Identification of 1850s Brown Zinc Paint Made with Franklinite and Zincite at the U.S. Capitol

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Research and analyses disclose that brown, zinc-based primer used on 1850s cast iron at the U.S. Capitol contains pigments made from the crushed ore of franklinite and zincite advertised by the New Jersey Zinc Company.

Fig. 1. The United States Capitol, 1867, looking southwest, as the 1850s extension project designed by Thomas U. Walter was nearing completion. The north (Senate) wing is in foreground; south (House) wing is in background. Courtesy of the Architect of the Capitol.

Introduction

Recent investigations of interior paints in the 1850s House and Senate wings of the United States Capitol have revealed for the first time the original brown zinc paints that were made by the New Jersey Zinc Company in Newark, New Jersey. Used as a factory-applied, rust-inhibitive primer on the cast-iron door and window enframements installed at the Capitol, this paint contains unusual pigments that were made by crushing franklinite and zincite ore from the celebrated Franklin and Sterling Hill mines in Sussex County in northwestern New Jersey.

The New Jersey Zinc Company was one of the first manufacturers of zinc oxide and zinc-based architectural and industrial paint in America. In addition to white, the company also made at least seven other colors of zinc paint, especially brown, for use principally as primers on metals but also for finish coats on exterior wood surfaces. The ore from which American-made zinc paint was first manufactured was discovered in Franklin, New Jersey, in the eighteenth century. The ore contained many minerals of different colors and composition, including the primary ones, zincite and franklinite, which occur nowhere else on earth.

The history of the Franklin-area mines and the zinc extracted from the ore are inextricably linked. The mines and innovative manufacturing processes gave birth to the zinc pigment, zinc paint, and ready-mixed-paint industries in nineteenth-century America. The incentive for the mining and manufacturing industries to develop zinc oxide as an alternative white pigment for architectural and industrial paints was created by the significant health problems associated with the manufacture of white lead and application of lead-based paints.

The findings of this project add not only to the history of the construction of the U.S. Capitol but also, and more significantly, to the history of zinc-paint manufacture and the use of minerals as architectural paint pigments in this country in the mid-nineteenth century. Much has been written about zinc paints and the Franklin-area mines; however, until the discovery at the Capitol, the use of crushed franklinite and zincite ore as pigments in an architectural paint was never studied in detail. Identification of these minerals can be used as a reliable benchmark for dating and/or authenticating a paint layer. The results suggest that future published studies concerning zinc pigments should include a more accurate history of their manufacture using franklinite and zincite in the mid-1800s in America.

Identification of Brown Zinc Paint at the Capitol

The Capitol was constructed in the late eighteenth and early nineteenth centuries. It was greatly expanded between 1850 and 1867 with the addition of north and south wings and a new cast-iron dome — all designed by architect Thomas U. Walter and overseen by engineer Capt. Montgomery C. Meigs.

The extension project, as it was called, comprised the two wings that housed new House and Senate chambers plus new offices, meeting rooms, ceremonial spaces, grand staircases, and elegant corridors (Fig. 1). Fireproofing was a great concern to Walter and others, especially after the British burned the Capitol in 1814. Consequently, Walter elected to trim all of the new door and window openings with cast-iron casings or enframements (Walter and Meigs called them window and door *dressings*). The door enframements in the basement were manufactured by the Baltimore firm of Hayward, Bartlett and Company, but the basement windows and all door and window enframements (as well as all ornamental ceilings and gallery fronts) in the upper floors were manufactured, starting in 1855, by Janes, Beebe and Company of New York.[1]

Many of the more than 600 cast-iron door and window enframements have detailed ornamental moldings on their architraves, all of which are so finely executed that when finish painted they resemble exquisitely carved and molded wood (Fig. 2). Walter may have even specified that Janes, Beebe and Company enframents be primed before shipment, as he did with the castings for the Congressional Library in 1853, giving instructions "to paint the castings with two coats before shipping, to prevent rust and to lay a good foundation for the ornamental painter."[2]

Recently, during three separate paint investigation and analysis projects throughout the first, second, and third floors of the interior of the north (Senate) and south (House) wings, brown zinc paint was identified for the first time as the primer on the mid-1850s cast-iron door and window enframements. These projects started in 2002 in Senate Office S-312 with the Office of the Senate Curator and continued in 2004 as part of a window-shutter survey throughout the Capitol with the Office of the Curator of the Architect of the Capitol. In 2005 the project culminated with taking additional samples from door and window enframements in other offices and public spaces in order to distribute the locations of samples throughout the first, second, and third floors in both wings. The basement rooms, dome, and ceilings were not sampled.

Fig. 2. Cast-iron enframement of doorway in Senate Room S-211, the Lyndon Baines Johnson Room, at the Capitol. All photographs by the author unless otherwise noted.

This last stage was unusual in that it focused on a prime paint layer, in contrast to most paint analysis, which typically concentrates on finish paint layers and their colors. It is rare that pigments in architectural paints are analyzed, and even more so for those that can be categorized as shop primers. This project focused specifically on the unusual color of and the pigments used to make the brownish gray oil primer on the door and window enframements in Senate Office S-312 and on all other door and window enframements subsequently sampled.

Numerous sites from door and window enframements in eight rooms in both wings were investigated and sampled. The selected spaces and features are representative from each floor and wing. They included H-128, window enframements; H-218, window enframements; H-319, window enframements; and the west grand staircase third-floor door enframements in the south wing (House side) and S-128, window enframements; S-211, door enframements; S-312, door enframements; and the east grand staircase third-floor door enframements in the north wing (Senate side).

In many cases, a sample of the cast-iron substrate could not be extracted with the paint layers intact, as is typically done with wood and plaster. As a result, the paint samples were thoroughly scraped off of the feature's surface using a curved X-Acto blade in such a way as to expose the cast iron, allowing all of the numerous tiny fragments that separated to fall into a sample envelope held below. The locations selected for sampling were consistently associated with inside corners of moldings and ornaments in order to get the thickest layer evidence, since paint tends to accumulate in crevices and corners.

The samples from the various features were analyzed microscopically, initially in a loose fractured state under the stereomicroscope and afterward in mounted cross sections. All samples exhibited the same brownish gray, oil-based, shop-prime paint layer(s). The color of the paint varies little from sample to sample and is very close to the Munsell color reference value of 2.5 YR 6/1. This color is described in the National Bureau of Standards Color Name Charts as Light Brownish Gray.

Stereomicroscopical studies show that this brownish gray paint layer contains a number of very colorful and unusually large (0.1 – 0.25mm), coarsely ground yellow, orange, red, and black pigment particles. Their size, color, and appearance in a paint film were totally unfamiliar. Upon initial inspection they did not share any characteristics of paint pigments heretofore seen or described in standard artist-pigment references (Fig. 3).

To identify these unknown pigments and, subsequently, their source and fascinating history of manufacture, they were analyzed microscopically and instrumentally to document their optical characteristics and chemical composition.[3]

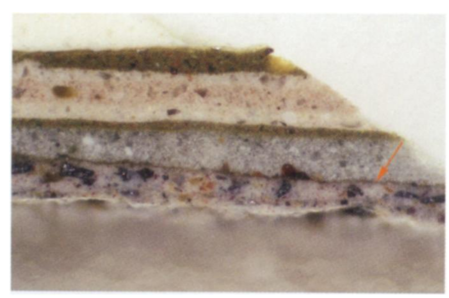

Fig. 3. Cross section of the layers of paint sample S-312-5 from the cast-iron architrave of the southern-most window on the east wall in Senate Office 312 (20X). The lowest layer exhibits the characteristic large, colored-pigment agglomerates of the original brownish gray, zinc-based, shop-prime paint. The yellow, orange, and red particles are zincite; the black pigment particles are franklinite. Note the thin dirt layer (arrow), a clue that the shop-prime paint was exposed and collected dirt during shipment and construction.

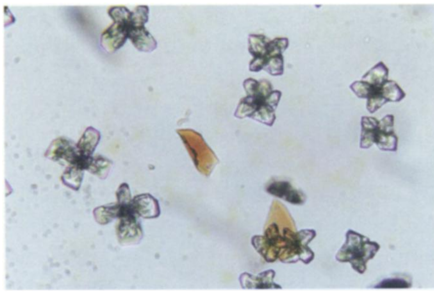

Fig. 4. Photomicrograph of the initial stages of reaction in the microchemical test for zinc, showing orange zincite pigment particles from the prime paint used on the enframements at the Capitol (50X). The cross-shaped crystals are precipitating in a solution of potassium mercuric thiocyanate.

Fig. 5. Photomicrograph of microchemical test for zinc, illustrating how the crystal precipitate grows into feathery crosses that appear black in the transmitted light of the microscope (50X). The precipitate formed is a salt: $[ZnHg(SCN)_4]$. The test confirms the presence of zinc in the orange pigment particles (zincite).

Analysis of the Brown Zinc Paints: Instruments, Techniques, and Findings

The identification of the pigments in the brownish gray paint from the Capitol enframements was not a simple exercise, especially since the pigments were ground in various sizes and distributed throughout the paint layer.[4] A variety of microanalytical instruments was employed to study the layer structure and color of this paint and to determine its pigment composition. Of primary interest were the colored pigment particles, but as the analyses progressed, the white pigments in the paint were also studied. The instruments specifically relevant to their analysis and identification included the stereomicroscope, polarizing light microscope (PLM), scanning electron microscope equipped with an energy dispersive spectrometer (SEM-EDS), ultraviolet microscope (UV), and the Raman spectrometer. With these five instruments and documentary research, a total of eight pigments was identified in the brownish gray prime paint. Of the eight, only one, zinc white, is a manufactured pigment. The other seven are all crushed minerals. The yellow, orange, and red pigment grains are zincite, and the black pigment is franklinite. The colorless pigments identified include willemite, tephroite, calcite, dolomite, and barite. The source of the franklinite, zincite, willemite, and tephroite could only have been the orebodies associated with the Franklin-area mines because they do not occur anywhere else as an associated group of minerals.

