PMA, Mrs. Butler held the post of Director of the Intermuseum Laboratory of the Intermuseum Conservation Association (ICA), Oberlin. The ICA provided conservation services to 17 Midwestern museums that were members of the Association. Over the last four years of this period, she was head of the ICA's graduate conservation training program.

Mrs. Butler has had many papers published regarding her research on the materials and techniques of such leading artists as Franz Hals, Paul Cézanne, and Jan van Eyck. She is a Fellow of both the American and the International Institutes for Conservation, and the Royal Microscopical Society. A member of the Board of Trustees of the National Conservation Advisory Council from 1973 to 1981, she served as its chairman during the last two of those years and then continued on the Board of Trustees of its successor organization, the National Institute for Conservation. She has served Mount Holyoke College's Art Museum Advisory Board as Chairman of the building committee. A member of the Board of Trustees of the Wyck House, Philadelphia, PA, she was a leader in the restoration of this important and once neglected Germantown historic site.