Article: A comparative study of protective coatings for marble sculpture
Author(s): Laura Kubick and Jennifer Giaccai
Contributor(s): Helen Ingalls and Hugh Shockey
Source: *Objects Specialty Group Postprints, Volume Nineteen, 2012*
Pages: 45-69
Compilers: Mina Thompson, Emily Hamilton, and Kari Dodson

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A COMPARATIVE STUDY OF PROTECTIVE COATINGS FOR MARBLE SCULPTURE

LAURA KUBICK AND JENNIFER GIACCAI

CONTRIBUTORS: HELEN INGALLS AND HUGH SHOCKEY

ABSTRACT

This paper presents the study of four protective coatings intended for use on marble sculpture displayed in an indoor museum context. The coatings tested include Renaissance microcrystalline wax and a cosmolloid wax-ketone resin mixture, both of which have been used historically for this purpose. In addition, the experiment also included materials that have not been traditionally used as marble coatings: Dow Methocel methyl cellulose and Avalure AC 315 polymer. The coatings were applied to polished and unpolished samples of Carrara marble tile. A colorimeter, gloss meter, and Fourier transform infrared spectroscopy were employed to assess the coatings' aesthetic properties, reversibility, and ability to protect marble from red wine, lipstick, and permanent marker. A portion of the samples was also light-aged to determine the effect of aging on the coatings' aesthetic and reversibility properties.

1. INTRODUCTION

Marble sculptures that are on display for extended periods of time and are accessible to the public tend to develop grimy areas from frequent touching by museum visitors. Additionally, there have been several documented occurrences of inappropriate visitor actions at the Smithsonian American Art Museum. Marble sculptures, including *Sleeping Children* by William Henry Rinehart and *Tennyson's Princess* by William Couper, were kissed by members of the public. The kisses left bright lipstick marks on the surfaces of the sculptures (figs. 1, 2). Another incident occurred in 2009 at the National Portrait Gallery: an unidentified, sticky, red liquid was dripped onto an unknown copyist's sculpture, *Marquis De Lafayette* after Antoine Houdon.

Marble is porous and prone to staining. It can be a difficult substrate to clean effectively and safely, particularly of oily materials or silicone-containing substances like lipsticks. Therefore, the application of a barrier coating could be useful to help protect the surfaces.

Sacrificial coatings for sculptures and architectural surfaces have been frequently used and documented in outdoor contexts, however they have been much less studied and possibly less frequently used in indoor environments. A literature search turned up only three sources on preventive coatings for use on marble in indoor environments, none with a recent publication date (Hempel and Moncrieff 1972; Larson 1978, 1980). While indoor artworks are not perceived to be as vulnerable as sculptures in outdoor contexts, marble, especially white marble, seems to be a particularly attractive substrate to touch and mark by members of the public. Not every marble sculpture is in need of a protective coating, but a suitable coating may prevent damage in cases where sculpture is deemed particularly vulnerable.

For this experiment, four materials were chosen for evaluation as protective coatings: a mixture of Cosmolloid 80H wax and Ketone N resin (also known as Laropal K-80), Renaissance microcrystalline wax, Dow Methocel A4C methyl cellulose, and Avalure AC 315 Polymer.

Wax-resin mixtures have historically been used as protective coatings for indoor marble sculptures, although there are very few published accounts. As such, it is unclear how often preventive treatments like this have been carried out. Conservation literature documents only the

Fig. 1. William Couper, *Tennyson's Princess*, 1882, marble, 62.3 x 48.7 x 31.6 cm. Gift of Mrs. Benjamin H. Warder (Courtesy of Smithsonian American Art Museum, 1918.5.26)

use of various Cosmolloid wax and ketone resin mixtures applied in white spirits by the Victoria and Albert Museum conservation department on indoor marble sculpture (Hempel and Moncrieff 1972; Larson 1978, 1980). The authors report that the coatings were successfully used to prevent the sulfation of marble and the buildup of dirt and grime. However, these publications only include general comments on the coatings and their effectiveness.

Renaissance microcrystalline wax is a common coating for many materials, including marble, and is widely used in conservation. Anecdotal evidence points to wax being widely applied to marble sculpture for aesthetic and probably protective reasons.

Methyl cellulose has been used recently as a sacrificial coating at the Smithsonian American Art Museum to protect marble surfaces from visitor damage. In 2008, after the lipstick was removed from the Couper sculpture discussed previously, a 2% solution of methyl cellulose was applied to the sculpture to protect it from future incidents. In this case, the methyl cellulose was chosen for its easy reversibility and aesthetic properties, but the regularity with which conservators use methyl cellulose as a preventive surface treatment for marble is not known. Methyl cellulose is widely used in conservation as an adhesive and gelling agent and is known to be stable and reversible (Feller 1994; Shashoua 1995). While there have been accelerated aging studies on

Fig. 2. Detail of *Tennyson's Princess* after a museum visitor kissed the sculpture with lipstick on (Courtesy of Hugh Shockey)

methyl cellulose showing its excellence as a material for conservation, review of the literature turned up no instance of methyl cellulose being used as a protective coating for marble.

Avalure AC 315 acrylic copolymer is a stable acrylic resin made by Lubrizol Corporation. It was developed for the cosmetics industry for use in nail polishes, forming a clear hard film when used alone. It is reversible in polar organic solvents as well as in alkaline pH water, none of which will harm marble in good condition. Avalure AC 315 has not been used widely in conservation, but has recently been applied as a masonry coating on the exterior of the National Building Museum by Richard Wolbers, whose findings were presented to the Architecture Specialty Group at the 2009 annual meeting of the American Institute for Conservation. Students at the Winterthur/University of Delaware Program in Art Conservation (WUDPAC) have studied the material as a coating for outdoor murals and stone. Information has not yet been published in the conservation literature on the material for use in indoor contexts, but the material has been studied for use outdoors. WUDPAC student Matt Cushman proposed Avalure AC 315 as a protective coating for outdoor marble surfaces in his paper presented at the 2006 conference of the Association of North American Programs in the Conservation of Cultural Property (ANAGPIC) (Cushman 2006). Amber Kerr-Allison tested the material with added ultraviolet radiation inhibitors as a coating for outdoor murals intended to prevent the fading of paints, presenting her findings at the 2007 ANAGPIC conference (Kerr-Allison 2007).

2. EXPERIMENTAL

2.1 EVALUATION CRITERIA

Several properties of the coatings were evaluated using a spectrophotometer, gloss meter, and Fourier transform infrared spectroscopy (FTIR): aesthetic properties, aging properties, ability to protect the marble from staining, and safe reversibility. Changes in gloss, yellowing, and darkening are problems cited in literature on coatings for outdoor marble, and these properties are important aesthetic considerations when choosing a coating (Tarnowski et al. 2007). Yellowing and darkening can be visually disturbing and suggest deterioration of the coating with age, which may signal the onset of irreversible change. Blanching or bleaching may signal other forms of coating failure, including cleaving from the surface and chemical deterioration. Simply applying a coating to a surface can cause a perceived change in gloss, as the coating may give a more or less saturated surface, however a change in gloss over time may also signal deterioration. Changes in color or gloss to the marble substrate can indicate damage as well. Color change is of course characteristic of staining, while gloss changes in the substrate can indicate mechanical or chemical damage.

2.2 SAMPLE PREPARATION AND EXPERIMENTAL PROCEDURE

2.2.1 Sample Tiles and Coatings

To prepare samples, commercially available 12” x 12” Carrara marble tiles were cut into 6” x 2” pieces. Each piece had four sites that could be analyzed separately using the colorimeter and gloss meter, and so were treated as four separate but conjoined samples. The tiles had a polished and an unpolished side and each tile was coated on only one side. Every coating was applied to an equal number of polished and unpolished surfaces. For each coating there was a set of samples with one application of the coating and another set with two coats of the material. The one exception to this procedure was Avalure, which did not produce good results when applying a second coating, so a 5% solution and a 7% solution described below were used to represent a thinner and thicker coating, respectively. All of the coatings were applied with brushes.