A brief explanation of the instruments and the microanalytical techniques used to identify these pigments and relevant findings derived from the analyses follows. Descriptions of the eight minerals are presented in Table 1. There is an extensive body of information on all of them in numerous mineralogical references.

Stereomicroscope. The stereomicroscope was used to evaluate the brownish gray color; to observe its layer structure and coarsely ground yellow, orange, red, and black particles; and to do preliminary microchemical tests, including using the reagent sodium sulfide (Na_2S) as described by Perrault for the detection of lead in the paint layer.[5] The results of this test were negative.

Polarizing light microscope. The PLM was used for further microchemical tests. Chamot and Mason describe many quick and reliable microchemical tests carried out on a microscope slide that can be used for detection of ions of elements in paint pigments.[6] Microchemical tests with the PLM using potassium mercuric thiocyanate $[(K_2Hg(SCN)_4]$ on both the paint film and the individual colored and black pigment particles yielded precipitated feathery crosses and orthorhombic prisms — a positive result indicating the presence of zinc (Figs. 4 and 5).

A sample of the brownish gray paint film was mounted on a glass slide under a cover slip using Aroclor mounting medium, which has a refractive index of 1.66, in order to observe and measure, at magnifications ranging from 40X to 1000X, the physical and optical characteristics of both the colored and transparent particles, such as shape, size, color, refractive index, birefringence, and polarization colors. Transparent mineral particles, which were difficult to identify because of their similar characteristics, were either identified or confirmed using dispersion staining. This technique is used for identification of transparent particles when mounted in a

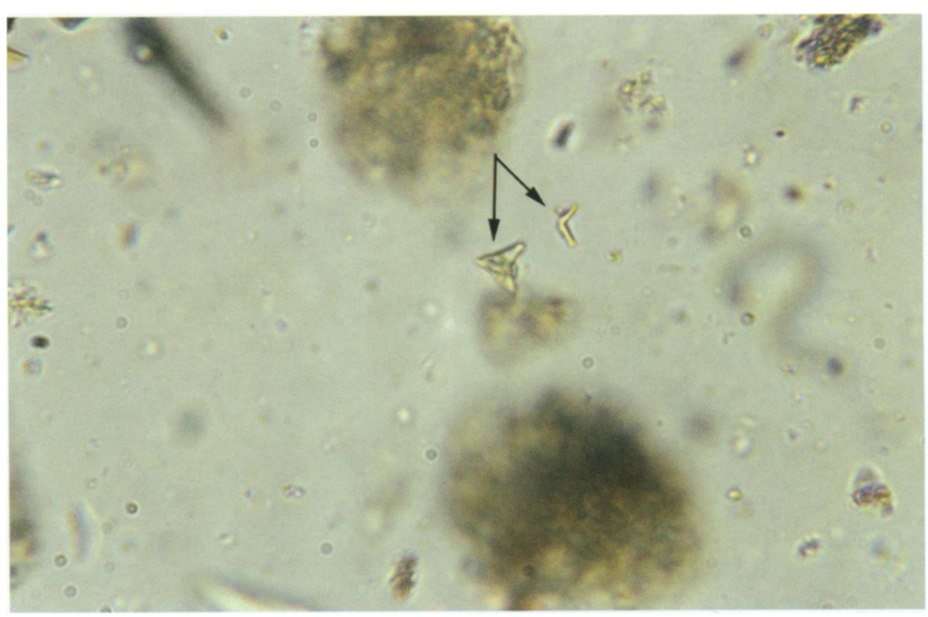

Fig. 6. Photomicrograph of zinc white crystals, showing characteristic skeletal two- and three-arm shapes (50X).

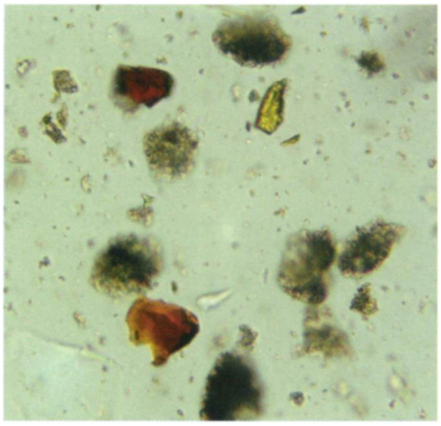

Fig. 7. Photomicrograph of pigments in the brownish gray prime paint from the enframements at the Capitol (50X). The yellow and orange particles are zincite, and the deep reddish brown particle is franklinite.

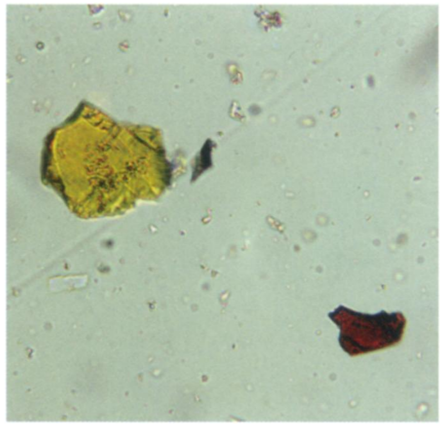

Fig. 8. Photomicrograph of pigments in the brownish gray prime paint from the enframements at the Capitol (50X). The yellow particle is zincite, and the deep reddish brown particle is franklinite.

medium of known refractive index and requires a special 10X dispersion-staining objective (DSO) equipped with an annular and a central stop in its back focal plane. Use of the stops produce dispersion colors on the particle boundaries.[7]

Many of the smallest particles in the paint show unique crystal forms of two, three, or four needles combined, like arms radiating from a central join: a distinguishing characteristic of the acicular form of zinc white pigment. These crystals typically look like there are only three joined needles because one of the four is almost always hidden from view; sometimes when broken, only two (a boomerang shape) or one (a single needle shape) are visible (Fig. 6).

The colored and black pigments from the paint exhibit conchoidal fractures and look like pieces of broken colored glass. Their refractive indices are all higher than the mounting media. The majority of the yellows and light oranges are bright yellow with crossed polars; the majority of the deep oranges and reds do not show birefringence. The pigments that are black by the reflected light of the stereomicroscope appear deep red to reddish brown in the transmitted light of the PLM, depending on the thickness of the conchoidally fractured grains, and they too do not show birefringence. These initial findings with the PLM suggested that the yellow, orange, and red minerals might be zincite and the black (or reddish brown), franklinite (Figs. 7 through 10). To confirm, more analyses were done.

With the PLM, some of the colorless particles in the paint film have one or both refractive indices higher than the mounting medium. In crossed polars all are birefringent, some more than others. Not all could be identified at this time. Those exhibiting low-order gray birefringence are barite. Several colorless pigments exhibit twinning striations that bisect the acute angle on well-formed rhombohedra and have strong interference colors characteristic of the carbonates, calcite, and dolomite. In Aroclor, dolomite has one refractive index higher and one lower than 1.66, whereas both refractive indices of calcite are lower. Dolomite was distinguished from calcite by observing its refractive indices relative to that of the mounting liquid (Fig. 11).

Two colorless particles were very difficult to distinguish and identify, willemite and tephroite. In plane-polarized light, the larger particles of willemite in the prime paint exhibit a very faint green coloration, while the smaller particles are colorless, as are tephroite particles.

With the dispersion-staining technique, both 10X and 15X oculars were used with the 10X DSO and the annular stop to observe the dispersion-staining colors on the borders of the transparent particles in the the paint from the Capitol. In Aroclor those particles with yellow borders are barite; orange red borders are calcite; faint blue are willemite; strong blue and golden yellow are dolomite. Those with black borders were identified later with the Raman spectrometer as tephroite. Reference samples of these colorless minerals were used for comparison using the DSO (Figs. 12 through 16).

Ultraviolet microscope. Many pigments fluoresce with characteristic colors under shortwave UV light. Some of the fluorescent minerals found in the Franklin-area mines include willemite, which fluoresces green; calcite, which fluoresces either red, pink, or orange red; and barite, which fluoresces white or bluish white.[8]

The ultraviolet microscope (UV) was used for detection and observation of fluorescent minerals (pigments), as well

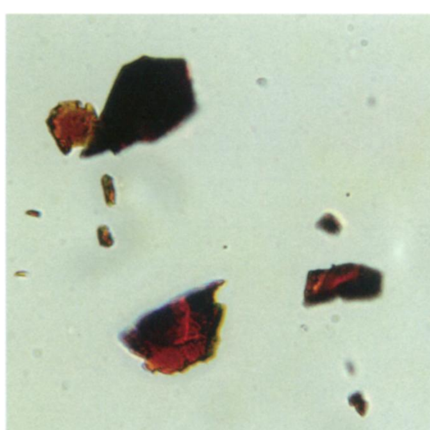

Fig. 9. Photomicrograph of crushed franklinite prepared as a reference sample from a mineral collection at Bryn Mawr College (50X).

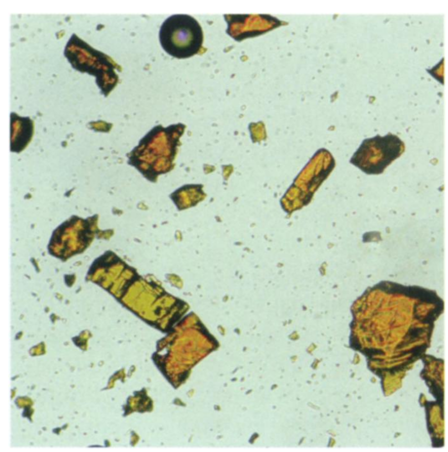

Fig. 10. Photomicrograph of crushed zincite prepared as a reference sample from a mineral collection at Bryn Mawr College (50X).

Table 1. Pigments and Minerals Identified in Brown Zinc Paint

Pigment or Mineral and (Formula)	Crystal System and Refractive Indices	Colors			Occurrence and Distinguishing Characteristics
		Reflected	Transmitted	Fluorescent	
Zinc Oxide (ZnO)	Hexagonal $\varepsilon = 2.02$ $\omega = 2.00$	White	Colorless	None	Manufactured pigment With PLM and SEM, acicular, skeletal shapes are like two, three, or four joined needles
Zincite *Zinc Oxide* (ZnO)	Hexagonal $\varepsilon = 2.02$ $\omega = 2.01$	Yellow-to-orange-to-red	Yellow-to-orange-to-red	None	Franklin-area mines Associated with franklinite, willemite, and calcite Yellow particles can demonstrate strong birefringence
Franklinite *Zinc Manganese Iron Oxide* $[(Zn,Mn^{2+},Fe^{2+})(Fe^{3+},Mn^{3+})_2O_4]$	Member of the spinel group of minerals and is not birefringent	Black	Deep red to reddish brown (depending on particle thickness)	None	Confined to Franklin-area mines; always associated with zincite and willemite
Willemite *Zinc Silicate* ($ZnSiO_4$)	Hexagonal $\varepsilon = 1.71$ $\omega = 1.69$	Varies in color from yellowish green, to red and brown, but is white when pure	Colorless to faint green depending on particle size	Light green	Franklin-area mines in association with franklinite and zincite Well known because of green fluorescence Faint blue borders with annular stop of DSO in 1.66 refractive-index liquid
Tephroite *Manganese Silicate* (Mn_2SiO_4)	Member of the olivine group of minerals Range of 1.77 to 1.82	Varies from gray to pink and is generally light brown or tan	Colorless	None	Ubiquitous at Franklin-area mines Best identified with Raman spectroscopy
Calcite *Calcium Carbonate* ($CaCO_3$)	Hexagonal $\varepsilon = 1.48$ $\omega = 1.65$	White	Colorless	Pink to red	Common Shows strong birefringence, exhibiting high-order polarization colors Well-formed calcite crystals will show twinning striations that bisect the acute rhomb angle
Dolomite *Calcium Magnesium Carbonate* ($CaMg(CO_3)_2$)	Hexagonal $\varepsilon = 1.50$ $\omega = 1.68$	White	Colorless	None	Found in Franklin-area mines, but not common Exhibits moderate to high birefringence. Shows high-order polarization colors and twinning striations on both short and long diagonals of well-formed rhomb crystals Can be differentiated from calcite by observing refractive indices relative to the mounting liquid, i.e., the Becke lines
Barite *Barium Sulfate* ($BaSO_4$)	Orthorhombic $\alpha = 1.636$ $\beta = 1.637$ $\gamma = 1.648$	Typically white but can vary to bluish white and yellow	Colorless	White to bluish white	Fairly common at the Franklin-area mines Pigment-sized particles show low-order white birefringence Yellow borders with annular stop of DSO in 1.66 refractive index liquid

as for the paint-layer structure. Only two of the pigments in the brownish gray paint layer fluoresced. One fluoresced light green, which is willemite, and the other fluoresced pale pink, which is calcite. These characteristics make UV examination one of the easiest ways to confirm the presence of these two minerals in a paint layer (Figs. 17 and 18).

Scanning electron microscope. The scanning electron microscope (SEM) used in this study is equipped with an energy dispersive spectrometer (EDS) accessory. In the SEM, a beam of electrons is used to scan a regular array of points on a specimen. An image is produced that derives from a detector that captures and analyzes the intensity of electron emissions from the specimen. In addition, using the EDS, X-ray emissions identify the elements present at each point analyzed.

The SEM was used both on the paint layers in cross section and on the individual yellow, orange, red, and black pigment particles (grains) that were picked out of the paint and mounted on a carbon stub.[9] A yellow zincite grain picked out from the prime paint for imaging with the SEM exhibited a cavity containing several of the skeletal two-and three-arm crystals of the processed zinc white pigment as observed with the PLM. Also in the image area was a 10-micrometer-long hexagonal prism-and-pyramid zincite crystal. This tiny crystal, when spot measured with EDS, was pure zinc oxide — no manganese. Spot measurements were also taken of individual pigment particles in a cross section of the brownish gray paint layer (Figs. 19 through 26).

The data gathered from the SEM analyses matches that presented in reference data for franklinite and zincite and was used to confirm the preliminary results gathered from the PLM analyses (Table 2 and Table 3).

Raman spectrometer. The Raman spectrometer is becoming a valuable analytical instrument for paint pigments. In Raman microprobe spectroscopy, a laser of a single wavelength is focused through a microscope objective onto a sample. The light that comes back is analyzed for its wavelengths and intensities, which provide molecular-structural information that can uniquely identify the compounds/minerals in the sample.[10]

The Raman spectrometer was used for analysis of the colored pigment particles that were picked out of a microscope prep of the brownish gray paint, as well as one of the colorless individual ones. (This analysis is in contrast to the colored grains that were picked out of a loose paint sample under the stereomicroscope for analysis with SEM.) The interpretation of the resulting Raman spectra and comparison to reference spectra was used to evaluate and confirm findings of franklinite and zincite obtained from the analyses using the SEM and the PLM.[11] The colorless particle that was difficult to identify and that has black borders with dispersion staining was identified as tephroite (Figs. 27 through 29).

When the individual colors of these eight pigments are crushed with the oil-paint films studied, they appear much like the brownish gray color of the paints used at the Capitol (Table 1).

Franklin and Sterling Hill Mines: Source of Minerals Used in Brown Zinc Paint

The analysis and identification of these pigments led to documentary research concerning the history of mid-nineteenth-century mining, manufacturing, and marketing of zinc oxide, zinc paints in general, and brown zinc paints in particular. The research disclosed that brown zinc paints were made by the New Jersey Zinc Company in the 1850s and that they contained crushed franklinite and zincite ore that the company mined in Franklin and Sterling Hill, Sussex County, New Jersey.

Iron initially attracted settlers to Sussex County in the eighteenth century. The principal ores used in early forges were haematite and magnetite. By the early 1800s experiments began with another black, local iron-bearing ore that looked like magnetite. The ore was called franklinite because of the location of its source.

Gradually franklinite, whose composition was known by 1819, was mined not only for its iron but also for zinc. The other zinc-containing minerals, which are intimately associated within the orebody, are zincite and willemite. The composition of zincite, the red mineral, was known by 1810. The composition of willemite, the fluorescent mineral, was not known until circa 1822-24, but willemite was not used as a zinc ore until 1866.[12]

These extraordinary zinc- and iron-containing minerals occur in deposits only in Franklin and Sterling Hill, New Jersey, and they were mined extensively for decades.[13]

What makes the Franklin-area mines even more intriguing and accordingly famous is that:

> approximately 10 percent of all mineral species known are found here. Such a claim cannot be made on behalf of any other locality on earth.... More valid mineral species have been described from this locality for the first time (69) than from any other locality. Also, about 10 percent of the minerals found locally are found nowhere else on earth; they are unique to these deposits....[14]

Had it not been for these deposits, the mines, and the innovative pigment-manufacturing processes associated with them, then the explosive growth of the zinc paint and ready-mixed-paint industries, may never have occurred in America.

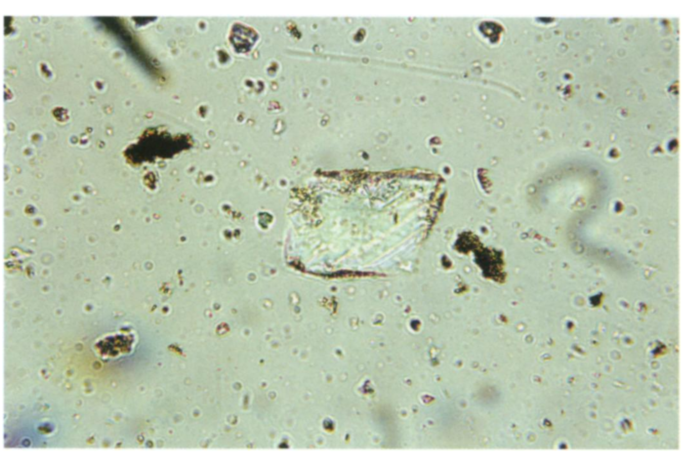

Fig. 11. Photomicrograph of a well-formed dolomite rhombohedron from the brownish gray prime paint from the Capitol, which exhibits characteristic twinning striations bisecting the acute angle (100X, plane polarized light).

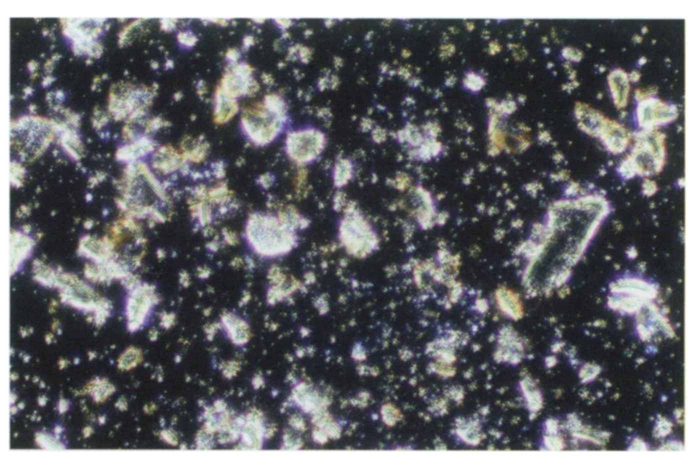

Fig. 12. Photomicrograph of a reference sample of crushed willemite using the central stop of the dispersion staining objective (50X). Dispersion staining colors on the borders of the willemite particles are a golden white.