The wax-resin recipe used for this experiment was obtained from objects conservator Ginny Naudé, who previously worked with John Larson. 20.75 g of Ketone N resin was mixed into 200 mL of Stoddard solvent. The solvent was heated and then 62.5 g of Cosmolloid 80H wax was added.

The Avalure solutions were mixed up from dry resin in 5% and 7% solutions (w/v) in ethanol. The methyl cellulose was prepared as a 2% (w/v) solution of Dow Methocel in water saturated with marble chips, mixed according to the manufacturer’s instructions. The marble chips were added in order to saturate the solution with ions and prevent solubilizing the marble samples.

The microcrystalline wax was applied from the container with no modifications.

For each combination of coating material, marble surface, and coating thickness, there were 48 samples. All 48 were examined to determine how applying the coating affected the color and gloss of the samples alongside two sets (unpolished and polished marble) of 16 control samples. Smaller subgroups were created from the 48 to evaluate how the coatings affected the substrate, how they aged, and how well they protected the marble from different staining agents. Twenty unstained samples and two sets of 16 controls were used to determine color change just from removing the coating. Four unstained samples of each combination of coating type and marble surface, and coating thickness, and two sets of four controls were sent away for light aging. Four samples of each type were analyzed by FTIR while the samples remained coated and four of each type were analyzed after the coatings were removed.

The gloss and color of all 48 samples of each type were tested with a gloss meter and spectrophotometer before and after the application of the coatings and the results were compared to help quantify aesthetic changes that occurred just by applying a coating. Observations were also made about the appearance of the coated samples.

2.2.2 Accelerated Aging

Four of each type of sample were sent to the Image Permanence Institute (IPI) for aging in their light fade unit (see section 2.3 Equipment below). Then observations were recorded and color and gloss data were recorded upon their return.

2.2.3 Application of Staining Agents

Staining agents were applied to a portion of the unaged samples. The staining agents chosen for testing were lipstick, red wine, and permanent marker. Each staining material was applied to eight samples of each type of coating in a manner that mimicked reality: the lipstick was kissed onto the tiles, the wine was splashed on with a pipette, and the marker was drawn on. Revlon Color Stay Ultimate Liquid Lipstick in Top Tomato was chosen for its bright shade of red and because it was advertised to stay on for 24 hours without need of reapplication, a very long time for a lipstick. D'Arenberg The Stump Jump Shiraz 2009 wine, a red wine, was used even though many museums have policies prohibiting red wine, because it was easier to detect whether the wine had penetrated a coating. A black Sharpie Fine Point Permanent Marker was used because this brand of marker is in frequent use and is widely available.

Each staining agent was left on the surfaces of the samples for a minimum of 24 hours to set the stain. After the stain-setting period, samples, including the uncoated controls, were wiped with an appropriate solvent to remove the bulk of the staining material before removing the coatings: mineral spirits to remove the lipstick, marble saturated water to remove the wine, and acetone on cotton pads to remove the marker.

2.2.4 Coating Removal

All of the coatings on all the sample types, stained and unstained, aged and unaged, were reversed, and color and gloss measurements and observations were recorded again. To reverse the wax-resin coating, two rounds of poultices of xylene on cotton pads were used, and then the tiles were wiped once with xylene on a cotton pad. To reverse the microcrystalline wax one round of xylene poulticing on cotton pads was followed by another cotton pad poultice with mineral spirits and then the tiles were wiped once with xylene on a cotton pad. The methyl cellulose was removed by wiping three times with a cotton pad soaked with marble-saturated water. The Avalure was removed with two ethanol poultices on cotton pads and then wiped with another ethanol soaked pad.

Ease of reversibility of the coatings was evaluated by observation and using FTIR during this process. Observations were made about whether the coatings appeared to be removed, while FTIR data gave evidence as to whether the coatings remained on the surfaces by comparing a coated sample of each type with another whose coating had been removed. Due to time restrictions only one sample of each type, including aged samples, were analyzed using FTIR.

2.3 EQUIPMENT

A GretagMacbeth SpectroEye spectrophotometer was used for colorimetry measurements. The measurements were taken using a D65 illuminant, a 2° standard observer angle, and results were recorded using the CIE L* a* b* color system.

A BYK Gardner micro-TRI-gloss meter was used for gloss measurements. It has an internal illuminant that is shone onto the surface of the samples at three different angles: 20°, 60° and 85°, and the amount of light reflected at each angle is detected. The data recorded at 20° was used to evaluate the polished tiles, while data recorded at 85° was used for the unpolished tiles. The reference standard for this instrument is black glass (RI 1.567) that measures 100 GU.

It was essential that measurements with the spectrophotometer and gloss meter were taken on the same spot every time to ensure accurate detection of any change. To this end, samples were placed in a jig, custom made for each instrument during analysis (fig. 3).

The aged samples were exposed at the Image Permanence Institute in Rochester, NY, inside their custom-built fluorescent light fade unit. The samples were exposed for 76 days at 50,000 lux, 24 hours per day. This is equal to 50 years of exposure, with 10-hour days of exposure at 500 lux over 365 days. Environmental conditions in the unit were near 70°F and 50% RH. This was ideal because the experiment was intended to mimic museum conditions and softening of the coatings from heat or RH would have interfered with obtaining accurate results.

The FTIR equipment used was Thermo Scientific Nicolet iS5 with a DTGS detector, loaned by Thermo Scientific for this experiment. The iS5 was used with the iD5 single-bounce diamond window ATR accessory, with the samples placed directly on the 2 mm ATR window and pressure applied from the reverse using the iD5 clamp. For each type of sample (varying coating, aging, polish, thickness and removal state), one spot on the tile was chosen randomly and analyzed for 32 scans at 4 cm^{-1} resolution. Removal success or failure in the IR data was determined by a lack of characteristic peaks for the coating in question; for example,

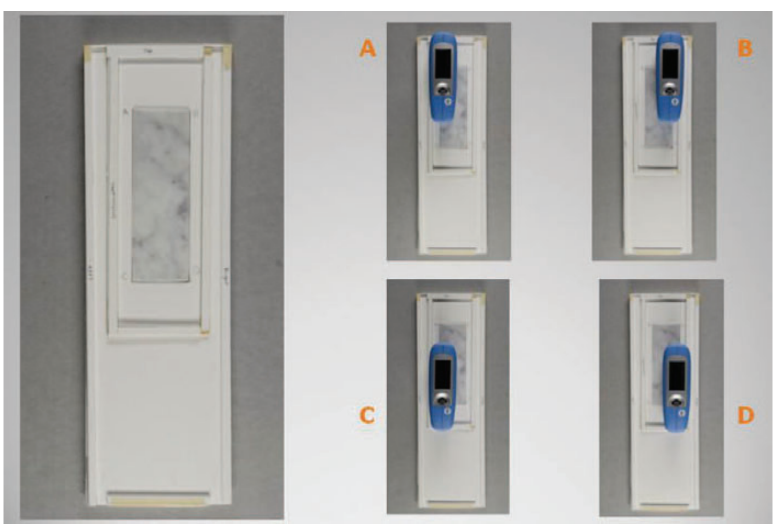

Fig. 3. Left, jig with a tile inside. Right, the gloss meter at the four different sample positions, A, B, C, and D using the jig (Courtesy of Laura Kubick)

unsuccessfully removed Avalure showed a carbonyl peak at approximately 1728 cm^{-1}, and unsuccessfully removed wax and wax-resin showed C-H stretch peaks between 2900–3000 cm^{-1}.