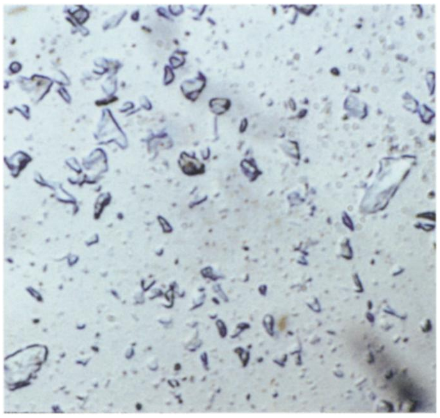

Fig. 13. Photomicrograph of a reference sample of crushed willemite using the annular stop of the dispersion staining objective (50X). Dispersion staining colors on the borders of the willemite particles are light blue.

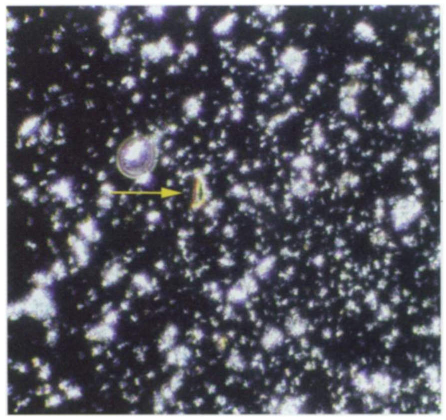

Fig. 14. Photomicrograph of a reference sample of crushed tephroite using the central stop of the dispersion staining objective (50X). Dispersion staining colors on the borders of the tephroite particles are white. Note the willemite particle in the center with the golden white borders (arrow). The presence of willemite was predicted by X-ray diffraction analysis of the reference sample prior to the mounting of the grains for microscopical examination.

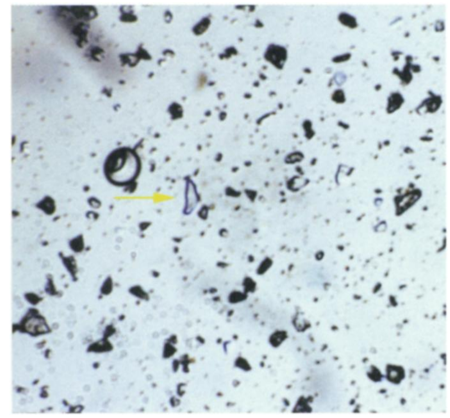

Fig. 15. Photomicrograph of a reference sample of crushed tephroite using the annular stop of the dispersion staining objective (50X). Dispersion staining colors on the borders of the tephroite particles are black. Note the willemite particle in the center with the light blue borders (arrow).

Manufacture of Zinc White Pigment

Zinc oxide, commonly known as zinc white, was manufactured and first introduced as an artist's pigment in France in the 1830s using the French, or so-called *indirect,* method. In the earliest process in France metallic zinc was first extracted from calamine, a mineral occurring in large deposits in Belgium.[15] In the early nineteenth century, mineralogist James Smithson discovered that the calamine was actually two distinct minerals: zinc carbonate and zinc silicate (hemimorphite).[16] The zinc metal was calcined in furnaces at very high temperature, producing fumes (white smoke) of pure white zinc oxide, which were collected.[17] This method became known as the French or indirect process because it involved two separate manufacturing procedures to obtain the zinc white pigment, zinc oxide. E. J. Leclaire and J. J. E. Barrnel of Paris, France, developed the process for which they were granted an American patent in this country in 1850.[18]

In America, however, the zinc-metal and zinc-paint industries did not emerge until the mid-1800s using the American, or so-called *direct,* method. It was developed by both accident and discovery. The zinc oxide was obtained directly by calcining the zinc ores — originally franklinite and zincite and, later, willemite — and trapping the resultant fumes in collection bags.[19]

The minerals, mining, inventions, discoveries, and manufacturing methods developed within a short period of time in the early to mid-1800s and together set the stage for the paint industry to develop and ultimately address, with zinc oxide and zinc-based paint, the serious concerns relating to the health hazards associated with the manufacturing of white lead pigment and application of lead-based paints.

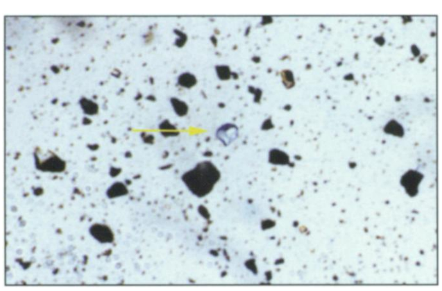

Fig. 16. Photomicrograph of paint sample from brownish gray prime paint from the Capitol using the annular stop of the dispersion staining objective (50X). Notice how the small particle of willemite with light blue borders, in the center of the prep, is clearly discernable amidst the other pigments in the paint layer, which appear black.

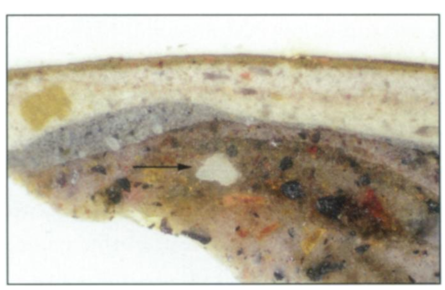

Fig. 17. Paint-layer cross-section photomicrograph (reflected light) of Capitol paint sample S-312-2, from the architrave of the entrance doorway. The lowest two layers are the original brownish gray, zinc-based shop prime paints with the characteristic colored-pigment agglomerates. The yellow, orange, and red particles are zincite; the black pigment particles are franklinite. Note the large white pigment particle (arrow).

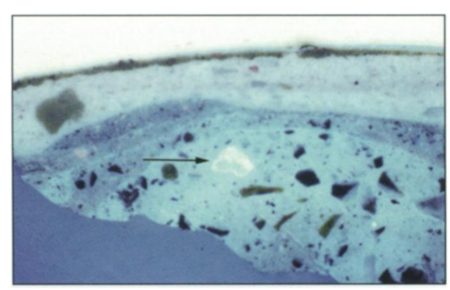

Fig. 18. Paint-layer cross-section photomicrograph (short-wave ultraviolet light) of Capitol paint sample S-312-2. Note the characteristic light green fluorescence of the large willemite particle (arrow).

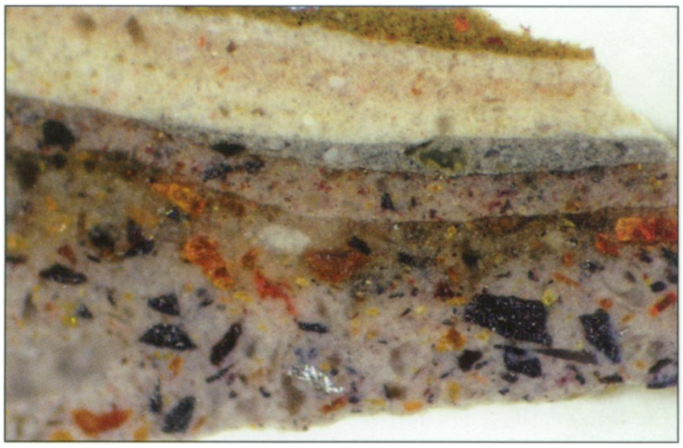

Fig. 19. Paint-layer cross-section photomicrograph of Capitol paint sample S-312-2. The lowest layer (0.57mm thick) and the one above it are the original brownish gray, zinc-based shop prime paints, which exhibit the characteristic large, colored-pigment agglomerates. The yellow, orange, and red particles are zincite; the large black pigment particles are franklinite. This image was used as a map for the subsequent SEM EDS imaging and analysis.

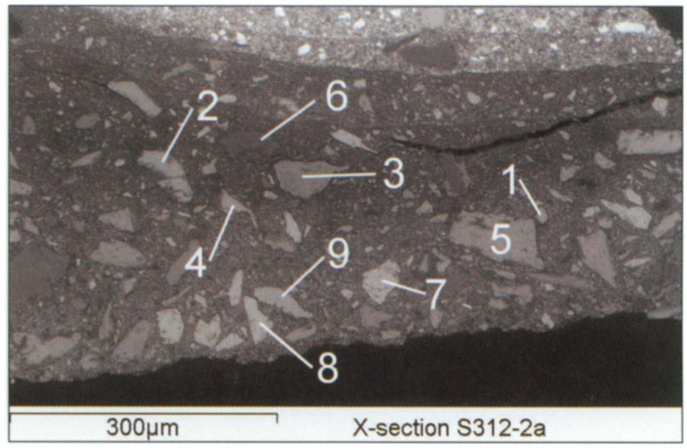

Fig. 20. SEM-EDS image of the paint-layer cross section of Capitol paint sample S-312-2. Using the point-and-i.d. option of the instrument, nine pigment particles were measured to collect data on their elemental composition. The results are presented in Table 2.

Zinc-Based Paint and the New Jersey Zinc Company

As the two competing manufacturing methods for zinc oxide became established in France and in New Jersey, the demands for zinc paint grew in Europe and in America.[20] Early French zinc paints were not widely accepted because of problems with body and brittleness.[21] At the same time, competition was taking shape in America. In New Jersey, about 1830, Dr. Samuel Fowler and George Ballou succeeded in making a bluish white zinc-based paint utilizing zinc oxide obtained from zincite, and they used it to paint Dr. Fowler's mansion at Franklin. This project was probably the first application of zinc paint in this country and preceded by several years the discoveries of Le Claire and Sorel in France in the late 1830s.[22]

Fig. 21. Franklinite – zincite ore from a mineral collection of the Geology Department of Bryn Mawr College. The red, orange, and yellow is zincite (ZnO); the black is franklinite $[(Zn,Mn^{2+},Fe^{2+})(Fe^{3+},Mn^{3+})_2O_4]$; and the white is calcium carbonate ($CaCO_3$).

As the industry developed, the marketing of zinc paints emphasized not only the health advantages over lead paints but also its rust-inhibitive qualities, once they were recognized.[23] This latter quality (plus its economy) addressed the rising demand for coatings for cast iron in the construction of commercial buildings and, most likely, was a consideration for Janes, Beebe and Company to use zinc-based paint to prime the cast-iron enframements for the U.S. Capitol.

In 1852 the New Jersey Exploring and Mining Company and the Sussex Zinc and Copper Mining and Manufacturing Company completed their merger (initiated in 1851) into the New Jersey Zinc Company and thereby took control of the major Franklin and Sterling Hill area mines. The New Jersey Zinc Company became the major manufacturer of zinc and zinc oxide as well as zinc paints in America, although other companies, e.g., the Passaic Mining and Manufacturing Company, also produced zinc oxide paint.[24]

The New Jersey Zinc Company not only mined the ore but also manufactured the zinc oxide pigment and the paints at their plant in Newark starting in the late 1840s. In addition, they experimented with manufacturing paints made with the crushed ore, franklinite and zincite, and they successfully marketed them in a variety of colors including orange, stone-color, light brown, brown, dark brown, black, and delicate blue. Documentary sources suggest that the company made these colored paints with the crushed ore only in the 1850s, starting as early as 1850. This fact is significant in that it may help establish dates of any paint identified as containing the crushed ore of franklinite and zincite. It is also very important because Kuhn mistakenly reported that the red-colored zinc ores were "useless as a pigment because of impurities" and "were never used."[25]

In 1850 geologist Dr. C. T. Jackson summarized the connection between the zinc-containing ore at the Franklin-area mines, the New Jersey Zinc Company, and the brown and colored zinc paints they were manufacturing with the crushed ore:

> During the past month I visited the celebrated mine of red oxide of zinc and Franklinite, in Franklin,... N.J., and subsequently...examined the zinc furnace and paint mills of Newark.
>
> The red zinc ore of Franklin and Sterling has been known for many years. It was originally mined by Lord Sterling, anterior to the American Revolution, under the mistaken idea that the ore was red oxide of copper....
>
> Recently, a few enterprising gentlemen of New York have undertaken to work the mine, with a view to the manufacture of zinc white, that beautiful and unchangeable paint lately

Table 2. SEM-EDS Data

Spectrum	C	O	Mg	Al	Si	S	Cl	Ca	Ti	Mn	Fe	Zn	Ba	Pb	Total
1: Yellow	40.21	18.14		0.19	0.40		0.28	0.35	0.29	0.69	1.84	36.73		0.89	100.00
2: Orange	34.29	24.86		0.36	0.44	0.24	0.32	0.43		1.11	0.75	36.46	0.74		100.00
3: Dark orange	26.36	40.83		0.30	0.65	0.63	0.23	0.33		0.34	25.30	4.22	0.81		100.00
4: Red	35.33	21.70		0.20	0.37	0.21	0.16	0.42		1.14	0.97	38.79	0.71		100.00
5: Black	27.19	28.30	0.22	0.16	0.28		0.20	0.35	0.19	5.35	25.30	12.47			100.00
6: Clear	32.47	30.27			0.33	6.13	0.39	1.53	1.31		1.00	4.87	21.70		100.00
7: Clear	28.05	29.93			0.29	6.65	0.25	0.29			1.55	3.82	29.18		100.00
8: Reflective	31.25	8.63			1.08	0.45	0.19	0.31		0.84	51.00	4.55	1.70		100.00

Cross section S-312-2a. Particles 1, 2, and 4 are zincite; 3 and 5 are franklinite, 8 may be franklinite or magnetite, and 6 and 7 are barytes. All elements analyzed (Normalised). All results in weight%.

Table 3. SEM-EDS Data

Particle	Manganese	Iron	Zinc	Oxygen	Total
Black	10.24	48.22	19.88	21.66	100
Red	3.07		77.16	19.78	100
Orange	2.47		77.78	19.75	100
Yellow			80.34	19.66	100

All results in weight%
Processing Option: Oxygen by stoichiometry (Normalized)

discovered and applied in France, as a substitute for white lead.

On our return from the mine we visited the furnace and mills in Newark, N.J. This furnace was erected for the purpose of manufacturing white oxide of zinc, and the mills are used for grinding the Franklinite and red oxide of zinc.

Not only is the zinc ore used for making zinc white, or metallic zinc, as may be required, but the ground ore itself is made into an orange colored paint of value. And the Franklinite is ground and used for a brown paint.[26]

Dr. Jackson made a similar report in December 1850 but added:

The Astor House in New York, and Mr. Alger's house in this city, are painted with zinc white. It is ground in spirits of turpentine, and mixed with varnish to give it consistence.

Franklinite alone makes an excellent grayish-brown paint, very permanent, and drying quickly. The red oxide of zinc also makes an excellent quickly drying red paint. By adding lamp black, Prussian blue, &c. several shades of color may be readily obtained, free from the disadvantages of lead.[27]

The New Jersey Zinc Company published numerous reports that described the success of the company's efforts in making, marketing, and selling zinc paints. One from 1852 explains that:

The sales of Paint for the last ten months have yielded the sum of $185,577.28 and the Company's sales agents state distinctly that not only have they found ready sale for all the dry and ground paints produced, but that as early as May last the demand exceeded the supply.... The sale of Zinc Ore above named, was for the purpose of being ground with brown paint. Whether it would sustain that price for conversion to white oxide, cannot now be decided; but the manufacturing establishment of this Company, if separated from the mining department, could pay handsome dividends upon the capital necessary to carry it on....

The favor with which Zinc paints are received, and the rapidity with which the demand is increasing, indicate with unerring certainty, the time is near at hand, when a single establishment, even possessing ten times the manufacturing facilities we now use, will prove inadequate to its supply.[28]

Advertisements for Brown Zinc Paint

The brown and other colored zinc paints were initially manufactured by the New Jersey Exploring and Mining Company, which then merged into the New Jersey Zinc Company. Advertisements by both companies from the early 1850s describe the paint products and their intended usage. Primarily they were advertised as prime paints for iron that was manufactured for the architec-

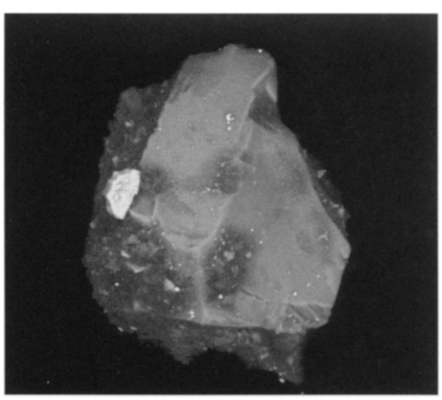

Fig. 22. Individual pigment particles were analyzed with SEM-EDS. This black particle is the only one containing iron; it is the franklinite $[(Zn,Mn^{2+},Fe^{2+})(Fe^{3+},Mn^{3+})_2O_4]$. The approximate particle width is 60 µm. See also Table 3.

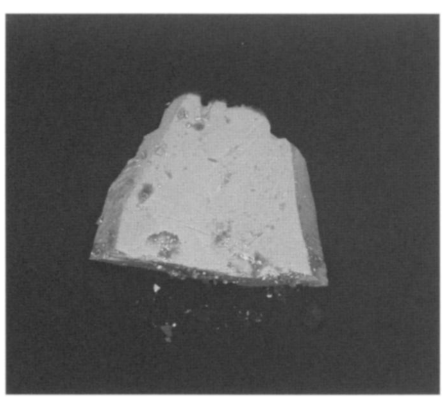

Fig. 23. This red particle contains zinc, manganese, and oxygen: it is zincite (ZnO). Note the relationship of manganese to the color of the zincite particles. The approximate particle width is 200 µm. See also Table 3.

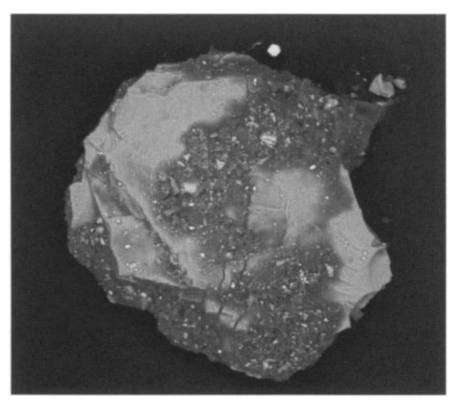

Fig. 24. This orange particle is also zincite. The approximate particle width is 125 µm. See also Table 3.