2.4 CALCULATIONS

Color change was calculated using the following CIE 1975 equation: $\sqrt{(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})} = \Delta E$. A just-noticeable difference is 1 ΔE. The values for ΔL*, Δa*, Δb* are determined using the following equations: $\Delta L^* = L^*_2 - L^*_1$, $\Delta a^* = a^*_2 - a^*_1$, and $\Delta b^* = b^*_2 - b^*_1$. The ΔE was calculated for each sample and the mean ΔE was calculated for each sample type from those values. The average ΔL* data reported were calculated as the mean of all of the ΔL* values from a given sample type.

Gloss change is calculated using the following equation: $G_2 - G_1 = \Delta G$. The gloss change was calculated for each sample and the mean ΔG was calculated for each sample type from those values. A just-noticeable difference in gloss is reported in the instrument's manual to be a change of about 5 GU, except with very matte surfaces where changes of 3 GU may be visible.

Standard deviations for color and gloss changes were calculated in Excel using $s = \sqrt{(\Sigma(x - x)^2/n - 1)}$.

3. RESULTS AND DISCUSSION

3.1 EVALUATION OF COATED SAMPLES

When observing the unaged, unstained samples with the naked eye from normal viewing distance (fig. 4), it appeared that the wax-resin and microcrystalline wax saturated the unpolished surfaces more than the methyl cellulose or Avalure. While this represents a visual change, in some cases it may be desirable to saturate matte surfaces.

The methyl cellulose looked essentially invisible on all of the samples. It seemed to abrade more easily than the other coatings tested.

The Avalure had mixed aesthetic results. It gave a plastic-like surface on the polished tiles and exhibited iridescence in areas. On the other hand, the Avalure coatings looked invisible on the unpolished surfaces. It should be noted that the polished marble samples were much shinier than typical marble sculpture; most of the samples had surfaces that gave gloss readings above 90 GU. For comparison, gloss measurements were taken from sculptures on view at the Smithsonian American Art Museum with results between 12 and 40 GU, suggesting that this aesthetic problem might not occur on typical museum objects. Caroline Roberts also evaluated Avalure as a coating for outdoor marble sculpture in an unpublished paper she completed as a WUDPAC student in 2010. Roberts' samples were made from salvaged architectural marble and she did not have this same problem when applying solutions of similar concentration (Roberts 2010).

The color change results, ΔE, comparing the color data from the spectrophotometer before and after coating is listed in table 1. All sample sets included individual samples that had changes of more than 1 ΔE. On average, the greatest change occurred in the unpolished wax-resin samples. It is worth noting that most of the color change for these samples occurred in the L* channel of the data. The average ΔL* for the unpolished wax-resin samples with thick coatings was –4.34 (s = 0.779), and –3.43 (s = 1.01) for the thin coatings. A negative ΔL* indicates darkening, which is consistent with the observation that the wax-resin saturated the

Fig. 4. Examples of control tiles and coated tiles. The top row has polished marble tiles and the bottom row has unpolished tiles. In each row, from left to right are: controls (no coating), wax-resin, microcrystalline wax, methyl cellulose and Avalure coated tiles. (Courtesy of Laura Kubick)

surfaces.

The data from the unpolished Avalure-coated samples showed an average color change greater than 1 ΔE, which was not noted during visual examination, but could be due to iridescence colors observed. However, these data sets had wide ranges and therefore high

Table 1. Color change (ΔE) of unaged, unstained samples after coating, given as a range. Also shown are the average (AVG) and standard deviation (s).

	Wax-resin	Microcrystalline wax	Methyl cellulose	Avalure	Control (no coating)
Unpolished, Thick coat	2.94 – 6.62 AVG = 4.36 s = 0.77	0.45 – 2.99 AVG = 1.41 s = 0.50	0.11 – 2.98 AVG = 1.05 s = 0.44	1.25 – 7.14 AVG = 2.78 s = 0.91	0.10 – 2.53 AVG = 0.57 s = 0.465
Unpolished, Thin coat	0.63 – 6.52 AVG = 3.45 s = 0.98	0.31 – 1.87 AVG = 0.80 s = 0.34	0.06 – 1.92 AVG = 0.77 s = 0.37	0.88 – 3.39 AVG = 1.65 s = 0.72	
Polished, Thick coat	0.07 – 1.51 AVG = 0.37 s = 0.26	0.11 – 1.58 AVG = 0.50 s = 0.34	0.09 – 3.61 AVG = 0.55 s = 0.63	0.09 – 3.45 AVG = 0.76 s = 1.20	0.02 – 1.33 AVG = 0.54 s = 0.626
Polished, Thin coat	0.06 – 2.80 AVG = 0.42 s = 0.43	0.04 – 1.00 AVG = 0.38 s = 0.25	0.08 – 1.37 AVG = 0.46 s = 0.31	0.05 – 2.57 AVG = 0.45 s = 0.43	

Table 2. Gloss change (ΔG) of unaged, unstained samples after coating, given as a range. Also shown are the average (AVG) and standard deviation (s).

	Wax-resin	Microcrystalline wax	Methyl cellulose	Avalure	Control (no coating)
Unpolished, Thick coat	−0.10 – 5.68 AVG = 1.31 s = 1.40	−0.32 – 4.41 AVG = 0.85 s = 0.92	−0.67 – 0.67 AVG = 0.19 s = 0.21	0.23 – 3.99 AVG = 1.61 s = 0.88	−1.59 – 1.31 AVG = 0.01 s = 0.70
Unpolished, Thin coat	0.00 – 6.53 AVG = 1.09 s = 1.43	−0.77 – 2.60 AVG = 0.72 s = 0.69	−1.65 – 1.37 AVG = 0.13 s = 0.34	0.00 – 4.6 AVG = 0.98 s = 0.77	
Polished, Thick coat	−26.89 – 5.83 AVG = −11.43 s = 8.61	−4.42 – 20.52 AVG = 8.06 s = 4.24	−36.05 – −8.08 AVG = −18.69 s = 4.46	−74.88 – −7.43 AVG = −35.12 s = 20.11	−0.81 – 0.60 AVG = −0.15 s = 0.39
Polished, Thin coat	−28.69 – 7.07 AVG = −11.49 s = 9.04	−2.55 – 16.80 AVG = 6.24 s = 4.77	−37.83 – 1.21 AVG = −14.13 s = 7.50	−54.70 – −9.92 AVG = −27.77 s = 10.36	

standard deviations in comparison to the average ΔE values, suggesting that the change was inconsistent. The other coating types performed similarly to each other. The unpolished samples with thick coats of microcrystalline wax and methyl cellulose both had average ΔEs greater than 1, but again the change detected in individual samples was quite variable.

The change in gloss detected, ΔG, after the coatings were applied is shown in table 2. The data for almost all of the sample types have high standard deviations. None of the unpolished sample types had a significant average change in gloss. The data for the polished samples have much wider ranges and are generally not consistent with the observations made by eye. Significant changes in gloss were not observed, except in the polished, Avalure-coated samples, which looked plastic-like. It is interesting to note that the microcrystalline wax is the only coating that showed a consistent increase in gloss on average.

3.2 EVALUATION OF SAMPLES AFTER COATING REMOVAL

After the coatings were removed from the unaged, unstained samples, no change in color or gloss was observed by eye on the methyl cellulose or Avalure-coated samples when compared with the uncoated controls. These coatings seemed easy to reverse and did not require the use of toxic solvents.

Neither the wax-resin nor the microcrystalline wax coatings appeared to reverse easily using the simple methods used for this experiment; the unpolished samples with those coatings retained a more saturated looking surface than uncoated samples. While there may be more effective methods of removing these coatings, such as the use of solvent gels, ease of reversibility was one of the properties to be evaluated and so a simple removal method was chosen for each of the coatings.

FTIR data (table 3) supported some of the observations made about the coatings' reversibility, however only one sample of each type could be analyzed using FTIR, so the FTIR data should not be considered conclusive. Methyl cellulose performed the best. No methyl

Table 3. FTIR results of unaged, unstained samples

	Wax-resin	Microcrystalline wax	Methyl cellulose	Avalure
Unpolished, Thick coat	Some coating remains	Some coating remains	No coating remains	Some coating remains
Unpolished, Thin coat	Some coating remains	Some coating remains	No coating remains	Some coating remains
Polished, Thick coat	No coating remains	No coating remains	No coating remains	Some coating remains
Polished, Thin coat	No coating remains	No coating remains	No coating remains	No coating remains

cellulose was detected on the samples where methyl cellulose had been removed, while traces of the other coatings remained. The microcrystalline wax had poor reversibility, but the FTIR data showed that it performed better than the Avalure in the unaged, polished samples. However, one of the spectra from an unpolished microcrystalline wax-coated sample had larger wax peaks on the sample where the coating had been "removed" than samples where the coating was still present (fig. 5), although the exact sample spot could not be compared before and after coating removal. With the exception of Avalure, in which thicker Avalure coatings still showed traces of coating in the infrared spectra, the coating thickness did not affect the removal of the coating. Rather, whether the marble substrate was polished or unpolished had more effect on the results. The more porous, unpolished samples exhibited less reversibility than the polished samples.

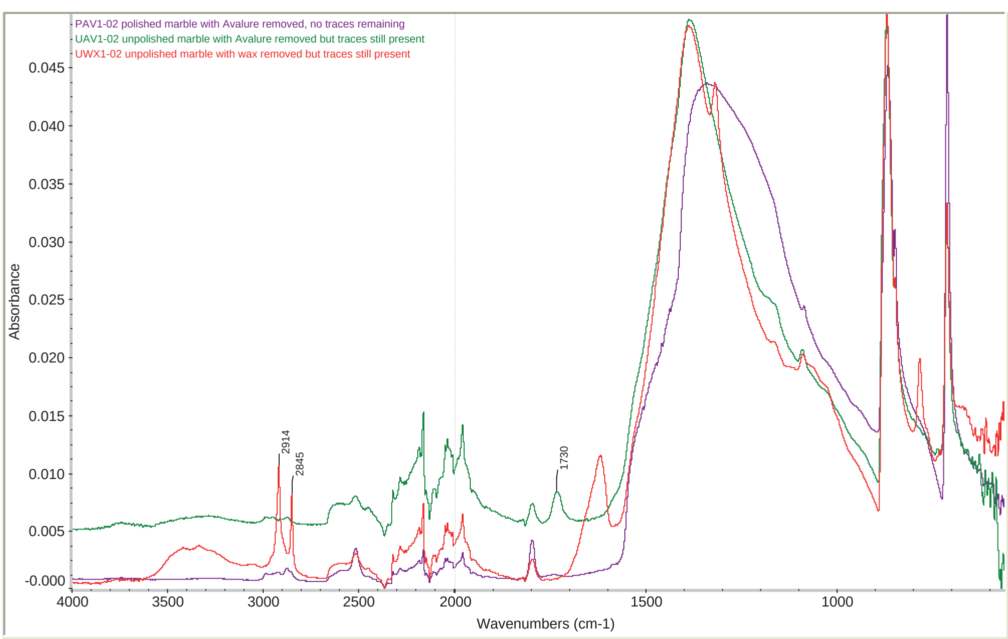

Fig. 5. Infrared spectra of three uncoated samples showing traces of Avalure remaining (green), wax remaining (red) or no coating remaining (purple) (Courtesy of Jennifer Giaccai)

Table 4. Color change (ΔE) of unaged, unstained samples after coating removal, given as a range. Also shown are the average (AVG) and standard deviation (s).

	Wax-resin	Microcrystalline wax	Methyl cellulose	Avalure	Control (no coating)
Unpolished, Thick coat	0.20 – 2.44 AVG = 0.57 s = 0.451	0.12 – 4.45 AVG = 1.00 s = 0.969	0.23 – 1.95 AVG = 0.94 s = 0.516	0.26 – 2.63 AVG = 1.13 s = 0.552	0.06 – 0.84 AVG = 0.31 s = 0.23
Unpolished, Thin coat	0.12 – 1 .67 AVG = 0.63 s = 0.528	0.16 – 7.80 AVG = 1.73 s = 2.02	0.10 – 2.24 AVG = 0.72 s = 0.606	0.08 – 3.14 AVG = 0.89 s = 0.726	
Polished, Thick coat	0.09 – 1.41 AVG = 0.35 s = 0.369	0.38 – 6.02 AVG = 3.09 s = 1.56	0.06 – 3.68 AVG = 0.72 s = 0.976	0.03 – 0.97 AVG = 0.36 s = 0.27	0.04 – 1.29 AVG = 0.43 s = 0.31
Polished, Thin coat	0.05 – 1.54 AVG = 0.33 s = 0.387	0.06 – 4.53 AVG = 1.49 s = 1.72	0.06 – 1.54 AVG = 0.31 s = 0.354	0.04 – 0.65 AVG = 0.23 s = 0.18	

As seen in table 4, when the coatings were removed, the microcrystalline wax-coated samples had the greatest average color change; but even this was not much change, and the change was not consistent across the samples. The unpolished Avalure samples with thick coatings showed what should have been a just-noticeable difference in the average color change as well. These changes were primarily the result of a decrease in the value of the L* channel of the data, indicating darkening. The ΔL* values for Avalure and microcrystalline wax coated samples are in table 5. None of the other sample types exhibited significant average color change.

Table 5. Color value change (ΔL*) of unaged, unstained Avalure and microcrystalline wax samples after coating removal, given as a range. Also shown are the average (AVG) and standard deviation (s).

	Unpolished thick coat	Unpolished thin coat	Polished thick coat	Polished thin coat
Avalure	−2.61 – −0.19 AVG = −1.12 s = 0.557	−1.08 – 0.34 AVG = −0.73 s = 0.55	−0.22 – 0.96 AVG = 0.29 s = 0.32	−0.20 – 0.38 AVG = −0.01 s = 0.3
Microcrystalline Wax	−4.37 – 1.06 AVG = −0.51 s = 1.3	−4.99 – 2.19 AVG = −0.72 s = 1.9	−5.85 – 5.73 AVG = 0.29 s = 3.35	−4.46 – 0.18 AVG = −1.41 s = 1.73

The gloss data for the samples after the coatings were removed is shown in table 6. The average gloss change data showed no significant change in the unpolished samples, and a decrease in gloss in the polished samples after coating removal. However, individual samples within the groups show more change than the averages, as standard

Table 6. Gloss change (ΔG) of unaged, unstained samples after coating removal, given as a range. Also shown are the average (AVG) and standard deviation (s).

	Wax-resin	Microcrystalline wax	Methyl cellulose	Avalure	Control (no coating)
Unpolished, Thick coat	−0.34 – 1.30 AVG = 0.17 s = 0.445	−0.45 – 0.74 AVG = 0.15 s = 0.25	−0.31 – 0.58 AVG = 0.01 s = 0.17	−0.23 – 0.23 AVG = 0.06 s = 0.11	−1.41 – 1.29 AVG = 0.024 s = 0.643
Unpolished, Thin coat	0.01 – 0.84 AVG = 0.24 s = 0.24	0.01 – 0.81 AVG = 0.18 s = 0.19	−0.34 – 0.40 AVG = 0.02 s = 0.16	0.01 – 0.66 AVG = 0.17 s = 0.16	
Polished, Thick coat	−9.01 – −0.47 AVG = −3.22 s = 2.15	−5.70 – 2.64 AVG = 0.18 s = 1.80	−9.06 – 4.41 AVG = −0.88 s = 3.51	−17.69 – 19.52 AVG = −5.38 s = 13.7	−1.39 – 4.09 AVG = −0.403 s = 2.01
Polished, Thin coat	−8.37 – 4.03 AVG = −1.59 s = 2.44	−8.58 – 2.14 AVG = −0.39 s = 2.22	−0.40 – 2.52 AVG = 1.05 s = 0.853	−10.03 – 2.73 AVG= −1.67 s = 2.96	

deviations were high. The Avalure and wax-resin coatings performed similarly, showing a more significant loss of gloss on their marble substrates than the other coatings. The decrease in gloss that is indicated for all the polished samples, even if not detectible by eye, could be due to scratching the highly polished surfaces of the tile during coating application and removal, or could signal incomplete removal of the coatings. Again the data varied considerably, and this could be another reason that decrease in gloss indicated by the data was not seen with the eye. Furthermore, the unstained polished samples, as a group, showed more change in gloss than the lipstick- or marker-stained samples. This is counterintuitive, as more handling, staining, and attempts at removing substances from the surface should promote more gloss change. Therefore, it is unlikely that the coating and removal procedures are the cause of the gloss changes. A larger set of samples would likely give a more consistent data set.