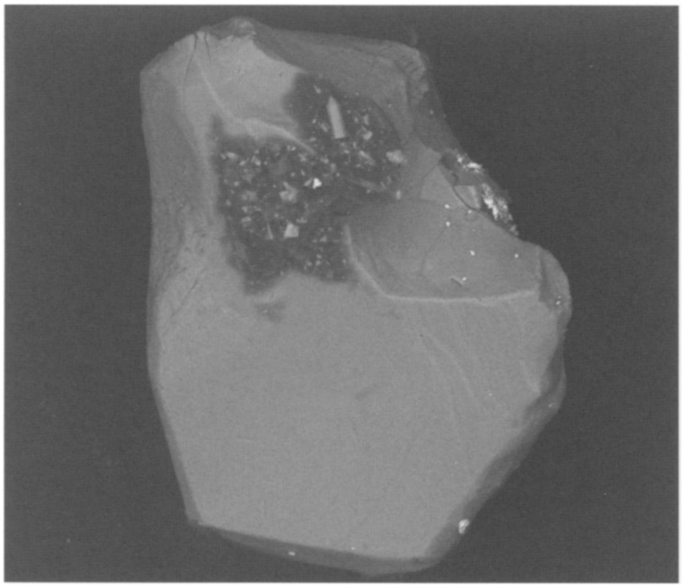

Fig. 25. This yellow particle is also zincite. The approximate particle width is100 μm. The depression (dark area) in the upper portion of this image is enlarged in Fig. 26. See also Table 3.

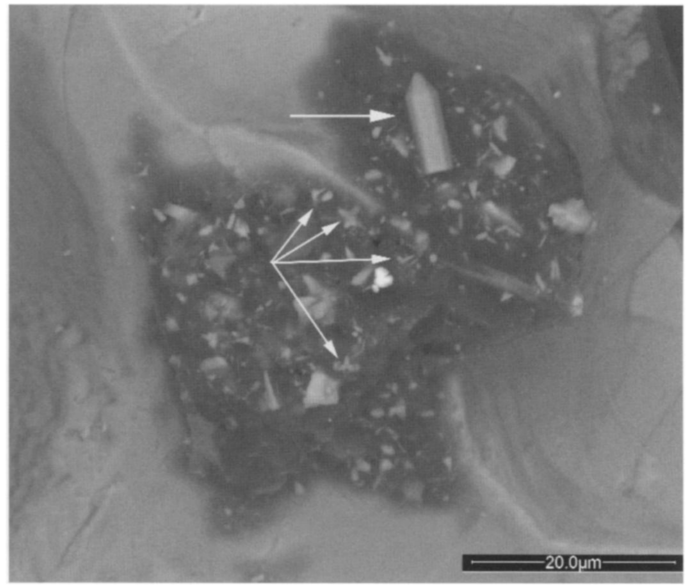

Fig 26. SEM image of a particle residing in a depression of the yellow pigment particle, zincite, showing a tiny crystal of pure zinc oxide (prism and pyramid) (arrow) and two- and three-arm crystals of zinc white (arrows).

tural, industrial, shipping (maritime), and railroad markets. The printed ads stressed the economical value of the paints, as well as their rust-inhibitive and adhesive qualities. The ads also state that the brown zinc paint was excellent for use as a finish coating for wood on houses. Both companies used sales agents for marketing their paints, and they are identified in the ads.

One of the earliest advertisements, which is undated but is most likely from 1850 or 1851 and reproduced by Dunn, is for "Zinc White Paint."[29] This ad is by S. T. Jones and Company, agents for New Jersey Exploring and Mining Company, No. 53 Beaver Street, N.Y. Near the bottom of this ad, there is the following description: "Brown zinc paint, requires no dryer; to black, a little may be added."[30]

One of the most descriptive of the paint advertisements is for the New Jersey Zinc Company. Although it is undated it is probably from before 1854. It has the address of sales agents Manning & Squire in New York. In part it reads:

> Brown and Black Zinc Paints, which are sold at the low price of 5½ cents per pound in oil, are the nearest to FIRE-PROOF of any paints in use. They are admirably adapted for painting roofs and all metallic surfaces, particularly iron, which they perfectly protect from rusting, whether exposed to heat or weather. Their use has been adopted in the Navy Yards at Brooklyn and Philadelphia, in the Novelty Works and other large foundries in the vicinity. They possess great drying qualities, so that, in a few hours from their application, they form a hard metallic coating upon wood, brick or stone, without the use of any siccative. They have been found to resist the action of salt water better than red lead, hence their value for marine purposes. Two coats of these Black and Brown Paints will cover as well as three coats of any preparation of Lead.[31]

The ads above do not describe how the paints were packaged for sale. However, the advertisement below from an 1854 issue of the *New York Tribune* mentions both dry and paste form and that the paste was packaged in kegs. A copy of this ad was published in the history of the New Jersey Zinc Company. It is probably one of the most

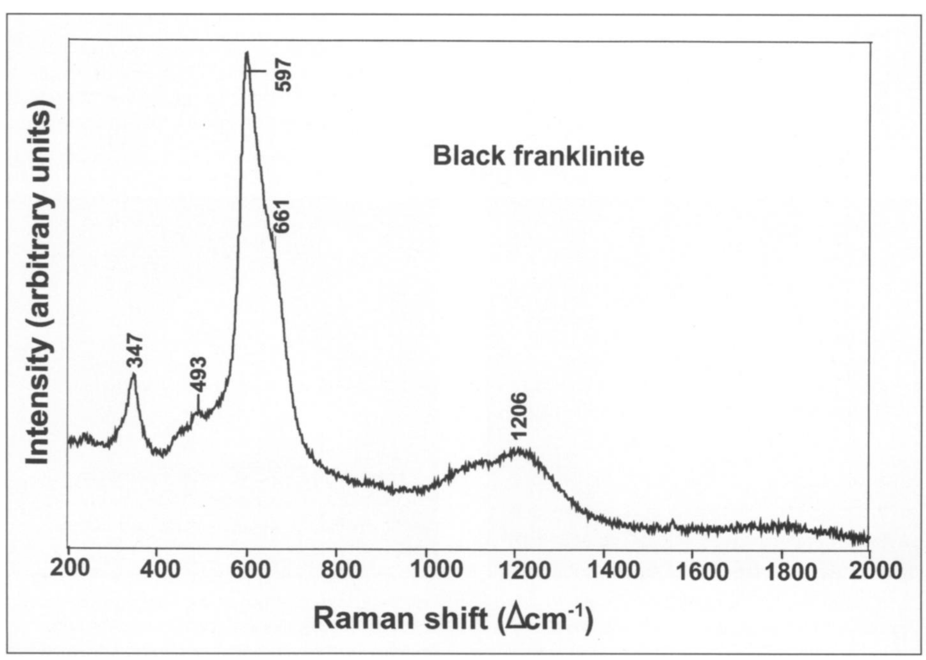

Fig. 27. Raman spectrum of reference sample of the mineral franklinite. Note the characteristic labeled peaks at 347, 493, 597, 661, and 1206. Spectrum by Jill Dill Pasteris.

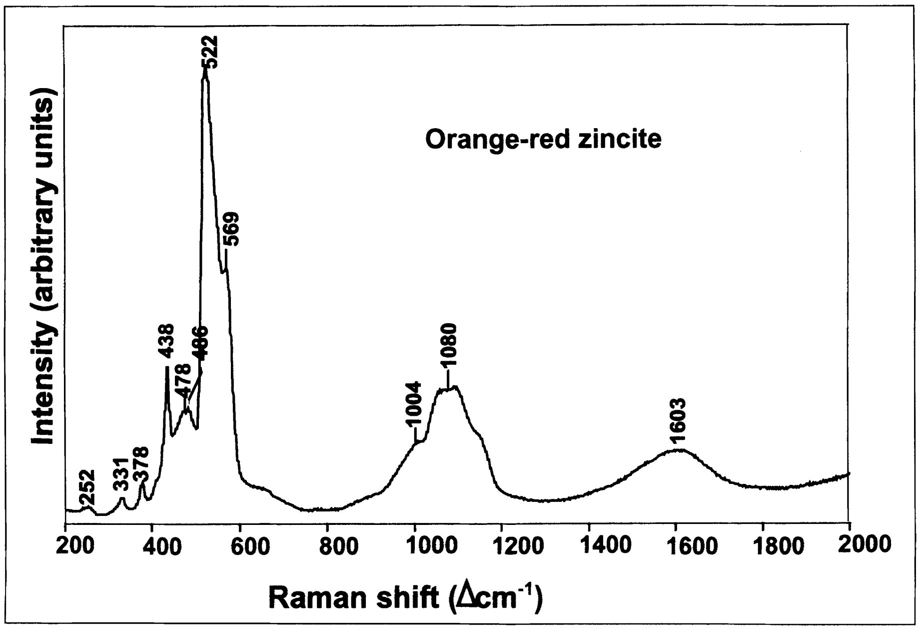

Fig. 28. Raman spectrum of an orange-red reference sample of the mineral zincite. Note the characteristic labeled peaks at 438, 478, 522, 569, 1080, and 1603. Spectrum by Jill Dill Pasteris.

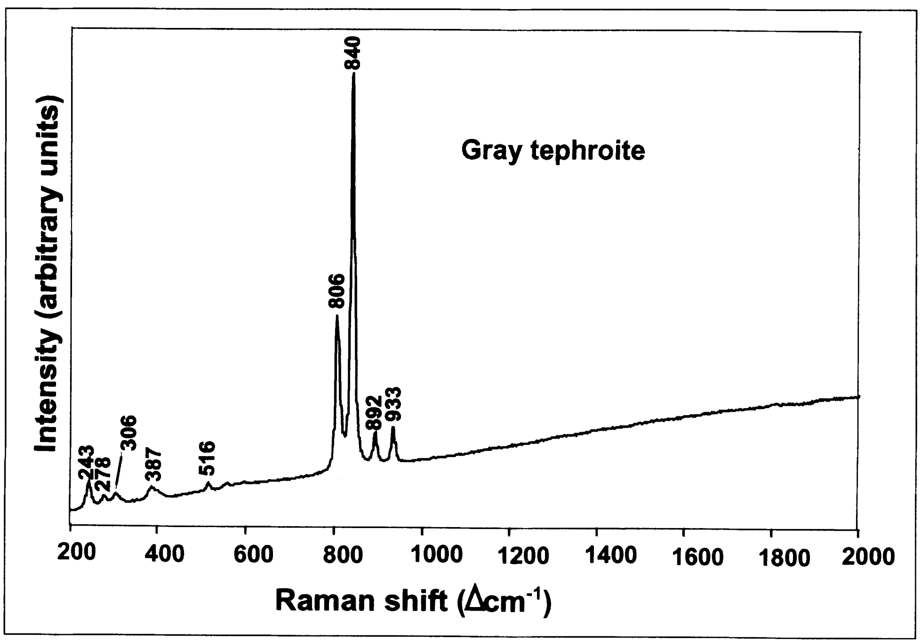

Fig. 29. Raman spectrum of reference sample of the mineral tephroite. Note the characteristic peaks at 806 and 840. Spectrum by Jill Dill Pasteris.

valuable historic documents, not only because of the product descriptions and date but also because the ad relates the ore from Franklin to the paints of the New Jersey Zinc Company.