3.3 EVALUATION OF AGED SAMPLES

Evaluation of the unstained samples compared the color and gloss after the samples were coated, before and after light aging. Due to time and equipment-related constraints, only four samples of each type could be light-aged, so the aging data should not be considered conclusive. No color or gloss change was observed in any of the coated samples after aging. Infrared spectra from the aged coated samples did not appear different from the unaged coated samples.

The reversibility of the coatings did not originally appear to be affected by aging. However, this observation was not fully supported by the FTIR data (table 7). In the case of the microcrystalline wax, this coating was less reversible in the aged samples. The aged wax coating was not removed from the polished marble, while the unaged coating could be successfully removed from the polished marble. On the other hand, Avalure showed more reversibility in

Table 7. FTIR results of aged, unstained samples. Four samples of each type were analyzed to obtain this data.

	Wax-resin	Microcrystalline wax	Methyl cellulose	Avalure
Unpolished, Thick coat	Some coating Remains	Some coating Remains	No Coating Remains	Some coating Remains
Unpolished, Thin coat	Some coating Remains	Some coating Remains	No Coating Remains	No Coating Remains
Polished, Thick coat	No Coating Remains	Some coating Remains	No Coating Remains	Some coating Remains
Polished, Thin coat	No Coating Remains	Some coating Remains	No Coating Remains	No Coating Remains

the aged unpolished samples with thin coatings. Again, only one aged sample of each type was analyzed, so this data cannot be considered conclusive.

The color change results from the spectrophotometer data for the coated aged samples are shown in table 8. There was almost no average change in color after aging overall. Methyl cellulose had the least average change, but the sample group included individuals that had a ΔE of 1 or more.

In the unpolished samples with thicker coatings, the wax-resin and Avalure samples had slightly more color change after aging. For the polished samples all of the coatings performed very similarly to the control, even those that had a ΔE of 1 or more.

The change in color detected in the control samples suggests that the color change may have been due to abrasion from travel to and from IPI. Most of these small changes were in the L* channel, but the average ΔL* for all sample types, including the controls, was positive,

Table 8. Color change (ΔE) of aged, unstained samples after coating, given as a range. Also shown are the average (AVG) and standard deviation (s).

	Wax-resin	Microcrystalline wax	Methyl cellulose	Avalure	Control (no coating)
Unpolished, Thick coat	0.86 – 1.14 AVG = 1.04 s = 0.128	0.57 – 0.73 AVG = 0.67 s = 0.07	0.45 – 1.09 AVG = 0.73 s = 0.27	0.90 – 1.53 AVG = 1.09 s = 0.298	0.33 – 1.02 AVG = 0.66 s = 0.34
Unpolished, Thin coat	0.37 – 0.88 AVG = 0.70 s = 0.23	0.24 – 0.92 AVG = 0.67 s = 0.31	0.45 – 1.00 AVG = 0.63 s = 0.25	0.31 – 0.53 AVG = 0.44 s = 0.10	
Polished, Thick coat	0.73 – 0.94 AVG = 0.82 s = 0.09	0.79 – 1.26 AVG = 1.06 s = 0.207	0.26 – 1.19 AVG = 0.93 s = 0.451	0.99 – 1.28 AVG = 1.13 s = 0.14	0.66 – 1.09 AVG = 0.95 s = 0.20
Polished, Thin coat	0.31 – 0.71 AVG = 0.49 s = 0.20	0.48 – 0.99 AVG= 0.84 s = 0.24	0.83 – 1.12 AVG = 0.92 s = 0.14	0.79 – 1.10 AVG = 0.87 s = 0.16	

Table 9. Gloss change (ΔG) of aged, unstained samples after coating, given as a range. Also shown are the average (AVG) and standard deviation (s).

	Wax-resin	Microcrystalline wax	Methyl cellulose	Avalure	Control (no coating)
Unpolished, Thick coat	0.68 – 3.31 AVG = 2.00 s = 1.30	–0.19 – 0.75 AVG = 0.80 s = 0.55	–0.13 – 0.28 AVG = 0.10 s = 0.17	1.18 – 1.98 AVG = 1.47 s = 0.375	–0.10 – 0.01 AVG = –0.04 s = 0.05
Unpolished, Thin coat	0.45 – 0.52 AVG = 0.48 s = 0.03	0.24 – 1.66 AVG = 0.872 s = 0.630	–0.01 – 0.38 AVG = 0.20 s = 0.17	0.47 – 0.73 AVG = 0.639 s = 0.114	
Polished, Thick coat	–24.48 – –2.46 AVG = –12.40 s = 9.21	1.82 – 8.66 AVG = 6.47 s = 3.22	–15.93 – –13.83 AVG = –14.71 s = 0.137	–52.96 – –21.64 AVG = –38.21 s =13.92	–2.59 – –1.20 AVG = –2.01 s = 0.835
Polished, Thin coat	–15.75 – –3.81 AVG = –9.22 s = 5.36	3.44 – 12.67 AVG = 8.08 s = 4.974	–4.21– –1.57 AVG = –2.76 s = 1.13	–24.08 – –19.25 AVG = –21.57 s = 2.32	

indicating lightening. This change could be the result of abrasion, or it could be the result of blanching, i.e. the beginning of light damage-related change.

Table 9 shows gloss data from the coated aged samples. None of the unpolished samples showed a noticeable average difference in gloss. All of the polished samples except the microcrystalline wax samples decreased significantly in gloss on average. Again, it is likely that abrasion from travel and handling could be the culprit, but it is possible that this is due to chemical deterioration.

Table 10 shows color change data from the aged samples, comparing these samples before they were coated and after the aged coatings were removed. The wax-resin data show

Table 10. Color change (ΔE) of aged, unstained samples after the coatings were removed, given as a range. Also shown are the average (AVG) and standard deviation (s).

	Wax-resin	Microcrystalline wax	Methyl cellulose	Avalure	Control (no coating)
Unpolished, Thick coat	3.59 – 4.35 AVG = 4.01 s = 0.319	0.91 – 2.03 AVG = 1.44 s = 0.496	0.22 – 0.54 AVG = 0.37 s = 0.16	0.90 – 1.53 AVG = 2.48 s = 0.625	0.62 – 1.02 AVG = 0.81 s = 0.17
Unpolished, Thin coat	1.40 – 2.30 AVG = 1.79 s = 0.381	0.25 – 0.74 AVG = 0.50 s = 0.20	0.41 – 0.73 AVG = 0.63 s = 0.15	0.80 – 1.66 AVG = 1.28 s = 0.39	
Polished, Thick coat	2.74 – 3.79 AVG = 3.42 s = 0.462	0.89 – 3.50 AVG = 2.38 s = 1.20	0.57 – 1.98 AVG = 1.10 s = 0.612	0.57 – 1.17 AVG = 0.76 s = 0.282	0.38 – 0.93 AVG = 0.61 s = 0.25
Polished, Thin coat	0.28 – 0.88 AVG = 0.49 s = 0.20	0.10 – 1.09 AVG = 0.51 s = 0.4280	0.15 – 0.62 AVG = 0.41 s = 0.22	0.79 – 2.05 AVG = 1.24 s = 0.562	

significantly more color change than the unaged samples. The aged Avalure samples also had more color change after their coatings were removed than the unaged samples did. These changes could be the result of abrasion and/or incomplete removal of coatings. It is interesting to note that there was more color difference in the aged samples after the aged coatings were removed than when they were still coated.