ZINC PAINTS. – The NEW JERSEY ZINC COMPANY having greatly enlarged their works and improved the quality of their product, are prepared to execute orders for their SUPERIOR PAINTS.

Their WHITE ZINC, which is sold dry or ground in oil, is warranted PURE, and unsurpassed for BODY and UNIFORM WHITENESS.

A method of preparation has recently been discovered which enables the Company to warrant their Paints to keep fresh and soft in the kegs for any reasonable time. In this respect their Paints will be superior to any other on the market.

Their BROWN ZINC PAINT, which is sold at a low price and can only be made from the Zinc Ores from New-Jersey, is now well known for its protective qualities when applied to iron or other metallic surfaces.

Their STONE-COLOR PAINT possesses all the properties of the Brown, and is of an agreeable color for painting cottages, depots, outbuildings, bridges, & c. Dealers supplied on liberal terms by MANNING & SQUIER, Agents, 165 Washington St., N.Y.[32]

The advertisements and the marketing of the zinc paints was extremely successful. The zinc-paint industry was born and flourished in the 1850s. The use of the crushed ores of franklinite and zincite as a paint pigment appears to have been a wide-scale experiment, and it was a triumph. It is unknown how long the company continued to manufacture paints using the crushed ores to make the brown and colored zinc paints. If it was short lived, changes in manufacturing could be attributed to economy of scale. As the refining processes for iron improved, it may have become more profitable to use the franklinite for both its iron content and zinc content rather than just for its unprocessed use as a pigment in an inexpensive, zinc-based prime paint. If the end date for its use as a crushed ore can be established, then it will create a significant benchmark for dating any paint layer in which franklinite and zincite are identified.

Conclusions

The analyses and research disclose that the 1850s brownish gray paint used as a primer on the cast-iron enframements at the Capitol and applied in the shop by their New York manufacturer, Janes, Beebe and Company, is the brown zinc paint manufactured by the New Jersey Zinc Company. The paint was made at their plant in Newark and advertised by their agents, Manning and Squier, and it was made from the crushed ore of franklinite and zincite, which do not occur anywhere else but in Franklin and Sterling Hill, New Jersey.

The documents cited indicate that distribution and use of the colored zinc paints made in the 1850s were extensive, so their use at other sites may be discovered. Perhaps some of the other colors described and advertised may be identified also. It is likely that most especially the dark brown, blue, and black were marketed to and purchased for use on industrial, railroad, and maritime equipment.

The research also discloses that in recent artists' materials publications there is no reference to these minerals for use as paint pigments — they have been overlooked. There are probably two important reasons for this oversight. One is that the paints made with the crushed franklinite or zincite ore were targeted for uses related to architecture, industry, shipping, and railroads, not the arts. Most paints, which are studied for their pigment composition, are those associated with the fine arts, for the purposes of documentation and/or authentication. The second reason, related to the first, is that most historic architectural paints are studied only for layer structure and color and occasionally the paint vehicle. Seldom is emphasis placed on the value of determining, through microanalysis, the pigment composition of architectural paints.

This research, which was in part funded by the United States Capitol Historical Society's Fellowship, underscores the potential of gaining new information by observing, noting, and analyzing the pigment composition of historic architectural paints, not just their color or vehicle. Pigment analysis can easily and economically become a part of comprehensive analyses related to historic architectural paints. The goal (and dividends) of such an effort would be to expand the information available in paint-pigment references by including, in future publications, the pigments used in paints for engineered and architectural structures (including wallpaper), as well as for industrial and maritime equipment. As it is now, funded research and publications focus mainly on information concerning artists' pigments. Thus, the readily available information at present is limited.

In addition to the analyses of the pigments, this research project uncovered the details of the history and intriguing connections between the mines, the minerals, and the individuals who made it all happen. The history of the Franklin and Sterling Hill area mines and the zinc, as well as the fields of mineralogy, economic geology, and the history of New Jersey, are inextricably linked. The mines in Franklin and the innovative manufacturing processes in Newark spawned the zinc pigment, zinc paint, and ready-mixed-paint industries in nineteenth-century America.[33]

After 100 years of intense operations, the mines finally were no longer economically viable. They were closed over a period of time in the mid- to late twentieth century. By that time 33 million tons of ore had been removed from the ground, and many tons of iron, zinc, and zinc paint were made.[34] Today, in testament to this rich history, museums at both sites are open to provide visitors ample opportunity to explore and become enriched by the fascinating story behind the Franklin and Sterling Hill mines and their important contribution to an American industrial legacy.

FRANK S. WELSH is president of Welsh Color and Conservation, Inc., Bryn Mawr, Pennsylvania. He received a Charles E. Peterson Fellowship in 1992-1993, was appointed research associate at Bryn Mawr College in the geology department in 2004, and was awarded a research fellowship in 2005 from the United States Capitol Historical Society.

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Notes

1. Susan Brizzolara Wojcik, "Thomas U. Walter and Iron in the United States Capitol: An Alliance of Architecture, Engineering, and Industry" (PhD diss., University of Delaware, 1998), 149–150.

2. Ibid., 309. The primary contact for architect Thomas U. Walter at Janes, Beebe and Company was Charles Fowler, originally from Connecticut.

3. In the summer of 2006, following the discovery of the brown zinc prime paint at the U.S.

Capitol, the identical brownish gray, zinc-based paint was identified on the exterior wood trim at Glen Alpin, an 1847 Gothic Revival masonry house in Harding Township, New Jersey. The house is located about 20 miles from Newark and 30 miles from Franklin and was undergoing a roof restoration that included repair and repainting of the cornice. As part of the cornice repair, the historic paints were sampled and analyzed to determine the layers and original colors. The results of the investigation and microanalysis of the paints from the cornice and bargeboards disclosed that the original 1847 paint finish was a medium brown, sand-finish paint. The sand was thrown onto and adhered to the paint before it dried to produce an appearance that imitated red-brown sandstone, the type and color of stone that surrounds the windows of the house. The second finish paint, dating to about 10 years after the initial paint layer, i.e., late 1850s, was another sand-finish paint layer but of a different color — a brownish gray paint with large (0.1 – 0.25) grains of yellow, orange, red, and black pigment particles. Subsequent comparison of this paint layer to those from the U.S. Capitol revealed that the Glen Alpin paint was identical in color and composition to that used as the shop prime on the late 1850s cast-iron enframements made by Janes, Beebe and Company.

4. The analysis of historic architectural paints generally focuses on layers and colors but seldom on pigments used to make the paint. On the other hand, the analysis of the paints used by artists almost always includes the study and identification of the pigments used. Hence, there are numerous authoritative references devoted to artists' pigments that typically serve as the principal sources of readily available information for those studying architectural paint pigments. Not all architectural paint pigments, however, are included in the artists' pigment references. Two of these are franklinite and zincite (and other associated minerals) that were used to make what was marketed in this country in the 1850s as brown zinc paint.

5. Carole L. Perrault, "Techniques Employed at the North Atlantic Historic Preservation Center for the Sampling and Analysis of Historic Architectural Paints and Finishes," *Bulletin of the Association for Preservation Technology* 10, no. 3 (1978): 24.

6. Émile Monnin Chamot and Clyde Walter Mason, *Handbook of Chemical Microscopy,* vol. 2, 2nd ed. (New York: John Wiley and Sons, 1940), 31–33.

7. Walter C. McCrone, Lucy B. McCrone, and John Gustav Delly, *Polarized Light Microscopy* (Ann Arbor: Ann Arbor Science Publishers, 1979), 169.

8. Pete J. Dunn, *Franklin and Sterling Hill, New Jersey: The World's Most Magnificent Mineral Deposits* (Alexandria, Va.: Pete J. Dunn, 2004), 1: 285.

9. Joseph G. Barabe at McCrone Associates, Westmont, Ill., did the initial SEM-EDS analyses. Additional and more extensive SEM-EDS analyses were done at West Chester University, CMIRT, with technical director, Frederick C. Monson.

10. Jill Dill Pasteris, Department of Earth and Planetary Sciences, Washington University, St. Louis, Missouri, email communication with the author, April 4, 2007.

11. Several colored and one transparent pigment particles were isolated and analyzed with Raman spectrometer by McCrone Associates. Jill Pasteris, whose specialties and interests include Raman spectroscopy and the minerals at Franklin, contributed to the interpretation of McCrone Associates' Raman spectra of the particles that Joseph G. Barabe isolated from the preparation of the grayish brown paint layer from the Capitol. Dr. Pasteris identified the colorless mineral particle as tephroite and also prepared reference spectra of franklinite, zincite, and tephroite.

12. Dunn, *Franklin and Sterling Hill, New Jersey,* 1: 112, 185.

13. Ibid., 185.

14. Ibid., 67.

15. Arthur Channing Downs Jr., "Zinc for Paint and Architectural Use in the 19th Century," *Bulletin of the Association for Preservation Technology* 8, no. 4 (1976): 81.

16. *Encyclopedia Britannica,* 11th ed. online via JRank, s.v. "Calamine," http://encyclopedia.jrank.org/BUN_CAL/CALAMINE.html (accessed Febr. 2, 2007).

17. Gettens and Stout, 177.

18. Downs, "Zinc for Paint and Architectural Use in the 19th Century," 83.

19. Dunn, *Franklin and Sterling Hill, New Jersey,* 1:186–187. Dunn cites G. C. Stone, "Early History of the N.J. Zinc Company," *Zinc* [magazine of the New Jersey Zinc Company] 1 (1916): 36–39; 99–105. W. R. Yates, "Samuel Wetherill, Joseph Wharton, and the Founding of the American Zinc Industry," *Pennsylvania Magazine of History and Biography* 98, no. 4, (1974): 469–514. W. R. Yates, *Joseph Wharton, Quaker Industrial Pioneer* (Bethlehem, Pa.: Lehigh Univ. Press, 1987), 413. J. P. Wetherill, "The Mine Hill Ore Deposits in New Jersey and the Wetherill Concentrating Plant," *Engineering and Mining Journal* 64 (1897): 65–66, 98–100. G. W. Baker, *Geological Report on the Mineral Belt of Sussex County, N.J., Sterling Hill-Mine Hill* (Philadelphia: Manganese Iron Ore Company, 1881).

20. Almost all of the modern published references concerning zinc white pigment concern the use of zinc white as an artists' pigment rather than as an architectural or industrial paint pigment. Such sources include the following: Philip Ball, *Bright Earth: Art and the Invention of Color* (New York: Farrar, Straus and Giroux, 2002), 152–153; Rutherford J. Gettens and George L. Stout, *Painting Materials: A Short Encyclopedia* (New York: Dover Publications, 1966), 177; R. D. Harley, *Artists' Pigments: c. 1600–1835, A Study in English Documentary Sources,* 2nd ed. (London: Butterworth Scientific, 1982), 176–180; Hermann Kuhn, "Zinc White," in *Artist's Pigments: A Handbook of their History and Characteristics,* vol. 1, Robert L. Feller, ed. (Washington: National Gallery of Art, 1986), 169–186. Gettens and Stout say sphalerite was used in the American process but do not say what was used in the French process. Does this suggest that they were not aware of the mines at Franklin and the early use of zincite and franklinite and willemite from the New Jersey Zinc Company to make the zinc metal and zinc oxide? Or were they referring to zinc and zinc oxide production at other mines in more recent times?

Because of the focus on zinc white as an artists' pigment, one must turn to other less-readily available sources for an accurate history of the minerals and mines which were the sources for American-made zinc white relating to architectural paints in the mid- to late nineteenth century. These sources include Arthur Channing Downs Jr. "The Introduction of American Zinc Paints, ca. 1850," *Bulletin of the Association for Preservation Technology* 6, no. 2 (1974): 36–37; Arthur Channing Downs Jr., "Zinc for Paint and Architectural Use in the 19th Century," 80–99; Pete J. Dunn, *Franklin and Sterling Hill, New Jersey,* 2 vols.; Pete J. Dunn, *Mine Hill in Franklin and Sterling Hill in Ogdensburg, Sussex County, New Jersey: Mining History, 1765–1900. Final Report: Part One,* (Alexandria, Va.: Pete J. Dunn, 2003), vols. 2 and 3; Pete J. Dunn, *Prospectuses of 19th-Century Mining Companies at Franklin and Sterling Hill, New Jersey* (Alexandria, Va.: Pete J. Dunn, 2004); New Jersey Zinc Company, *The First Hundred Years of New Jersey Zinc Company: A History of the Founding and Development of a Company and an Industry, 1848–1948* (New York: New Jersey Zinc Company, 1948), 15; Maximilian Toch, *The Chemistry and Technology of Paints* (New York: D. Van Nostrand Company, 1925), 36–40; Theodore Zuk Penn, "Decorative and Protective Finishes, 1750–1850: Materials, Process and Craft," *Bulletin of the Association for Preservation Technology* 16, no.1 (1984): 3–46.

In addition, in the more recently published references on artist materials and pigments, the zinc ores — franklinite and zincite — are not mentioned as the original minerals used for American-made zinc oxide. Instead, only sphalerite is identified as the source. For example, Gettens and Stout on p. 177 in *Painting Materials* say that "in the American or direct process, zinc ores, principally sphalerite (zinc blend, ZnS), are mixed with coal coke and burned, and the white smoke of zinc oxide is collected in suitable chambers." Philip Ball on p. 152 in *Bright Earth* summarizes that "this 'direct' or American process uses the zinc ore itself (sphalerite) as the raw material." Only Hermann Kuhn on page 176 in his chapter "Zinc White" in *Artists' Pigments* correctly mentions that "the American or direct process involves the heating of zinc ores, usually various combinations of franklinite, zincite, and willemite."

21. Despite these problems with body and brittleness, early French zinc paints were imported to America from Belgium. Dunn, *Mine Hill in Franklin and Sterling Hill,* 2: 246.

22. Ibid., 2: 248. Dunn references G. B. Heckel, "The Story of the New Jersey Zinc Company," *Drugs, Oils and Paints* 49 and 50 (1934).

23. Pete J. Dunn, *Prospectuses,* 80. The pent-up need for an alternative to white lead pigment was immense. Few who worked in the lead pigment factories avoided lead poisoning, and few who applied lead-based paint avoided what was known as painter's colic. Dunn references the Consolidated Franklinite Company, "Superiority of Zinc Paints over White Lead, with testimony relating thereto: History of and Documentary Evidence Relating to the Property of the Consolidated Franklinite Company," and quotes Samuel Wetherill, patent holder and manufacturer:

I have been engaged in the manufacture and sale of white lead for fourteen years. Laboring men, after being engaged three months in the manufacture of white lead, lose their color, grow very pale, and, to an experienced eye, men engaged at this occupation can be picked out of a crowd, by their extreme pallor. The first difficulty is great costiveness, which is followed by loss of appetite – blueness around the gums next the teeth, and excruciating pains (spasmodic) in the stomach; besides this disease – lead colic – they are subject to paralysis, swelling of the joints, resembling chronic rheumatism. The health of the men is always more or less impaired after three months' employment; some, however, escape violent diseases of lead for a long time. These diseases arise from white lead and from no other cause. The grinding and handling of white lead, either in water or oil, produces paralysis of the hands, fingers, and arms. "Screening" as it is called, or separating the white from the blue scraps, by means of dry sifting, is the most dangerous part of the business. The men are obliged to take turns at this occupation; and, after screening their turn, are almost invariably obliged to take medicine. I have suffered severely from lead colic – the pains are excruciating, and the business, closely followed, invariably breaks down the constitution, if continued in sufficiently long. I left the business on account of its unhealthiness. About a year and a half ago, since I have been engaged in the manufacture of white oxide of zinc, having many men employed, twenty hands were under my own immediate charge, I have never known a man sick from zinc, even for a day or hour. My own health has been improved since my engagement, and I have every reason to believe that it is from the tonic effect of the zinc.

The white of zinc is collected in bags after being sublimed in the furnaces from the ore. It flies about the works as freely as flour in a flouring mill. If zinc were unhealthy, it would be impossible to make it in this way. If white lead flow about (as dust) in the same way, it would kill every man exposed to it in three weeks.

24. Dunn, *Mine Hill in Franklin and Sterling Hill,* 2: 300.

25. Kuhn, 176.

26. *Proceedings of the American Association for the Advancement of Science, Fourth Meeting, Held at New Haven, Conn., August, 1850* (Washington City: S. F. Baird and New York: G.P. Putnam, 1851), 335–337.

27. Boston Society of Natural History, *Proceedings of the Boston Society of Natural History, 1848 to 1851,* vol. 3 (Cambridge: Bolles and Houghton, 1851), 321.

28. Edward Sandford, "Reports of the New Jersey Zinc Company: Report of the Special Commission in Relation to Zinc Paint," reproduced in *Prospectuses of 19th-Century Mining Companies at Franklin and Sterling Hill, New Jersey,* comp. by Pete J. Dunn (Alexandria, Va.: P. J. Dunn, 2004), 24–25.

29. Dunn, *Mine Hill in Franklin and Sterling Hill,* 2: 173. Dunn quotes from the "testimony for Alexander Farrington, mining engineer of the Sussex Zinc and Copper Mining and Manufacturing Company on November 10, 1858." It says: [Accordingly,] "application was made to the Legislature of New Jersey during its session of 1852, and a supplement was obtained to the charter of the New-Jersey Exploring and Mining Company, changing the name of the company to that of the New Jersey Zinc Company...." This implies that the date for the advertisement, which Dunn reproduced on page 172, probably is no later than 1852. On page 175 is the transcription for the merger of the companies dated September 1851. Therefore, it may be that the ad is 1851 or earlier.

30. Advertisement for zinc white paint by S. T. Jones and Company, Agents, J. J. Exploring and Mining Company (undated), reproduced in Dunn, *Mine Hill in Franklin and Sterling Hill,* 2: 172.

31. Advertisement for zinc paints manufactured by the New Jersey Zinc Company (undated), reproduced in Dunn, *Mine Hill in Franklin and Sterling Hill,* 2: 250.

32. New Jersey Zinc Company, 12.

33. Dunn, *Franklin and Sterling Hill, New Jersey,* 1: 99.

34. Ibid., 1: 67.