The gloss data from the aged samples comparing before they were coated and after the coatings were removed did not show significant average gloss changes in the samples except in the polished wax-resin samples with thin coatings (average $\Delta G = 5.27$, $s = 2.28$) and the polished microcrystalline wax-coated samples with thin coatings (average $\Delta G = 8.02$, $s = 2.49$). The fact that these samples increased in gloss suggests incomplete coating removal.

3.4 EVALUATION OF LIPSTICK STAINED SAMPLES

Data from the lipstick stained samples was calculated by comparing the samples before they were coated and after the stain and coatings were removed. Selected lipstick-stained samples can be seen in figure 6.

All of the samples that had been coated appeared to have less staining than the uncoated control samples. Tiny pink particles, visible with the naked eye, remained in small divots in

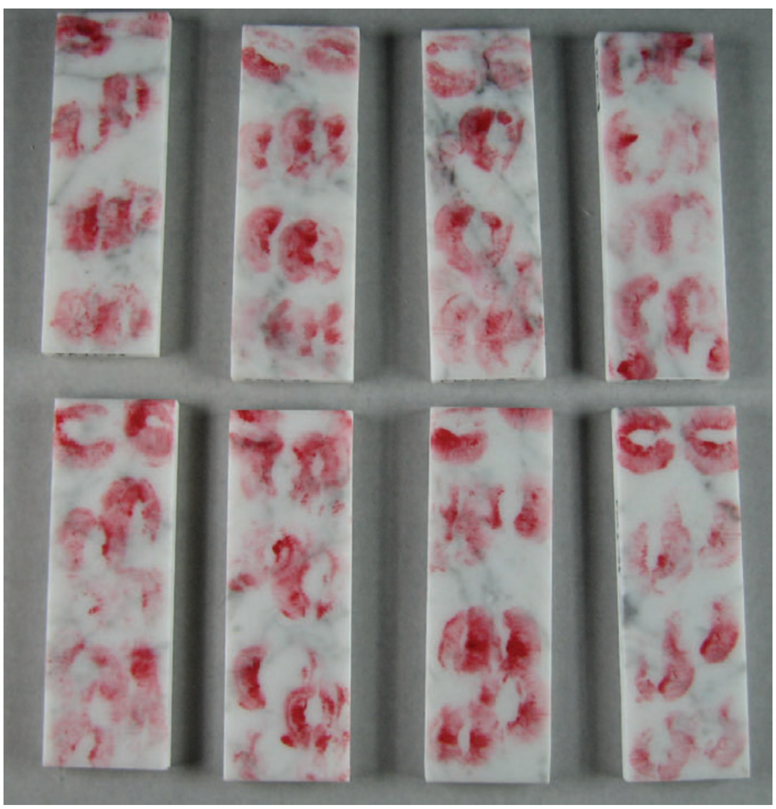

Fig. 6. Selected polished samples with lipstick applied. The samples in the top row have thin coatings and those in the bottom row have thick coatings. From left to right in each row the samples are coated with: Avalure, methyl cellulose, wax-resin, microcrystalline wax. (Courtesy of Laura Kubick)

Fig. 7. Selected polished, lipstick stained samples after the coatings were removed. Samples that had thin coatings are in the top row. Control samples are in the middle. The bottom row contains samples with thick coatings. From left to right, the samples in each column were coated with wax-resin, microcrystalline wax, methyl cellulose and Avalure. (Courtesy of Laura Kubick)

Fig. 8. Selected unpolished, lipstick stained samples after the coatings were removed. The samples are shown in the same order as in figure 6. (Courtesy of Laura Kubick)

the tiles with microcrystalline wax and wax-resin, but this was only discovered upon close inspection by eye, not from normal viewing distance (figs. 7, 8).

The color change data for the lipstick stained samples is recorded in table 11. As you can see, each coating generally had the same or less change than the controls and all of the coatings performed similarly, although the standard deviations are high for many of the sample sets. Avalure and methyl cellulose performed especially well with the polished samples when a thicker film was applied.

Most of the gloss change data for the lipstick-stained samples showed no noticeable change. A single polished sample with a thick wax-resin coating had a decrease in gloss of –8.97 GU. Additionally, a single polished sample with a thin coat of microcrystalline wax showed a decrease in gloss –6.03 GU.

3.5 EVALUATION OF WINE-STAINED SAMPLES

As above, data for the wine-stained samples, seen in figure 9, was calculated by comparing the samples before they were coated and after the coatings were removed.

Table 11. Color change (ΔE), given as a range, of unaged, lipstick stained samples after coating. Also shown are the average change (AVG) and standard deviation (s).

	Wax-resin	Microcrystalline wax	Methyl cellulose	Avalure	Control (no coating)
Unpolished, Thick coat	0.28 – 2.30 AVG = 1.07 s = 0.77	0.25 – 2.31 AVG = 1.12 s = 0.79	0.44 – 2.20 AVG = 0.93 s = 0.62	0.82 – 2.37 AVG = 1.29 s = 0.50	0.77 – 3.11 AVG = 1.84 s = 1.17
Unpolished, Thin coat	0.50 – 1.89 AVG = 1.14 s = 0.49	0.52 – 3.07 AVG = 1.26 s = 0.96	0.39 – 5.81 AVG = 1.77 s = 1.75	0.73 – 3.41 AVG = 1.98 s = 0.84	
Polished, Thick coat	0.15 – 2.91 AVG = 1.20 s = 1.18	0.12 – 3.82 AVG = 1.72 s = 1.39	0.07 – 0.54 AVG = 0.22 s = 0.16	0.05 – 0.67 AVG = 0.29 s = 0.41	1.73 – 5.65 AVG = 3.55 s = 1.99
Polished, Thin coat	0.14 – 3.39 AVG = 1.71 s = 1.37	0.15 – 3.94 AVG = 1.74 s = 1.49	0.11 – 3.85 AVG = 1.20 s = 1.45	0.06 – 1.38 AVG = 0.34 s = 0.43	

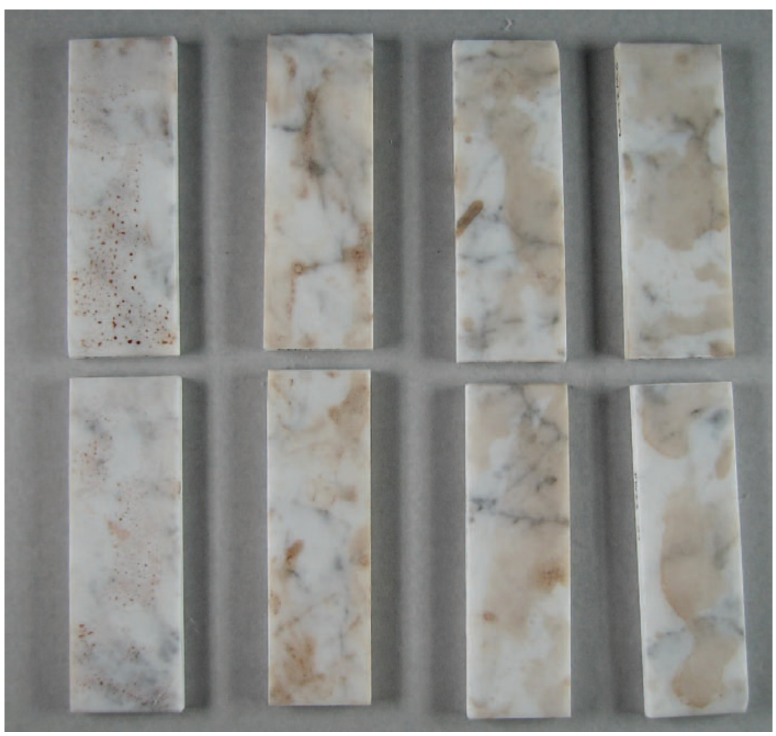

Fig. 9. Examples of coated polished marble samples with wine stain applied. The samples in the top row have thin coatings and the samples in the bottom row have thick coatings. From left to right in each row, the tiles are coated with Avalure, methyl cellulose, wax-resin, and microcrystalline wax. (Courtesy of Laura Kubick)

Fig. 10. Selected wine-stained, polished marble samples after coatings were removed. The control tile is on the left. From top to bottom, the other tiles were coated with Avalure, methyl cellulose, microcrystalline wax, and wax-resin. Etching is visible on all samples except those coated with Avalure. (Courtesy of Laura Kubick)

Fig. 11. Selected polished, wine-stained samples after the coatings were removed. Samples that had thin coatings are in the top row. Control samples are in the middle. The bottom row contains samples with thick coatings. From left to right, the samples in each column were coated with wax-resin, microcrystalline wax, methyl cellulose and Avalure. (Courtesy of Laura Kubick)

Observation by eye detected that wine staining was reduced on all of the tiles, including the control samples, after the coatings were removed. However, some staining remained on all samples (figs. 11, 12). The polished marble samples were left with a brownish haze, while the unpolished samples had darker, more discreet stain spots. None of the unpolished samples looked very good after the coatings were removed, but the microcrystalline wax samples retained the most staining material.

One dramatic result of the wine exposure was that all of the polished samples, except those coated with Avalure, exhibited significant etching of the polished surfaces (fig. 10). This is important, because while more may be done to reduce the staining of the marble, the etching is irreversible unless the surface of the stone is repolished.

Avalure is not soluble in acidic aqueous solutions. This resistance to acids is likely what allowed it to protect the marble from the acidic wine. Further evidence of Avalure's resistance to the wine can be seen in figure 9. When the wine was applied to the Avalure coated tiles (on the left side of the image) the wine beaded and did not wet onto the surfaces well. In contrast, the wine easily wetted the samples coated with the other materials.

Fig. 12. Selected unpolished, wine-stained samples after the coatings were removed. Samples are shown in the same order as in figure 11. (Courtesy of Laura Kubick)

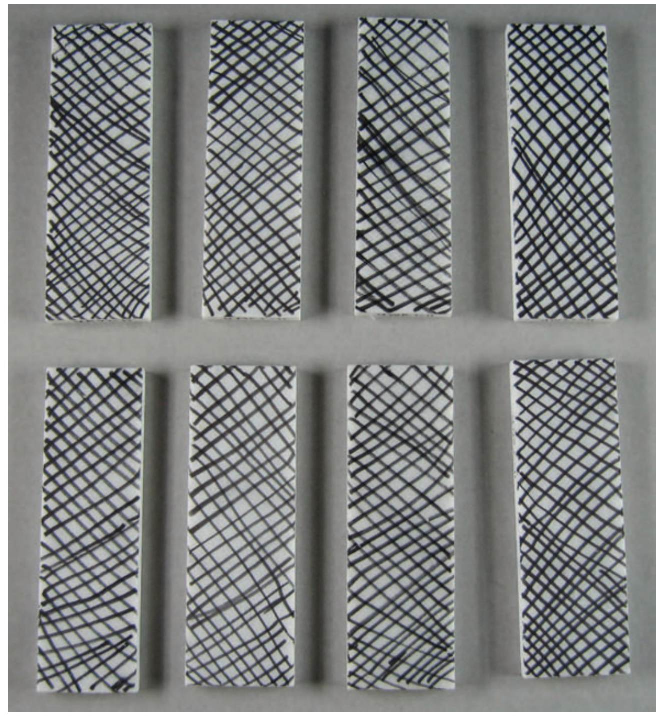

Fig. 13. Examples of unpolished samples with marker applied. The samples in the top row have thin coatings and those in the bottom row have thick coatings. From left to right in each row the samples are coated with: Avalure, methyl cellulose, wax-resin, microcrystalline wax. (Courtesy of Laura Kubick)

Table 12 shows the color change data for the wine-stained samples. The microcrystalline wax had the most change of all the coatings when comparing similar marble surface types. The unpolished samples generally retained much more color than the polished samples. Much of the color change in the polished samples can actually be attributed to the gloss change, which gives a blanched appearance, and that is why comparatively little change is reflected in the polished Avalure samples.

The gloss data, shown in table 13, were consistent with the etching observed. The unpolished samples did not change in gloss, but all of the polished samples except the Avalure had a significant decrease in gloss.

3.6 EVALUATION OF SAMPLES STAINED WITH PERMANENT MARKER

Data from samples stained with permanent marker, as seen in figure 13, were compared between the uncoated, unstained samples and the samples after they had been stained and the coatings were removed.

Visual examination revealed that almost all of the coated, polished tiles looked like new after the coatings were removed, except one of the wax-resin tiles, which retained very faint lines from the marker (fig.14). This tile looked very similar to the polished control sample.

The unpolished samples of all types retained more staining in general, but there was significantly less staining if a coating was present (fig. 15). The unpolished wax-resin samples

Table 12. Color change (ΔE), given as a range, of unaged, wine-stained samples, comparing before the samples were coated with after the coatings were removed. Also shown are the average change (AVG) and standard deviation (s).

	Wax- resin	Microcrystalline wax	Methyl cellulose	Avalure	Control (no coating)
Unpolished, Thick coat	0.34 – 1.91 AVG = 1.26 s = 0.67	0.19 – 8.23 AVG = 3.32 s = 2.89	0.68 – 5.36 AVG = 1.87 s = 1.59	1.16 – 7.11 AVG = 3.82 s = 2.23	0.64 – 6.19 AVG = 3.16 s = 2.82
Unpolished, Thin coat	0.88 – 2.71 AVG = 1.68 s = 0.64	0.85 – 11.93 AVG = 5.47 s = 3.17	0.83 – 4.51 AVG = 2.59 s = 1.38	0.39 – 7.98 AVG = 4.26 s = 2.63	
Polished, Thick coat	0.99 – 5.40 AVG = 2.34 s = 1.70	0.21 – 4.75 AVG = 2.39 s = 1.58	0.57 – 2.06 AVG = 1.33 s = 0.47	0.05 – 1.28 AVG = 0.58 s = 0.45	0.66 – 5.75 AVG = 2.78 s = 2.24
Polished, Thin coat	0.60 – 5.53 AVG = 2.84 s = 1.77	1.16 – 5.26 AVG = 3.19 s = 1.55	0.99 – 3.19 AVG = 1.91 s = 0.74	0.04 – 1.66 AVG = 0.55 s = 0.50	

Table 13. Gloss change (ΔG), given as a range, of unaged, wine-stained samples, comparing before the samples were coated with after the coatings were removed. Also shown are the average change (AVG) and standard deviation (s).

	Wax-resin	Microcrystalline wax	Methyl cellulose	Avalure	Control (no coating)
Unpolished, Thick coat	0.04 – 0.47 AVG = 0.25 s = 0.166	–0.27 – 0.50 AVG = 0.20 s = 0.28	–0.60 – 0.04 AVG = –0.15 s = 0.227	–0.06 – 0.69 AVG = 0.13 s = 0.150	–0.14 – –0.03 AVG = –0.10 s = 0.51
Unpolished, Thin coat	0.06 – 1.38 AVG = 0.41 s = 0.440	–0.67 – 0.59 AVG = 0.12 s = 0.42	–0.20 – 0.03 AVG = –0.06 s = 0.082	0.05 – 0.46 AVG = 0.29 s = 0.150	
Polished, Thick coat	–64.00 – –9.50 AVG = –33.49 s =18.05	–33.09 – –1.53 AVG = –17.83 s = 14.33	–57.62 – –6.87 AVG = –37.52 s = 14.58	–3.09 – –0.07 AVG = –1.53 s = 0.960	–47.83 – –30.72 AVG = –39.10 s = 7.105
Polished, Thin coat	–81.60 – –1.53 AVG = –29.67 s = 31.78	–35.12 – –2.96 AVG = –15.39 s = 10.82	–74.77 – –10.93 AVG = –47.36 s = 20.62	–4.97 – 6.95 AVG = –0.53 s = 3.44	

had the least amount of staining visible and the microcrystalline wax coated samples appeared to perform the worst, allowing the most staining to occur. The gloss did not appear to change in any of the marker stained samples.

The color change data for the tiles stained with permanent marker, shown in table 14, indicated that the microcrystalline wax had the most color change, i.e. the worst staining. The gloss data for the marker stained samples did not show a noticeable change in any of the samples, except a single polished sample, with a thin microcrystalline wax coating (ΔG = –9.85).

Fig. 14. Selected polished, marker-stained samples after the coatings were removed. Samples that had thin coatings are in the top row. Control samples are in the middle. The bottom row contains samples with thick coatings. From left to right, the samples in each column were coated with wax-resin, microcrystalline wax, methyl cellulose and Avalure. (Courtesy of Laura Kubick)

Fig. 15. Selected unpolished, marker-stained samples after the coatings were removed. Samples are shown in the same order as in figure 14. (Courtesy of Laura Kubick)

4. CONCLUSION AND SUGGESTED FURTHER RESEARCH

All of the coatings provided some protection from soiling. However, microcrystalline wax is not recommended as a barrier. While it performed well aesthetically, it provided the least protection against the wine and marker stains. It also did not reverse easily, although it is possible that more effective methods of removal could be used.

The wax-resin performed better than the wax alone as a barrier and it had good aesthetic properties. Unfortunately, it allowed the wine to etch the polished marble surfaces. Another drawback, compared with Avalure or methyl cellulose, is that it requires toxic solvents to reverse and was more difficult to reverse.

The Avalure stood out because it was the only coating to prevent etching of polished surfaces by the wine. In addition, Avalure can be applied in ethanol or alkaline water, which are both safe for marble and are less toxic than the solvents required to reverse the wax-based coatings. While Avalure did not provide an aesthetically acceptable coating on the polished marble samples, it looked invisible on the unpolished surfaces and most sculpture is not as glossy as the polished samples used in this experiment.

Table 14. Color change (ΔG), given as a range, of unaged marker stained samples, comparing before the samples were coated with after the coatings were removed. Also shown are the average change (AVG) and standard deviation (s).

	Wax-resin	Microcrystalline wax	Methyl cellulose	Avalure	Control (no coating)
Unpolished, Thick coat	0.28 – 5.61 AVG = 2.29 s = 1.61	1.23 – 10.99 AVG = 5.81 s = 3.80	0.90 – 6.83 AVG = 3.47 s = 1.80	1.17 – 9.39 AVG = 4.30 s = 3.14	7.97 – 14.64 AVG = 12.56 s = 3.12
Unpolished, Thin coat	0.73 – 18.57 AVG = 5.46 s = 5.812	2.95 – 19.06 AVG = 11.47 s = 5.44	1.63 – 15.28 AVG = 8.08 s = 4.496	0.67 – 13.86 AVG = 4.82 s = 4.09	
Polished, Thick coat	0.14 – 4.80 AVG = 1.74 s = 1.73	0.11 – 3.61 AVG = 1.58 s = 1.49	0.07 – 1.87 AVG = 1.04 s = 0.754	0.05 – 3.06 AVG = 0.93 s = 1.15	0.34 – 0.75 AVG = 0.46 s = 0.19
Polished, Thin coat	0.17 – 2.55 AVG = 1.06 s = 0.84	0.12 – 3.64 AVG = 1.42 s = 1.32	0.06 – 0.44 AVG = 0.17 s = 0.13	0.03 – 0.86 AVG = 0.29 s = 0.29	

The methyl cellulose also performed very well. Aesthetically, it was not visible on the samples and had the best reversibility when using non-toxic materials. It also provided some protection from the staining agents. Unfortunately, it allowed etching to occur on the wine-stained samples.

This experiment only broaches the topic of evaluating coatings for use on indoor marble sculpture. The field would benefit from a similar study with both a larger sample size and more coating materials. The results point to a few specific areas that warrant more research.

The methyl cellulose performed surprisingly well; because there are so many varieties of methyl cellulose, perhaps an even better coating for stone could be discovered among them. Further evaluation of Avalure for use on stone indoors and outdoors would also be useful, as it is acid-resistant and provides a reasonable barrier. Investigation into different application methods for this material, such as spray coating, would be valuable and may provide a more aesthetically pleasing appearance.

ACKNOWLEDGEMENTS

The authors would like to thank the Smithsonian Institution for funding this experiment, and especially the Smithsonian American Art Museum and the Museum Conservation Institute (MCI) for use of their facilities and access to their staff's expertise. The authors are also grateful to the Image Permanence Institute for their aid in this research, Thermo Fisher Scientific for the loan of the iS5 FTIR spectrometer, and the Indianapolis Museum of Art (IMA) for funding the presentation of this work at the 2012 AIC Annual Meeting.

Special thanks to Helen Ingalls and Hugh Shockey, objects conservators at the Smithsonian American Art Museum for their direct contributions to this research. Mary Ballard, senior textile conservator and Carol Grissom, senior objects conservator at MCI also acted as helpful resources in developing the experiment.

The authors would also like to acknowledge the following individuals for their help and support: Daniel Burge, senior research scientist, Image Permanence Institute; James Reilly, director, Image Permanence Institute; Debra Hess Norris, chair, WUDPAC; Ginny Naudé, president, Norton Art Conservation; Caroline Roberts, Samuel H. Kress fellow, Kelsey Museum of Archaeology; Gregory D. Smith, Otto N. Frenzel III senior conservation scientist, IMA; and Richard Wolbers, associate professor, WUDPAC.

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SOURCES OF MATERIALS

Avalure AC 315 Polymer resin
The Lubrizol Corporation
29400 Lakeland Boulevard
Wickliffe, OH 44092
www.lubrizol.com

Carrara marble tiles
Morris Tile Distributors
2525 Kenilworth Avenue
Tuxedo, MD 20781
www.morristile.com

Cosmolloid 80H wax, Dow Methocel A4C methyl cellulose, Ketone N resin, Renaissance Microcrystalline Wax

Distributed by Talas
330 Morgan Avenue
Brooklyn, NY 11211
www.talasonline.com

D'Arenberg, The Stump Jump Shiraz: d'Arenberg
PO Box 195
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LAURA KUBICK is the assistant conservator of objects and variable art at the Indianapolis Museum of Art. She completed her Smithsonian Post-graduate Fellowship in Conservation at the Smithsonian American Art Museum to carry out the research for this paper, after graduating from the Winterthur/University of Delaware Program in Art Conservation in 2010. Address: Indianapolis Museum of Art, 4000 Michigan Road, Indianapolis, IN 46220.
E-mail: lkubick@imamuseum.org

JENNIFER GIACCAI is a conservation scientist at the Museum Conservation Institute at the Smithsonian Institution. She has an M.S.E. from Johns Hopkins University and her recent research has included investigations into the analytical limitations when examining mixed media paintings, and technical studies of paintings by Richard Diebenkorn and Henry Ossawa Tanner. Address: Museum Conservation Institute, Smithsonian Institution, 4210 Silver Hill Road, Suitland, MD 20746. E-mail: giaccaij@si.edu

This article was presented at the Objects Specialty Group or in the joint Research and Technical Studies/OSG Sessions at the 2012 AIC Annual Meeting in Albuquerque. The papers presented in this publication have been edited for clarity and content but have not undergone a formal process of peer review.